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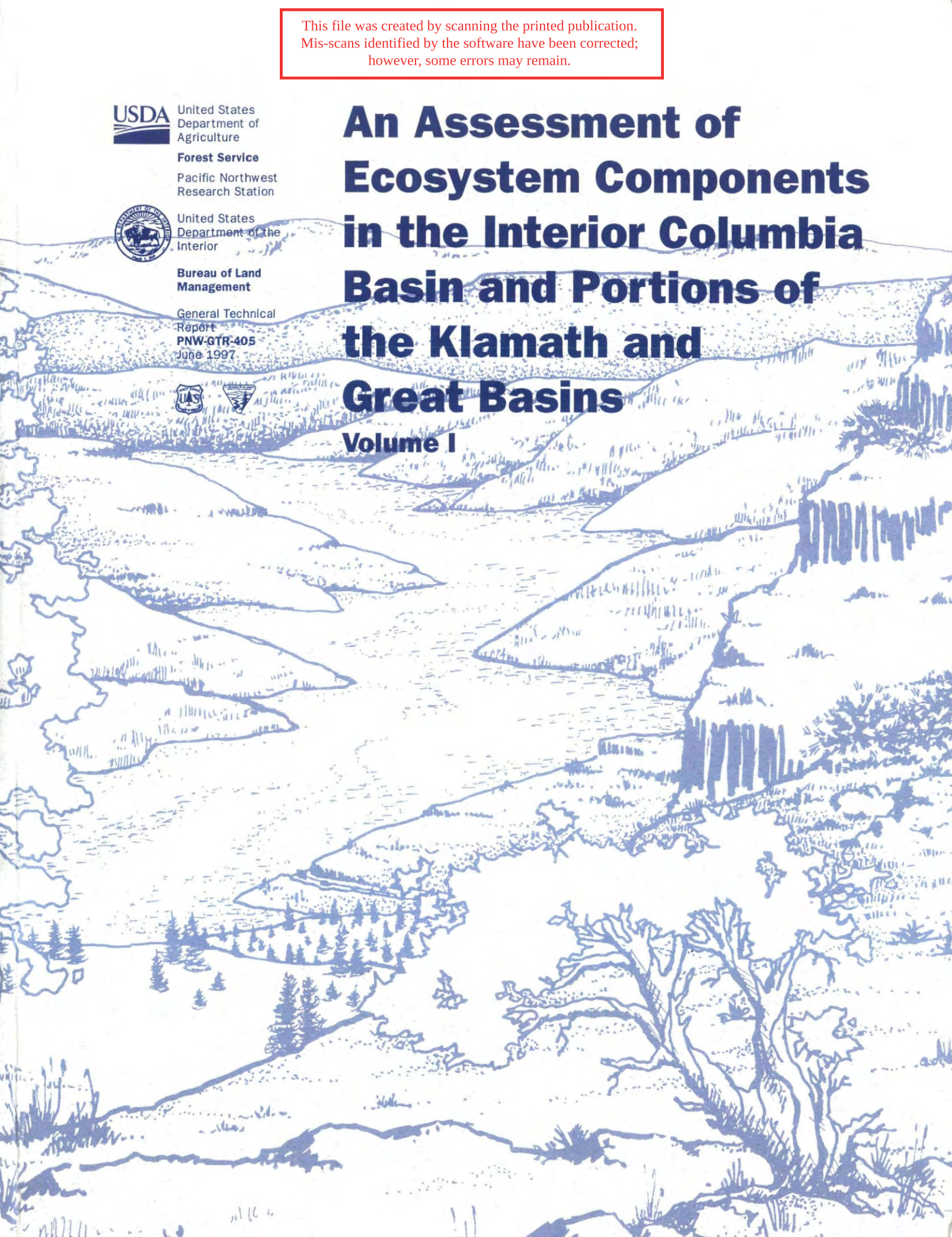
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General Technical
Report
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June 1997

An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins

Volume I





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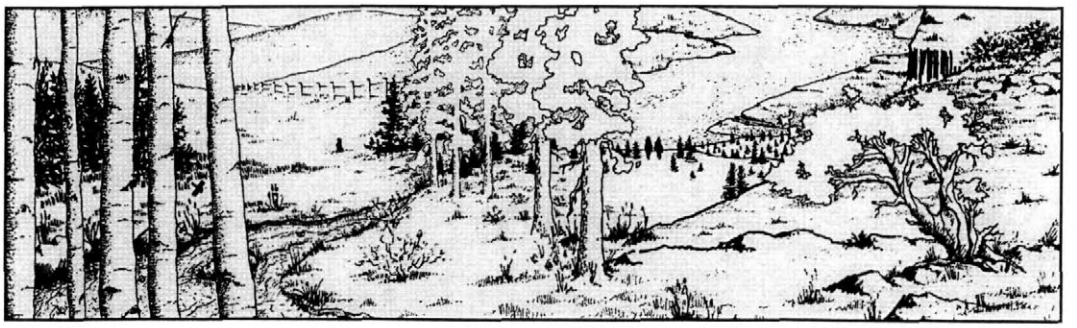


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Interior Columbia Basin Ecosystem Management Project

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An Assessment of Ecosystem Components in the Interior Columbia Basin

And Portions of the Klamath and Great Basins: Volume I

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Volume I contains pages 1 through 335

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Abstract

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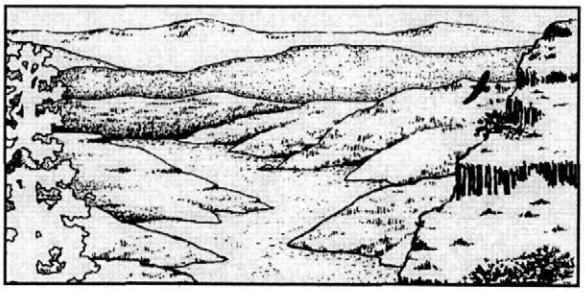
The *Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins* provides detailed information about current conditions and trends for the biophysical and social systems within the Basin. This information can be used by land managers to develop broad land management goals and priorities and provides the context for decisions specific to smaller geographic areas. The Assessment area covers about 8 percent of the U.S. land area, 24 percent of the Nation's National Forest System lands, 10 percent of the Nation's BLM-administered lands, and contains about 1.2 percent of the Nation's population. This results in a population density that is less than one-sixth of the U.S. average. The area has experienced recent, rapid population growth and generally has a robust, diverse economy. As compared to historic conditions, the terrestrial, aquatic, forest, and rangeland systems have undergone dramatic changes. Forested landscapes are more susceptible to fire, insect, and disease than under historic conditions. Rangelands are highly susceptible to noxious weed invasion. The disturbance regimes that operate on forest and rangeland have changed substantially, with lethal fires dominating many areas where non-lethal fires were the norm historically. Terrestrial habitats that have experienced the greatest decline include the native grassland, native shrubland, and old forest structures. There are areas within the Assessment area that have higher diversity than others. Aquatic systems are now more fragmented and isolated than historically and the introduction of non-native fish species has complicated current status of native fishes. Core habitat and population centers do remain as building blocks for restoration. Social and economic conditions within the Assessment area vary considerably, depending to a great extent on population, diversity of employment opportunities, and changing demographics. Those counties with the higher population densities and greater diversity of employment opportunities are generally more resilient to economic downturns. This Assessment provides a rich information base, including over 170 mapped themes with associated models and databases, from which future decisions can benefit.

Keywords: Columbia basin, biophysical systems, social systems, ecosystem.

Preface

This document represents a substantial portion of the work of the Science Integration Team (SIT) of the Interior Columbia Basin Ecosystem Management Project (ICBEMP). This product results from the efforts of literally hundreds of scientists and technical specialists. The SIT provided leadership to the entire effort that took more than three years to complete. Summaries of the work and synthesis products, *An Integrated Assessment of the Interior Columbia Basin and portions of the Klamath and Great Basins* and *Status of the Interior Columbia Basin Ecosystem Management Project Summary of Scientific Findings,* appeared before the formal publication of this document. Combined, these pieces constitute the Scientific Assessment of the Interior Columbia Basin and portions of the Klamath and Great Basins. The Assessment benefitted greatly by interactions with the ICBEMP Environmental Impact Statement Team members and Project Leaders. The open process undertaken through this effort represented a first for such a scientific endeavor. We learned a great deal from the many individuals and groups who took interest in and participated in the many open meetings and presentations held. The products are better because of this openness.

The leadership of Charlie Philpot, Denver Burns, and particularly Tom Mills during the closing months of the process, helped the SIT through the significant internal and external political process that surrounded the ICBEMP process and products. We recognize that existence of the document is a result of Jodi Clifford's efforts and persistence in organizing, coordinating, and editing.



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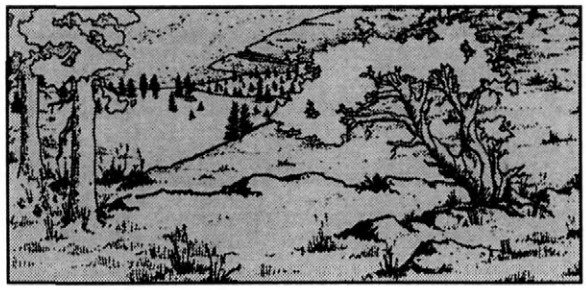
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VOLUME CONTENTS



VOLUME I

Chapter 1 - Introduction

- **Executive Summary-Biophysical Environments**
- **Executive Summary-Landscape Dynamics**
- **Executive Summary-Broadscale Assessment of Aquatic Species and Habitats**
- **Executive Summary-Terrestrial Ecology**
- **Executive Summary-Economic Assessment**
- **Executive Summary-Social Assessment**
- **Executive Summary-Information System Development and Documentation**

Chapter 2 - Biophysical Environments of the Basin

VOLUME II

Chapter 3 - Landscape Dynamics of the Basin

VOLUME III

Chapter 4 - Broadscale Assessment of Aquatic Species and Habitats

Chapter 5 - Terrestrial Ecology of the Basin

VOLUME IV

Chapter 6 - Economic Assessment of the Basin

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Chapter 8 - Information System Development and Documentation

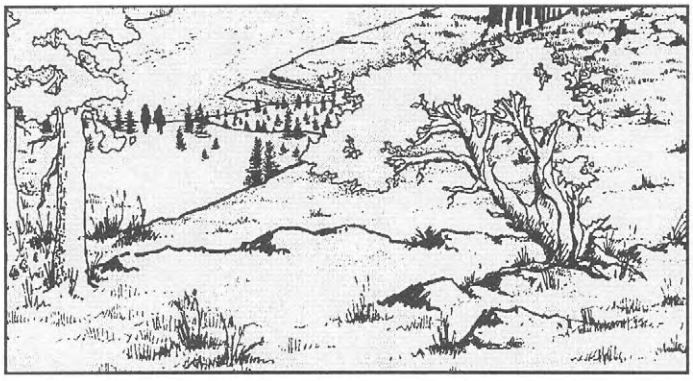
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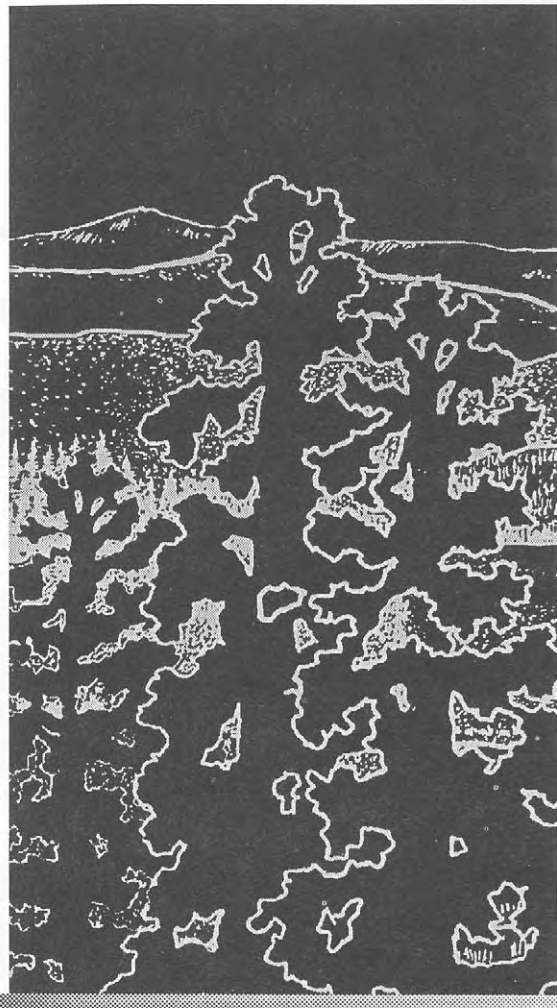
Literally hundreds of individuals have contributed to this publication. We thank all those who contributed to any portion of the overall Assessment effort. Individual chapters have included acknowledgments specific to that component of the Assessment. Editing and assembly of these chapters has been an enormous effort. Jodi Clifford, Liz Galli-Noble, Kathy Helm, Lynn Starr, Ann Marie Walker, Shari Whitwell, Lisa Meabon, Mary Carr, Ellen Eberhardt, Laurienne Riley, Tracy Noel, Cindy Dean, Heidi Bigler Cole, Kathy Campbell, Connie Gilbreath, Eloisa Munden, Dan Mayer, Minnie Williams, Kelly Wenzlick, Krista McHugh, and Berna MacIntosh have all contributed to this task. Irene Stumpf and Shari Whitwell created or edited many of the graphics. Traci McMerritt provided the cover design. Managing data, maps, tables, and databases for the Assessment was the specific responsibility of the Spatial Analysis Team: Becky Gravenmier, Terry Locke, Arthur Miller, Andy Wilson, Thang Lam, Dave Gilde, Mike Dana, Cary Lorimor, and Dora DeCoursey. Undoubtedly, we have failed to recognize many who made significant contributions to the Assessment, we apologize for any oversights.

Continue

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CHAPTER 1



Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins: An Introduction

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TABLE OF CONTENTS



Introduction 5

The Interior Columbia Basin Ecosystem Management Project 5

The ICBEMP Assessment 11

Scale, Geographic Extent, and Data Resolution 14

Use of Ecosystem Principles and Concepts in the ICBEMP Assessment 14

Ecological Reporting Units and Ecosystem Modeling 16

Scenarios 18

Overview of the Basin 18

Chapter Organization and Development 19

Literature Cited 21

Acknowledgments 23

Glossary 24

Appendix 1A 27

LIST OF TABLES

Table 1.1 Ownership of lands within the Basin assessment area. 7

Table 1.2 Land ownership, by Ecological Reporting Unit for the Basin assessment area. 7

Table 1.3 Major products expected from the Interior Columbia Basin Ecosystem Management Project. 11

Table 1.4 Policy questions identified from the Charter. 12

LIST OF FIGURES

Figure 1.1 Issues and events that led to the Interior Columbia Basin Ecosystem Management Project. 10

LIST OF MAPS

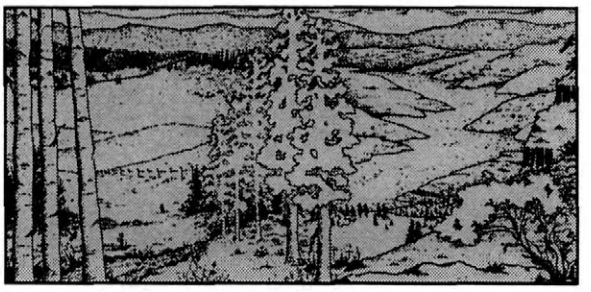
Map 1.1 Columbia River Basin of the United States and portions of the Klamath River Basin and the Great Basin that will be assessed in developing an ecosystem approach for managing public land administered by the Forest Service and Bureau of Land Management in the Interior Northwest. 6

Map 1.2 Landscape Characterization Boundary. 9

Map 1.3 Economic Analysis Areas of the interior Columbia Basin. 15

Map 1.4 Ecological Reporting Units. 17

INTRODUCTION



The Pacific Northwest has been involved in controversy over the ownership, management, and disposal of natural resources since the descendants of Europeans began inhabiting the area 150 years ago. In recent decades, the debate over public land management has focused primarily on resource allocation, as commodity production took precedence over the custodial protection of national forest lands that characterized the early 20th century. In recent years concerns have grown about issues related to species associated with old forest structures, anadromous fish, forest health (including widespread insect and disease mortality and fire), and rangeland health. Appendix 1-A contains a chronology of recent, related events that reflect these concerns.

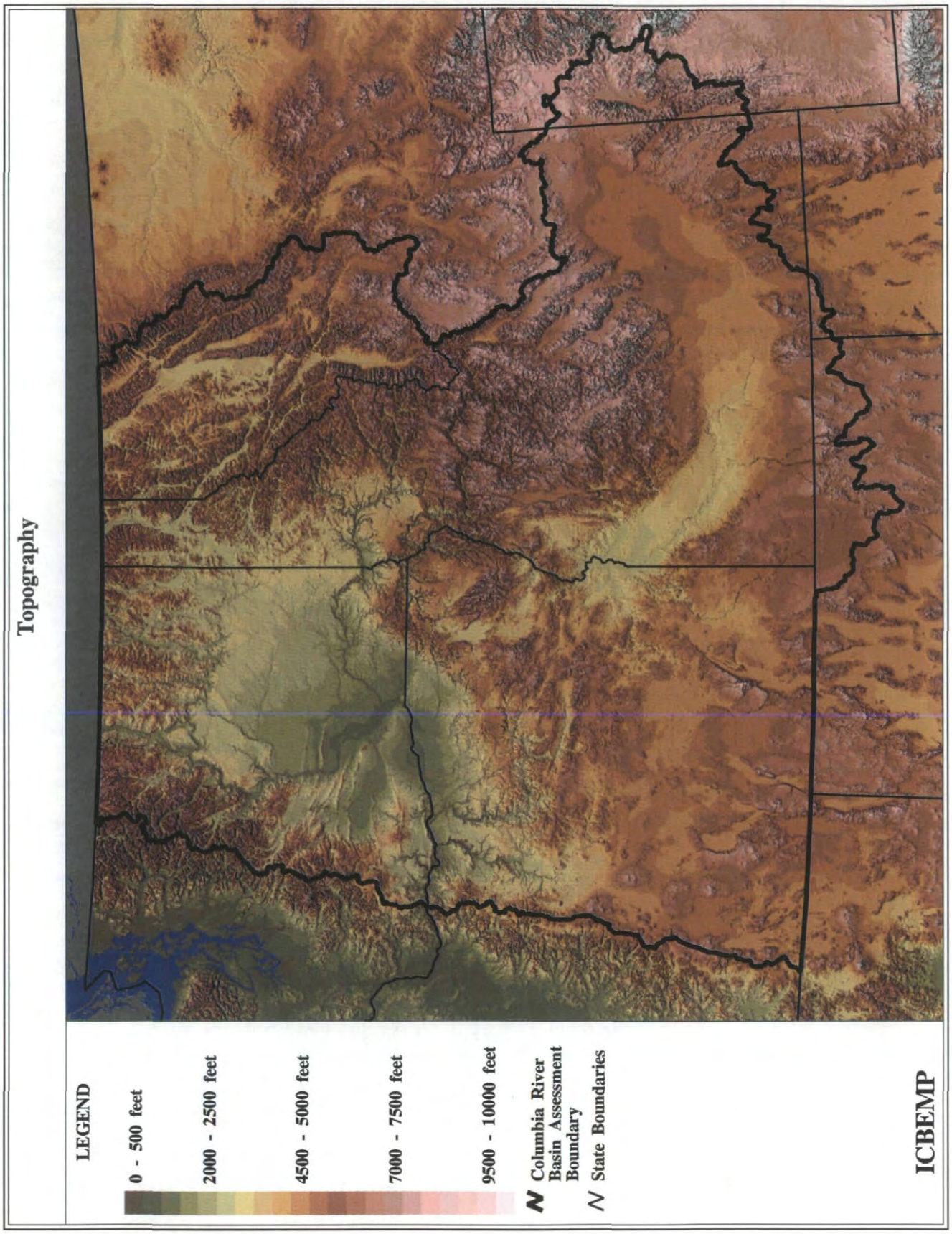
This assessment was precipitated by the current debate over the management of USDA Forest Service (FS) and USDI Bureau of Land Management (BLM) administered lands in those portions of the Columbia River basin within the United States and east of the Cascade crest and those portions of the Klamath and Great basins in Oregon. (This entire area is referred to as "the Basin" in this document.) To fully understand this debate and the implications associated with it, one needs to understand the biophysical, social, and economic components of ecosystems within the Basin. This assessment area includes Federal, State, county, and private resources. Such a broad examination provides information on conditions, trends, and potential outcomes associated with management of the Basin's natural resources.

The Interior Columbia Basin Ecosystem Management Project

President Clinton's 1993 Forest Conference held in Portland, Oregon, was designed to address forest management gridlock within the range of the northern spotted owl. A major outcome of the conference was the designation of the Forest Ecosystem Management Assessment Team (FEMAT). When announcing the completion of the FEMAT process, President Clinton directed the USDA Forest Service to take the lead in developing "a scientifically sound, ecosystem-based strategy" for managing the forests east of the Cascades.

The Interior Columbia Basin Ecosystem Management Project (ICBEMP) was established by the Eastside Ecosystem Management Project Charter (the Charter) in January 1994. The Charter was signed by the Chief of the Forest Service and the Director of the Bureau of Land Management. The charter provided instructions to develop specific products that would lead to the adoption of a scientifically sound, ecosystem-based strategy for managing FS- or BLM-administered lands within the Basin. Information necessary to develop the strategy required assessing a large portion of the inland northwest (map 1.1).

The total assessment area of the Basin is 58.4 million hectares (ha), 30.9 million ha of which are administered by 35 national forests and 17 BLM districts (tables 1.1 and 1.2). The remaining area is shared among other Federal, State, county, and



Map 1.1—Columbia River Basin of the United States and portions of the Klamath River Basin and the Great Basin that will be assessed in developing an ecosystem approach for managing public land administered by the Forest Service and Bureau of Land Management in the Interior Northwest.

Continue

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Table 1.1— Ownership of lands within the Basin assessment area.

Ownership	Lands		
	-----Acres-----	---Hectares---	--Percent--
BLM- or FS-administered lands	76,274,273	30,867,100	53
Other Wilderness and National Parks	1,599,761	647,400	1
Private and other lands	54,666,141	22,122,600	38
State and other Federal lands	6,236,940	2,524,000	4
Tribal lands	5,437,061	2,200,300	4
Basin total	144,214,176	58,361,400	100

Note: Areas generated from 1 sq. kilometer grid using Geographic Information System. Totals will not match official Government Land Office totals.

Table 1.2— Land ownership, by Ecological Reporting Unit for the Basin assessment area.

	Ownership/Administration					
ERU	FS/BLM	Other Wilderness/ National Parks	Private	State/ other Federal	Tribal	Total land area
	hectares					
1. Northern Cascades	1,399,800	54,100	609,300	181,300	296,800	2,541,300
2. Southern Cascades	768,700	0	440,300	20,200	126,200	1,355,400
3. Upper Klamath	737,700	31,300	786,600	11,800	0	1,567,400
4. Northern Great Basin	3,160,300	0	782,500	240,300	7,200	4,190,300
5. Columbia Plateau	1,053,600	800	7,514,700	674,900	282,600	9,526,600
6. Blue Mountains	2,667,900	0	2,378,100	35,200	600	5,081,800
7. Northern Glac. Mtns	2,734,200	256,400	2,500,800	294,000	1,155,200	6,940,600
8. Lower Clark Fork	1,782,000	0	803,000	120,100	3,400	2,708,500
9. Upper Clark Fork	1,238,100	0	1,033,900	19,800	1,900	2,293,700
10. Owyhee Uplands	5,452,500	0	2,002,200	355,300	117,000	7,927,000
11. Upper Snake	1,427,700	21,400	1,483,800	275,000	185,000	3,392,900
12. Snake Headwaters	1,635,400	283,200	639,100	55,400	24,400	2,637,500
13. Central Idaho Mtns	6,809,200	200	1,148,300	240,700	0	8,198,400
Basin total	30,867,100	647,400	22,122,600	2,524,000	2,200,300	58,361,400

(Source: Basin GIS data, converted to 1 sq. kilometer raster data)

tribal governments and private land owners. The combined land managed by the BLM and the FS is about 53 percent of the total assessment area. Data were collected from an area somewhat larger than the assessment area to assist in landscape characterizations (Landscape Characterization Boundary, map 1.2).

The Charter provided guidance on the structure and organization of the overall project (fig. 1.1). An interagency approach to natural resource issues was used because such an approach recognizes the multiple geographic extents, the complexity of resources and issues, and the multiple jurisdictions within the Basin. To provide direction and oversight, the Columbia Basin Executive Steering Committee was established. The committee consists of the Regional Foresters from Forest Service Regions 1, 4, and 6; the Directors of the Forest Service Pacific Northwest Research Station and the Intermountain Research Station; and the BLM Directors from Oregon-Washington, Idaho, and Montana.

The Charter provided direction for the completion of a framework for ecosystem management and a scientific assessment of the Basin (table 1.3). The document, *A Framework for Ecosystem Management in the Interior Columbia Basin and Portions of the Klamath and Great Basins (Framework)* (Haynes and others 1996), describes the principles and planning and analysis processes applicable for managing ecosystems in the Basin at multiple geographic extents and resolutions of data. The scientific assessment of the Basin (ICBEMP Assessment), of which this document is a part, examines the status of ecosystems within the Basin including their historic trends, current status and trends, and projections about their future outcomes and conditions.

The Charter also required the preparation of two Environmental Impact Statements (EISs), one for the Upper Columbia River Basin (UCRB) and one for eastern Oregon and Washington (EEIS), and the scientific evaluation of the EIS alternatives. The draft EISs present seven alternative management strategies based on ecosystem management concepts intended to provide long-term direction for agency lands within the assessment area. The scientific evaluation of EIS alternatives analyzes the effects of implementing each alternative management strategy. The Executive Steering Committee plans to adopt an ecosystem management strategy for managing FS- and BLM-administered lands in the Basin after completion of the EISs.

The Science Integration Team (SIT) was established to develop the *Framework*, the Scientific Assessment of the Basin, and an evaluation of EIS alternatives. The EISs were prepared by other teams.

Major policy questions summarized from the Charter represent the minimum questions the Executive Steering Committee viewed as essential to address through the assessment/decision processes of the project (table 1.4). The policy questions include concerns about outcomes of current levels of activities on ecologic and human systems, maintenance of long-term productivity, mimicking disturbance on the landscape, sustainability, biological diversity, rural communities, old-growth ecosystems, forest health, adaptive management, and endangered and other species viability. In the Assessment, the SIT provided information needed by the EIS teams to address policy questions and other issues brought forward through the EIS process.

The SIT was organized around the functional staff areas of landscape ecology (physical and vegetative resources), terrestrial resources, aquatic resources, economics, and social sciences. A staff of Geographic Information System (GIS) specialists supported the spatial and data processing needs of the functional groups. The SIT was composed of Federal employees from the FS, BLM, Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), and Bureau of Mines (USBM). Contractors were brought in for specific tasks and assignments. SIT headquarters were in Walla Walla, Washington. Detached analysis units were located in Missoula and Kalispell, Montana; Boise, Moscow, and Coeur d'Alene, Idaho; Portland and Corvallis, Oregon; Seattle, Spokane, and Wenatchee, Washington; and Reno and Las Vegas, Nevada.

Map 1.2—Landscape Characterization Boundary.

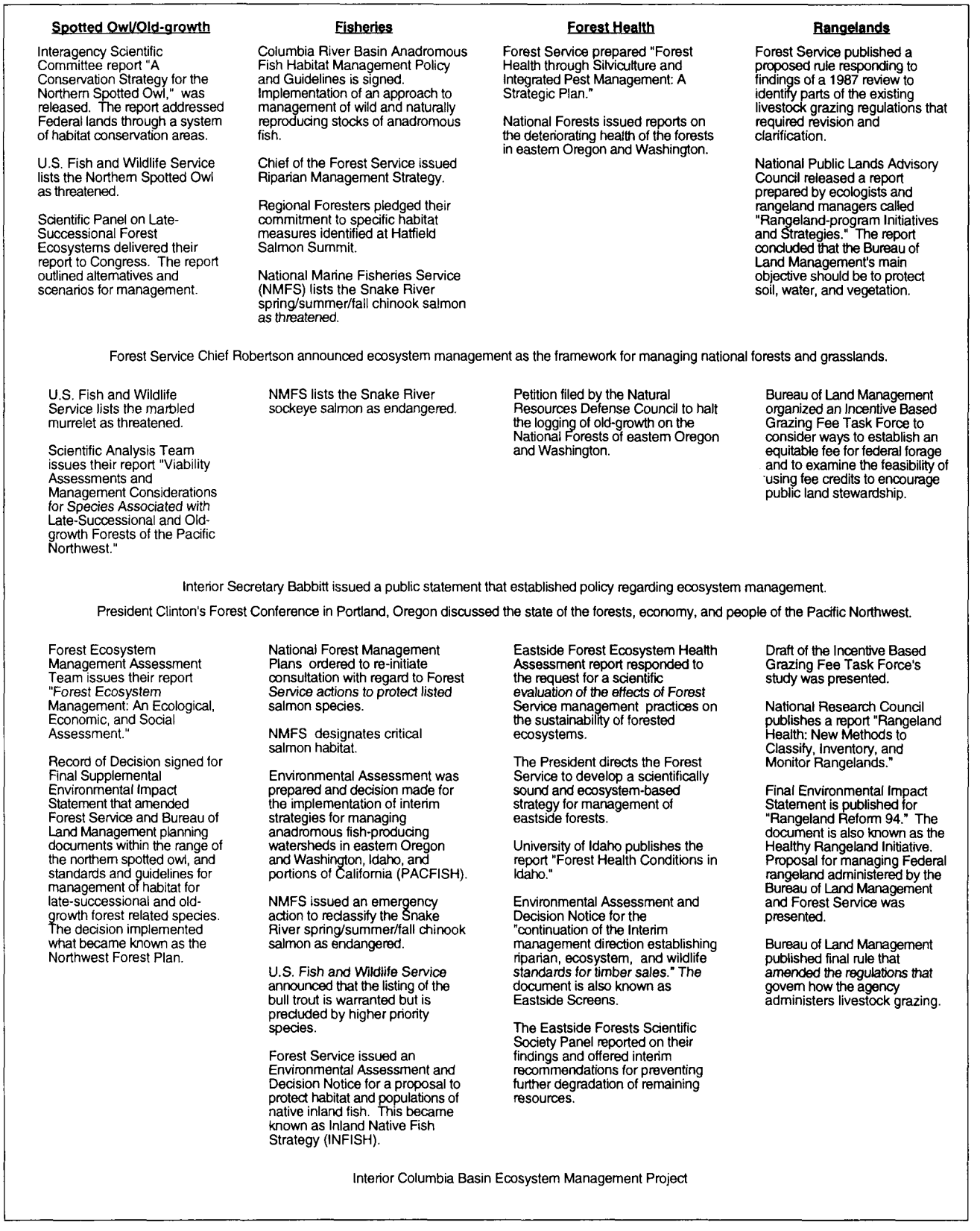


Figure 1.1—Issues and events that led to the Interior Columbia Basin Ecosystem Management Project.

Table 1.3— Major products expected from the Interior Columbia Basin Ecosystem Management Project.

Product	Responsible Team	Description
Scientific Assessment	Science Integration Team	Assessment of the historic, current, and potential future status and trend for terrestrial, aquatic, landscape ecology, economic, and social systems in the Basin
Framework	Science Integration Team	Description of the principles and processes appropriate for managing ecosystems within the Basin
Eastside EIS	Eastside EIS Team	Proposal of new goals, objectives, standards, and guidelines applicable to national forests and BLM districts in eastern Oregon and Washington
Upper Columbia River Basin (UCRB) EIS	UCRB EIS Team	Proposal of new goals, objectives, standards, and guidelines applicable to national forests and BLM districts in the UCRB
Evaluation of Alternatives	Science Integration Team	Evaluation of EIS alternatives that discloses outcomes, tradeoffs, consequences, and relative risks to ecological integrity and economic resiliency

The ICBEMP Scientific Assessment

The ICBEMP Scientific Assessment provides information about current conditions and trends. The information can be used by land managers to develop broad land management goals and priorities. It also provides the context for decisions specific to smaller geographic areas. The objectives of the assessment are to:

- Characterize and describe the conditions of the landscape ecology, aquatic/riparian, terrestrial, social, economic, and landscape conditions of the Basin. These characterizations describe the present conditions of the Basin, the historic conditions, their evolution, and the likely future of the Basin under different scenarios.
- Provide information that can be used to implement ecosystem management at different geographic scales within the Basin. The assessment provides information that local land managers can use to put decisions and management practices into a larger geographic context. It also provides information that the regional land manager can use to define processes or structures that may be important for maintaining ecosystems and supplying goods and services. In addition, the assessment supplies information that can address the issue of ecosystem integrity for various geographic areas within the Basin and for the Basin as a whole.
- Identify information gaps that need to be addressed through research and development. Implementing ecosystem management strategies allows flexibility based on local assessments of the area's conditions and trends as the concept of ecosystem management evolves.

Table 1.4— Policy questions identified from the Charter.

Major Policy Questions
What are the effects of current and potential Forest Service and Bureau of Land Management land allocations on ecologic, economic, and social systems in the Basin?
What are the ecologic, economic, and social system outcomes associated with current (early 1990s) Forest Service and Bureau of Land Management levels of activities?
What is required to maintain long-term productivity (in terms of various systems)?
What can the Forest Service and Bureau of Land Management do to mimic disturbance elements on the landscape?
What is required to maintain sustainable and/or harvestable and/or minimum viable population levels?
What is required to maintain and restore biological diversity (biodiversity)?
What is the impact of ecosystem management on major social issues and the maintenance of rural communities and economies?
What is the impact of ecosystem management on maintenance of late-successional and old-growth systems?
What management actions will restore and maintain ecosystem health (forest, rangeland, riparian, and aquatic health)?
What can the Forest Service and the Bureau of Land Management do to implement adaptive management and what are its consequences on ecologic, economic, and social systems in the Basin?
What can the Forest Service and Bureau of Land Management do to protect endangered species (such as salmon, grizzly bear, gray wolf, caribou) and ensure the viability of native and desired non-native plant and animal species?
Effects of Specific Policy Actions
Within the context of the President's Northwest Forest Plan, what are the options for achieving the objectives where the President's Plan overlaps the Eastside strategies?
What is the effect of implementing the interim direction of the Pacific Anadromous Fish Strategy and/or other proposed aquatic conservation strategies on Forest Service and Bureau of Land Management administered lands in the Basin?
Process Questions
What are the principles and processes that can be used for ecosystem management?
How can we use the assessment to identify emerging policy issues that relate to ecosystem management within the Basin?
How can we deal with uncertainty in ecological processes, social values, predicting outcomes, and scientific understanding?

The ICBEMP Scientific Assessment used information from many sources and disciplines and on all lands within the Basin, not just FS- and BLM-administered lands. Understanding ecosystem components, structures, processes, and functions that operate at multiple geographic and temporal extents and providing context for decisions requires that all lands be included in the assessment. While respecting the rights of landowners within the Basin, information was gathered from both public and private sources. Because of the broad level of data resolution used in the assessment and the large geographic extent, the assessment relied primarily on remote sensing or readily available information from third party sources. An effort was made to use the existing information about the past and present condition of the Basin. To the extent possible, the SIT relied on existing simulation models to project future conditions of the Basin. Where existing models were not available, new models were constructed. Inferences about future conditions were made from the available information and the model results.

The ICBEMP Scientific Assessment has resulted in the preparation of several major documents. It also generated many smaller documents and a number of databases and models. The databases contain information on vegetation, landform, climate, stream inventories, terrestrial species relationships, county indicators and economic conditions. The models range from those that predict change in vegetation under different disturbance regimes to those that describe community resiliency.

Database/information systems/information gathering for this project can be generally categorized into five basic groups: 1) databases (more than 20 were acquired or developed, 2) GIS themes (over 170 were generated), 3) expert panels/workshops (about 40 were convened), 4) contract reports (over 130 were used), and 5) current literature reviews. A list of databases and GIS themes are included in the chapter titled Information System Development and Documentation.

This document is an *Assessment of Ecosystem Components*, composed of detailed reports from each functional staff area. It addresses the biophysical and social conditions of the Basin. Another document, *An Integrated Scientific Assessment for Ecosystem Management for the Interior Columbia Basin and portions of the Klamath and Great Basins* (Quigley and others 1996) integrates the information presented here and discusses current conditions. The Integrated Assessment also examines the extent of ecological risk and departure from historical and potential vegetation conditions. This is accomplished by integrity indices and probable outcomes of management under various possible futures. In support of these documents, and as background to the conclusions, other technical reports will be published in the future. More detailed explanations of databases, models, and information layers will be useful to both public and private land managers.

Unlike previous efforts where public involvement occurred only when mandated under the National Environmental Policy Act (NEPA), the ICBEMP encouraged public participation during all phases of the project. Members of the public were encouraged to attend workshops and regularly scheduled public meetings. Reports from contractors and other draft materials were readily available. For example, the Project provided a local printing/copying service with copies of draft project reports so that the public could obtain their own copy. Much of the material was accessible through an electronic library maintained by project personnel. Finalized data layers and maps were available to the public. Although this approach required a commitment of both personnel and financial resources from the SIT, it helped remove the potential for surprise and helped SIT members better understand public expectations.

The scientific documents developed by the SIT were subjected to peer review using a modified double-blind process. A science review board (SRB) was formed comprising six members and two co-chairs. The SRB independently chose reviewers from a list of knowledgeable scientists,

land managers, and regulatory personnel. This ensured an impartial but informed review process. Products of the SIT were received by the SRB co-chairs and forwarded to other SRB members for assignment to outside reviewers for diverse points of view. These reviews were sent to SIT without integration, attempts at consensus, or accompanying advice.

Scale, Geographic Extent, and Data Resolution

Following the classification system presented in the *Framework*, the Basin assessment includes elements of both a regional and sub-regional assessment. This approach was undertaken because several of the policy questions and issues could not be adequately addressed using a regional assessment alone. This approach also provided consistency across geographic areas as well as the context for decisions specific to a landscape or a watershed.

The degree of data resolution sought for each component of the analysis (landscape ecology, aquatic, terrestrial, economic, and social) was determined by the policy questions. Current vegetation cover and structure were mapped using a continuous one-square-kilometer (1 km^2) resolution, which relied on satellite images and validation workshops with field ecologists. Potential vegetation was mapped at 1-km^2 resolution using biophysical characteristics and existing field data. Other map themes characterized the broad, regional environment.

To gain insight into the variability in disturbance processes, vegetation patterns, and vegetation structure within the Basin, sampling was done at the mid, sub-regional assessment level. Comparisons were made between recent (1920-1945) and current vegetation characteristics measured through aerial photography interpretation on 335 sub-watersheds within the Basin. This mid, sub-regional assessment data provided information relating to insect and disease attributes, shifts in cover types and structural stages, and changes in fire regimes. Combined, the broad, regional and mid, sub-regional information provided the basis for interpretation of habitat changes, aquatic interactions, disturbance processes, and human interactions.

In landscape ecology terms, there is often referral to broad-scale information and mid-scale information. In this context, the broad scale refers to information with the lowest degree of resolution, similar to classifying landscape patterns from a photograph taken from five miles above the earth's surface. Mid-scale refers to information with more resolution, similar to classifying landscape patterns from a photograph taken from one mile above the earth's surface.

The social and economic information used in this Assessment was generally at the state and county level of aggregation. Communities within the Basin were sampled to determine basic characteristics and the degree to which the communities could absorb change without major disruptions within their social/economic systems. Bureau of Economic Analysis reporting areas were used to characterize centers of trade and economic activity. These represent groupings of several counties per analysis area (map 1.3).

Use of Ecosystem Principles and Concepts in the ICBEMP Assessment

To paraphrase Salwasser and others (1993), ecosystems can be defined as communities of organisms interacting with their environments as integrated units. They are places where all plants, animals, soils, waters, climate, people, and processes of life interact as a whole. Because humans have developed the capacity to rapidly alter the environment and because humans are dependent, like all species, on the environment, humans are included in this Assessment as a component of ecosystems.

Several broad ecosystem principles and concepts guided the work for the Assessment and are briefly discussed below. For a more complete discussion of ecological principles and concepts, see the *Framework* or the Biophysical Environments chapter of this document. First, ecosystems are dynamic, evolutionary, and resilient. Change is

Map 1.3—Economic Analysis Areas of the interior Columbia Basin.

inherent, which allows ecosystems to develop along many paths (O'Neill and others 1986; Urban and others 1987). Second, ecosystems are viewed spatially and temporally within multiple organizational levels. These levels can be organized within a hierarchy in which every level has discrete ecological functions but also is part of a larger whole (Allen and others 1984; Allen and Starr 1982; Koestler 1967), although terrestrial, aquatic, economic, and social systems may operate within different hierarchies. In the Assessment, the landscape ecology, aquatic, terrestrial, economic, and social elements are discussed in the hierarchies that are determined to be most appropriate for each. Third, ecosystems have biophysical, economic, and social limits. Fourth, ecosystem patterns and processes are not completely predictable although predictability varies over temporal and spatial organizational levels (Bourgeron and Jensen 1994).

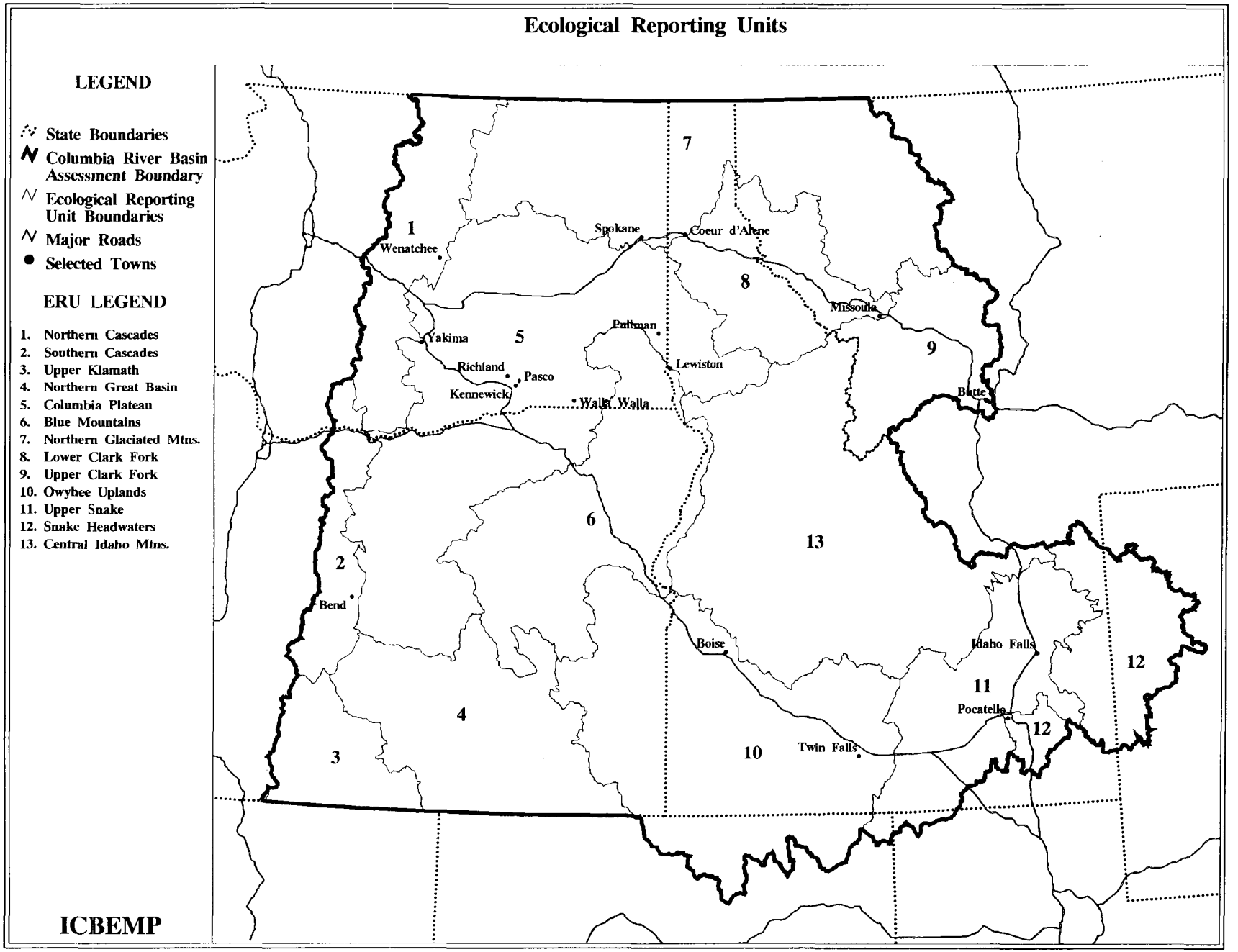
Ecological integrity, the degree to which all components of a system and their interactions are represented and functioning, is an important concept. An ecosystem is resilient when it returns to some constant state after change or disturbance or when it cycles within some definable bounds (Hilborn and Walters 1992). In the social and economic sense, resiliency is the capacity of a system or community to confront and adapt to change.

In the Assessment, the SIT looked at historical conditions and the dynamic processes at work on the landscape that have led to the current conditions. Although the SIT did not state threshold values or definite limits for system components, sufficient information is presented on current conditions and trends for the reader to understand where the greatest amount of departure from historic conditions has occurred. Discussions about ecological integrity and socioeconomic resiliency are presented in both this document and in the *Integrated Scientific Assessment.*

The *Framework* describes how assessments, risks, and decisions relate at multiple levels. Risks are defined as activities or events that pertain to the likelihood of not reaching desired goals. Uncertainty refers to the type of events that dominate ecosystem change where outcomes cannot be predicted in probabilistic terms. This Assessment is aimed at understanding the relations among events, activities, outcomes, and opportunities. Thus, it is an essential step in the cycle of risk management.

Ecological Reporting Units and Ecosystem Modeling

To facilitate the analysis and presentation of information and results on areas smaller than the entire Basin, the Basin was divided into 13 geographic areas called Ecological Reporting Units (ERUs). ERUs were defined by the landscape ecology, terrestrial, and aquatics staff of the SIT. Proposed ERU boundaries from the terrestrial team were based primarily on the section delineations from "Ecological Subregions of the United States: Section Descriptions" (McNab and Avers 1994) and subsection delineations produced through the ICBEMP. The section/subsection boundaries were adjusted to the nearest sixth (6th) field hydrologic unit boundary, or subwatershed that ranges in size from 12,350 acres to 49,400 acres. Boundaries proposed by the aquatics staff emphasized aquatic ecosystem components and were based primarily on groupings of fourth (4th) field hydrologic units, or watersheds that range in size from 98,800 to 617,500 acres. These 4th-field groupings contained similar hydrologic characteristics that were identified through cluster and discriminant analysis of watershed characteristics and stream-gauging station data. This strategy also incorporated general data about the distribution of aquatic species and zoogeographic data. These approaches yielded similar delineations and were combined using 6th-field hydrologic units as the basic mapping unit to create the ERUs (map 1.4).



Map 1.4—Ecological Reporting Units.

To the extent possible, the ERUs provided the basis for the descriptions of biophysical environments, the characterization of ecological processes, the discussion of the effects of land management activities and observed trends from past management, and the discussion of the complexities of managing landscapes in the future. However, some ecological processes and functions do not conform well to the ERU boundaries. Where this occurred, the assessment used a more appropriate context. For some topics, lack of detailed information resulted in evaluating the entire Basin and not smaller units.

Scenarios

The *Integrated Scientific Assessment* brings together a discussion of interactions and outcomes associated with possible futures. A scenario is a description of a possible course of action and its probable outcomes. Scenarios can be used to improve the understanding of possible outcomes of various actions or policies. Unlike EIS alternatives, they need not be designed to achieve a particular purpose but may be used to explore key factors in how systems operate. Scenarios can also be very broad and encompass changes that are beyond the authority of a specific decision-maker in the Basin. Scenarios were used in this project to test analytical models, predict possible trends in conditions on lands within the Basin, and facilitate the development of EIS alternatives by providing insights into outcomes associated with a wide range of futures. Four scenarios were developed, each of which emphasized a different type of management. They are broadly described as: 1) continuation of current management, 2) emphasis on commodity production, 3) passive management of ecological processes, and 4) active management of ecosystem functions and processes. These scenarios provided background for the development of the EIS alternatives and initial model parameters for simulating futures. The *Integrated Scientific Assessment* contains discussions of assumed societal goals, management options inferred by those goals, and ecological integrity of expected outcomes. Some discussion of scenario outcomes can be found in the following chapters as well.

Overview of the Basin

The lands in the Basin are highly diverse. They range from the Cascade crest in the west to the Continental Divide in the Rocky Mountains on the northeast and east. The Bitterroot, Selkirk, Cabinet, Salmon River, Lemhi, and Purcell mountain ranges in central Idaho and western Montana commonly have elevations over 3,000 meters. The Basin also encompasses the extensive basalt plateau of eastern Oregon, eastern Washington, and southern Idaho as well the high desert of the Klamath Basin in southwest Oregon and the plains of the Great Basin in northern Nevada, northern Utah, and southern Idaho.

Events during the Pleistocene epoch shaped much of the Basin's landscapes. Lobes of the ice sheet originating in Canada excavated and molded valleys in the northern portion of the Basin while alpine glaciers occurred in most of the mountainous areas. Many large lakes formed as a result of the wetter climate, particularly in southern portions of the assessment area where closed basins exist. Repeated breaching of ice dams by glacial Lake Missoula led to cataclysmic flooding that carved the "channeled scablands" of eastern Washington. Spillover of pluvial Lake Bonneville into the Snake River system modified the valley of the Snake River and left large cataract complexes. Sedimentary deposits including glacial till, outwash, and loess, and valley fill, terraces, and scour features occur over much of the Basin. Soils developed from loess deposits in the Columbia Plateau and Snake River plain have enabled these areas to develop into highly productive agricultural areas.

The Basin is in a transition-type climate zone, and climate patterns are dominated by topographic features. Type and distribution of vegetation varies depending on the soils, long-term precipitation patterns, and climate. Forested vegetation varies among the dry, moist, and cold potential vegetation types. Dry forest potential vegetation is typical on lower elevation sites with low levels of precipitation and is generally more dominant in the western and southern portions of the Basin. Moist forest

potential vegetation is typical of mid-elevation areas with higher levels of precipitation. These areas are more typical of the northern and central areas of the Basin. Cold forest types are typical of higher elevation areas, such as along the Continental Divide. Grassland, shrubland, and woodlands are also present across the Basin. These vary between desert (very dry) areas and high elevation (very cold) areas.

Most of the area is drained by the Columbia River and its tributaries. The portion of the Klamath Basin that occurs in the project area is drained by the Klamath River and its tributaries; the portion of the Great Basin within the project area has closed basins. Stream modifications to facilitate navigation on the Columbia River system began in 1876 with the construction of locks and canals. By 1975, the waterway between Lewiston, Idaho, and the Pacific Ocean had become a series of reservoirs. This dam system provides 40 percent of the Nation's hydropower production, navigation and irrigation benefits, flood control, and recreational opportunities. Irrigation from both surface and ground water sources is by far the dominant off-stream use of water in the Basin.

The Basin covers about 8 percent of the U.S. land area and contains about 1.2 percent of the Nation's population. This results in a population density that is less than one-sixth of the U.S. average. The area has experienced recent, rapid population growth. Thirty-one percent of the Basin's population lives in urban areas in contrast with the rest of the nation where 77.5 percent of the population lives in urban areas. The racial and ethnic composition of the Basin is also quite different from the rest of the country. Generally, the Basin has a higher percentage of Caucasians; a greater proportion of American Indians; and a smaller proportion of African-Americans, Hispanics, and Asians than the United States in general.

The Basin covers about 24 percent of the Nation's National Forest System lands and 10 percent of the Nation's BLM-administered lands. Designated wilderness within the Basin accounts for 29 percent of the wilderness acres within the contiguous United States. The relatively large amount of Federal land and designated wilderness in the Basin is one of the reasons why available recreation resources are greater than the national average. The relative rate of participation in outdoor recreation is significantly higher than in other regions of the Nation.

The Basin has a diverse economy which composes 3.6 percent of the U.S. economy. Six metropolitan counties have been the center of its economic growth. Spokane, Boise, Richland/Pascoe/Kennewick ("Tri-Cities"), Yakima, Bend, and Wenatchee are the major urban areas in the Basin. The past two decades have seen the evolution of what was a mature, resource-based economy into a diverse economy oriented toward the technology, transportation, and service sectors. Economic strengths of the Basin include agriculture and agricultural services.

Chapter Organization And Development

The Scientific Assessment provides information about current conditions and trends within the Basin that can be used by land managers to develop broad land management goals and priorities and that provides the context for decisions specific to smaller geographic areas. This document, composed of detailed reports from each functional staff area, addresses the biophysical and social conditions of the Basin.

Each of the functional staff areas developed approaches that best suited an examination of the resource and policy questions related to their specific area of study. The following chapters reflect that variation in approach. All of the chapters discuss study methodologies and results but contain varying amounts of discussion related to ERUs, scenarios, and ecosystem integrity. The amount of detail also varies between chapters. Summaries for all chapters are located immediately following this section.

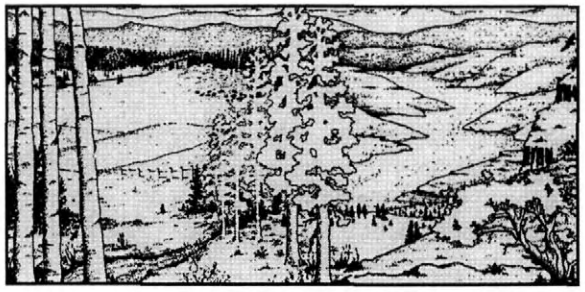
Chapters 2 and 3 contain information on the ecology of the Basin's landscapes. Chapter 2 presents a discussion of biophysical environments including multi-scale descriptions of geologic, climatic, geoclimatic, potential vegetation, soils, and hydrologic system organization. The hydrologic integrity for 12 forest and range clusters is also discussed. Chapter 3 discusses multi-scale landscape dynamics including processes of change; changes in vegetation, cover types and patterns; and forest and range conditions.

Aquatic and terrestrial species and habitats are discussed in Chapters 4 and 5. Chapter 4, Broadscale Assessment of Aquatic Species and Habitats, includes descriptions of the primary elements of change that affect the integrity of aquatic ecosystems; the relation between small-scale stream features, landscape-scale features, and human activities; the distribution and status of fishes in the Basin; and ecological opportunities and risks. Chapter 5 contains information on the terrestrial ecology of the Basin including distribution of species, species habitats, and key environmental correlates. Viability projections for both aquatic and terrestrial species that may be associated with various management alternatives are not included in this document.

Socioeconomic information is presented in Chapters 6 and 7. The Economic Assessment includes discussions of regional economies, economic efficiency, and equity. Economic issues related to particular resources managed by the FS and BLM including fish, minerals, range, recreation, special forest and range products, timber, and water are analyzed. The importance the BLM and FS lands to the economies of the Basin is also explored. The Social Assessment includes information on history; population demographics; attitudes, beliefs, and values of various segments of society; communities and lifestyles; the role of public land amenities; public participation; and institutional issues. The chapter also provides information on American Indians and the trust responsibilities of the Federal Government.

Information System Development and Documentation for the assessment is presented in Chapter 8. This chapter describes how the data collected for the assessment were managed using Geographic Information Systems (GIS), conventional databases, and other electronic tools.

Other technical reports will be published in the future. Such reports may include those that were completed in preparation for this assessment, those that contain more detailed information not included in these chapters, and those that may be completed by researchers using information gathered for this project, but not yet fully analyzed. More detailed explanations of databases, models, and information layers will be useful to both public and private land managers. Documentation of data themes and GIS layers are available as part of the administrative record for this project.



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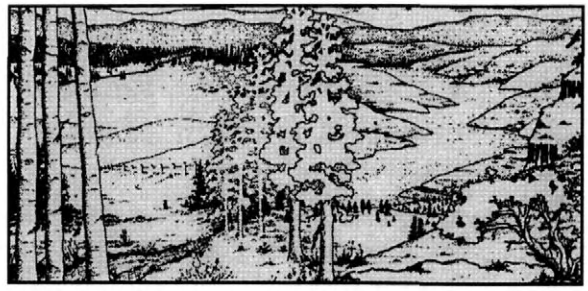
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GLOSSARY



adaptive management - Feedback which consists of knowledge or data on the effects or results of an action. Information is purposely collected and used to improve future management actions.[1]

biodiversity (biological diversity) - The diversity of plant and animal communities, including endemic and desirable naturalized plant and animal species.

biomass - The total mass of living matter within a given volume of environment.[2]

biome - An entire community of living organisms in a single major ecological region.[2]

biophysical - The combination of biological and physical components in an ecosystem.

biotic - Living; relating to life or specific life conditions.[2]

decision-maker - In the use of federal land management, the person authorized to make land management decisions.

desired future condition - A portrayal of the land or resource conditions that are expected to result if goals and objectives are fully achieved (36 CFR 219).

disturbance - Any event that alters the structure, composition, or function of terrestrial or aquatic habitats; fire, flood, and timber harvest are examples of large-scale disturbance.

disturbance regime - Natural pattern of periodic disturbances, such as fire or flood, followed by a period of recovery from the disturbance. Such as regrowth of a forest after fire.

diversity - The distribution and abundance of different plant and animal communities and species within the area covered by a land and resource management plan (36 CFR 219.3).

ecoregion - A continuous geographic area with similar climate that permits the development of similar ecosystems on sites with similar properties.

ecosystem - A community of organisms and their physical environment interacting as an ecological unit.[3]

ecosystem integrity - System integrity where the system is defined as the degree to which all components and their interactions are represented and functioning within an ecosystem. Integrity is the quality or state of being complete, a sense of wholeness.

ecosystem management-"...management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function."[8]

endemic species - Plants or animals that occur naturally in a certain region and whose distribution is limited to a particular locality.

exotic - Not native; an organism or species that has been introduced into an area.

hierarchy - A general integrated system comprising two or more levels, the higher controlling to some extent the activities of the lower levels; a series of consecutively subordinate categories forming a system of classification.[3]

hypothesis - An assertion or working explanation that leads to testable predictions; an assumption providing an explanation of observed facts, proposed in order to test its consequences.[3]

landscape - A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout.[4]

monitor - To check systematically or scrutinize for the purpose of collecting specified categories of data.

monitoring - A process of collecting information to evaluate whether or not objectives of a project and its mitigation plan are being realized. In land management monitoring is used to describe continuous or regular measurement of conditions that can be used to validate assumptions, alter decisions, change implementation or maintain current management direction.

montane - Of, growing in, or inhabiting mountain areas.[2]

native - Indigenous; living naturally within a given area.[3]

population viability - Relative measure of the estimated numbers and distribution of reproductive individuals in a species population necessary for that species' continued existence; a minimum number of reproductive individuals in a habitat that will both support them and enable them to interact is necessary for a species' maintenance [adapted from 36 CFR 219.9]

resiliency - The degree to which systems adapt to change.

resolution - Separation or reduction of something into its constituent parts; here, the degree of detail incorporated in the data; finer data resolution provides greater detail.[2]

scale - Defined in this framework as geographic extent; for example, regional, sub-regional, or landscape scale.

scenario planning - Planning that focuses on an outline of a hypothesized or projected chain of events.[2]

seral stage - The developmental stages of a plant community not including the climax community; typically, young-seral forest refers to seedling or sapling growth stages; mid-seral forest refers to pole or medium sawtimber growth stages; and old or old-seral forests refer to mature and old-growth stages.

spatial - Of, relating to, or having the nature of space.[2]

species - The lowest principal category of a biological classification distinct from other groups.[3]

stakeholders - Tribal, State, county, local governments, and private land holders, as well as individuals and groups representing local and national interests in Federal land management. This is meant to be inclusive of all organizations and individuals with an interest in Federal lands. This also includes all United States citizens who use, value, and depend upon the goods, services, and amenities produced by federally administered public lands.

succession - Currently: The more or less predictable changes in species composition in an ecosystem over time, often in a predictable order, following a natural or human disturbance. An example is the development of a series of plant communities (called seral stages) following a major disturbance.[5]

systems modeling - Using a model of a system to study (or experiment) with the system itself.[7]

temporal - Related to, concerned with, or limited by time.[2]

viable - Having the capacity to live, grow, germinate, or develop.

virtual system - A system that is the essence of reality but not actual fact, or form.

watershed - The region draining into a river, river system, or body of water.[2]

weed - Any plant growing where it is not wanted.[3]

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[7] Gordon, G. 1978. System simulation. 2nd ed. Englewood Cliffs, New Jersy: Prentice Hall. 324 p.

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APPENDIX 1-A

Detailed chronology of events leading to the establishment of the Interior Columbia Basin Ecosystem Management Project.

Date	Northwest Forest Plan	Fisheries	Forest Health	Range
Summer 1988				USDA Forest Service published a proposed rule that responded to findings of a 1987 review. The review identified parts of the existing livestock grazing regulations that required revision and clarification.
Fall 1988	Record of Decision signed for Supplemental EIS for amendment to the Pacific Northwest Regional Guide. Adopted guidelines to manage northern spotted owl habitat on national forests.		USDA Forest Service prepared "Forest Health through Silviculture and Integrated Pest Management: A Strategic Plan". Included initiation of forest health monitoring program.	
Fall 1989	Interagency Scientific Committee was established to address the status of the northern spotted owl.			
Spring 1990	Interagency Scientific Committee report, "A Conservation Strategy for the Northern Spotted Owl" was released. The report addressed Federal lands through a system of habitat conservation areas. US Fish and Wildlife Service listed the northern spotted owl as threatened.			
Winter 1991		Columbia River Basin Anadromous Fish Habitat Management Policy and Guidelines was signed. Recognized the USDA Forest Service's role, support, development, and implementation of an approach to manage of wild and naturally reproducing stocks of anadromous fish. Chief of the Forest Service issued "Riparian Management Strategy." The strategy provided an approach for implementation, goals for accomplishments, a priority action program, and broad-based support. Regional Foresters pledged their commitment to specific habitat measures identified at Hatfield Salmon Summit which included riparian and watershed restoration.		

Winter (January-March); Spring (April-June); Summer (July-September); Fall (October-December)

Date	Northwest Forest Plan	Fisheries	Forest Health	Range
Spring 1991			Malheur, Umatilla, and Wallowa-Whitman National Forests issued "Blue Mountains Forest Health Report Strategies and Recommendations- New Perspectives in Forest Health". They reported on the deteriorating health of the forests in northeast Oregon.	
Fall 1991	Scientific Panel (also known as Gang of Four) on Late-successional Forest Ecosystems delivered a report to Congress that outlined alternatives and scenarios for management.			
Winter 1992	Record of Decision signed for Final EIS on Management for the Northern Spotted Owl in National Forests. Adopted USDA Forest Service alternative which was equivalent of the Interagency Scientific Committee Conservation Strategy.			National Public Lands Advisory Council released a report prepared by ecologists and rangeland managers "Rangeland-Program Initiatives and Strategies". Concluded that the USDI Bureau of Land Management's main objective should be to protect soil, water, and vegetation.
Spring 1992		NMFS listed the Snake River spring/summer/fall chinook salmon as threatened.	Scientific societies formed the Eastside Forests Scientific Society Panel to "initiate a review and report on the eastside forests of Oregon and Washington".	
Summer 1992	Forest Service Chief Robertson announced ecosystem management as the framework for managing national forests and grasslands.			
Summer 1992			Report prepared by the Malheur, Umatilla, and Wallowa-Whitman National Forests on "Restoring Ecosystems in the Blue Mountains". The report provided direction to the Forest Supervisors to continue the use of the ecosystem approach to identify areas in need of restoration work and activities.	
Fall 1992	US Fish and Wildlife Service listed the marbled murrelet as threatened.			Conservation organizations wanted the USDI Bureau of Land Management to improve its grazing administration. USDI Bureau of Land Management organized an Incentive Based Grazing Fee Task Force to consider ways of establishing an equitable fee for federal forage and examining the feasibility of using fee credits to encourage public land stewardship.

Winter (January-March); Spring (April-June); Summer (July-September); Fall (October-December)

Date	Northwest Forest Plan	Fisheries	Forest Health	Range
Winter 1993	Scientific Analysis Team issued their report "Viability Assessments and Management Considerations for Species Associated with Late-successional and Old-growth Forests of the Pacific Northwest.	NMFS listed the Snake River sockeye salmon as endangered.	The "Blue Mountains Ecosystem Restoration Strategy" was submitted to the Regional Forester. The report provided a broad scope of project opportunities. The "Northeastern Washington National Forest Health Proposal" was submitted to the Regional Forester. The report provided a list of projects which would aggressively address the serious problem of declining health. Petition filed by the Natural Resources Defense Council to halt the logging of old growth on the national forests of eastern Oregon and Washington. Concern that habitat for certain old growth associated species was not being adequately provided.	
Winter 1993	Interior Secretary Babbitt issued a public statement that established policy regarding ecosystem management.			
Spring 1993	President Clinton's Forest Conference in Portland, Oregon discussed the state of the forests, economy, and people of the Pacific Northwest.			
Spring 1993		Eastside Forest Ecosystem Health Assessment was issued. The report responded to the request for a scientific evaluation of the effects of USDA Forest Service management practices on the sustainability of eastern Washington and Oregon forested ecosystems.	Eastside Forest Ecosystem Health Assessment was issued. The report responded to the request for a scientific evaluation of the effects of USDA Forest Service management practices on the sustainability of eastern Washington and Oregon forested ecosystems. "A First Approximation of Ecosystem Health, National Forest System Lands, Pacific Northwest Region" was issued. The report provided a generalized snapshot of the overall health/condition of the national forests from an ecosystem framework.	Draft of the Incentive Based Grazing Fee Task Force's study presented. Western Governor's Association drafted resolution on grazing fees. The resolution called for a fee structure that is predictable, affords stability, and is linked to credits for land stewardship.
Summer 1993	President issued a statement on the "President's Forest Plan"; "Management of eastside forests will need to focus on restoring the health of forest ecosystems impacted by poor management practices of the past..." The President directed the USDA Forest Service to develop a scientifically sound and ecosystem-based strategy for management of eastside forests.			

Winter (January-March); Spring (April-June); Summer (July-September); Fall (October-December)

Date	Northwest Forest Plan	Fisheries	Forest Health	Range
Summer 1993	Forest Ecosystem Management Assessment Team issued their report "Forest Ecosystem Management: An Ecological, Economic, and Social Assessment".		Direction provided to screen timber sales where they might affect riparian habitat, reduce the amount of old-growth timber and impact wildlife habitat associated with old growth. Timber industry challenged the "eastside screening" process in court.	Interior Secretary proposes rulemaking intended to revise grazing administration regulations to place greater emphasis on rangeland stewardship and ecological health.
Fall 1993		Umatilla and Wallowa-Whitman National Forests ordered to re-initiate consultation on Management Plans with regard to USDA Forest Service actions to protect listed salmon species. NMFS designated critical salmon habitat.	USDA Forest Service updated their "1988 Strategic Plan" and issued "Healthy Forests for America's Future: A Strategic Plan". The Strategic Plan continued the goals of the 1988 Plan and incorporated new goals that specifically address exotic pests, urban-wildland interface, prevention and restoration. The Idaho Forest, Wildlife and Range Policy Analysis Group published the report "Forest Health Conditions in Idaho".	
Winter 1994		Environmental Assessment for the Implementation of Interim Strategies for Managing Anadromous Fish-producing Watersheds in Eastern Oregon and Washington, Idaho, and Portions of California (PACFISH) is released for public comment.		National Research Council published a report "Rangeland Health: New Methods to Classify, Inventory and Monitor Rangelands".
Winter 1994	USDA Forest Service, USDI Bureau of Land Management, US Fish and Wildlife Service, and NMFS signed an Interagency Memorandum of Understanding to manage federally administered lands for the conservation of species that are tending toward Federal listing. USDA Forest Service was charged with developing a scientifically sound and ecosystem-based strategy for management of forests east of the Cascade crest. The Forest Service and USDI Bureau of Land Management directed that an ecosystem management framework and assessment be developed for lands administerd by the Forest Service and USDI Bureau of Land Management on those lands east of the Cascade crest in Oregon and Washington and within the Interior Columbia River Basin. The Interior Columbia Basin Ecosystem Management Project was established by charter on January 21, 1994.			
Spring 1994	Record of Decision signed for Final Supplemental EIS that amended USDA Forest Service and USDI Bureau of Land Management planning documents within the range of the northern spotted owl, and standards and guidelines for management of habitat for late-successional and old-growth forest related species. (The decision implemented what was known as the President's Forest Plan and later known as the Northwest Forest Plan).		Regional Forester signed a Decision Notice for the "continuation of the Interim Management Direction Establishing riparian, ecosystem, and wildlife standards for timber sales" (also known as Eastside Screens). Amended all eastside (Oregon and Washington) Forest Plans to include the direction as new standards and guidelines.	Draft EIS, "Rangeland Reform 94" was issued.

Winter (January-March); Spring (April-June); Summer (July-September); Fall (October-December)

Date	Northwest Forest Plan	Fisheries	Forest Health	Range
Summer 1994		NMFS issued an emergency action to reclassify the Snake River spring/summer/fall chinook salmon from a threatened status to endangered. US Fish and Wildlife Service announced that the listing of the bull trout was warranted but precluded by higher priority species.	The Eastside Forests Scientific Society Panel reported on their findings and offered interim recommendations for preventing further degradation of remaining resources until more comprehensive data are gathered and long-term protection and restoration can be implemented.	
Fall 1994	Judge Dwyer ruled that the Federal defendants acted within the lawful scope of their discretion in adopting 1994 Forest Plan.	USDI Bureau of Land Management and USDA Forest Service issued a letter of direction for the management of bull trout habitat to ensure that the actions of the agencies do not further contribute to loss of species viability or Federal listing.	The Court enjoined the US Forest Service from applying the August 1993 interim screens to the remaining 1993 sales until it complied with plan amendment and public participation requirements. USDA Forest Service issued their report "Western Forest Health Initiative" to provide a national strategy on forest health. Developed a number of recommendations that build on the "1993 Strategic Plan".	Final EIS was published for "Rangeland Reform 94" (also known as Healthy Rangeland Initiative and Healthy Rangeland Reform). Proposal for managing Federal rangeland administered by the USDI Bureau of Land Management and USDA Forest Service.
Winter 1995		PACFISH Decision Notice/Decision Record was signed by the Chief of the Forest Service and Bureau of Land Management Director to amend regional guides and supplement management direction. Boise, Challis, Clearwater, Payette, Salmon, Sawtooth, and Nez Perce National Forest Management Plans were ordered to re-initiate formal consultation with regard to USDA Forest Service actions to protect listed salmon species. NMFS issued Biological Opinion on eight Forest Service Management Plans that identified goals, objectives, and guidelines that will be applied until the Plans are amended. USDA Forest Service issued an Environmental Assessment for a proposal to protect habitat and populations of native inland fish. This became known as the Inland Native Fish Strategy or INFISH.		USDI Bureau of Land Management published final rule that amended the regulations that govern the administration of livestock grazing. The objectives of the regulations are to promote healthy sustainable rangeland ecosystems, to accelerate restoration and improvement of public rangelands, establish efficient and effective administration, and to provide for the sustainability of the western livestock industry and communities that are dependent.

Winter (January-March); Spring (April-June); Summer (July-September); Fall (October-December)

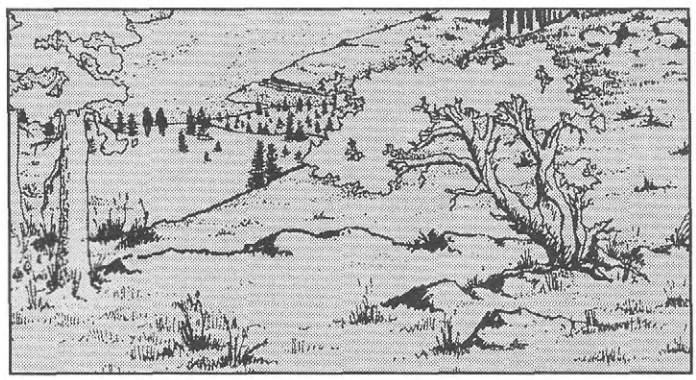
Date	Northwest Forest Plan	Fisheries	Forest Health	Range
Spring 1995			Decision Notice was signed to revise the decision to implement Interim Management Direction for Eastside Screens. A Report was prepared by scientists in the Northwest for Governor Kitzhaber to help define environmentally sound *timber harvest in eastern* Oregon.	
Summer 1995		Decision Notice for the Inland Native Fish Strategy was signed. The President issues Executive Order 12962 requiring federal agencies to improve the quantity, function, sustainable productivity and distribution of aquatic resources for increased recreational fishing *opportunities.*		
Fall 1995				USDI Bureau of Land Management in Idaho, Utah and Montana issue Notices of Intent to prepare standards for Rangeland Health, guidelines for grazing management, and modifications to land use plans.

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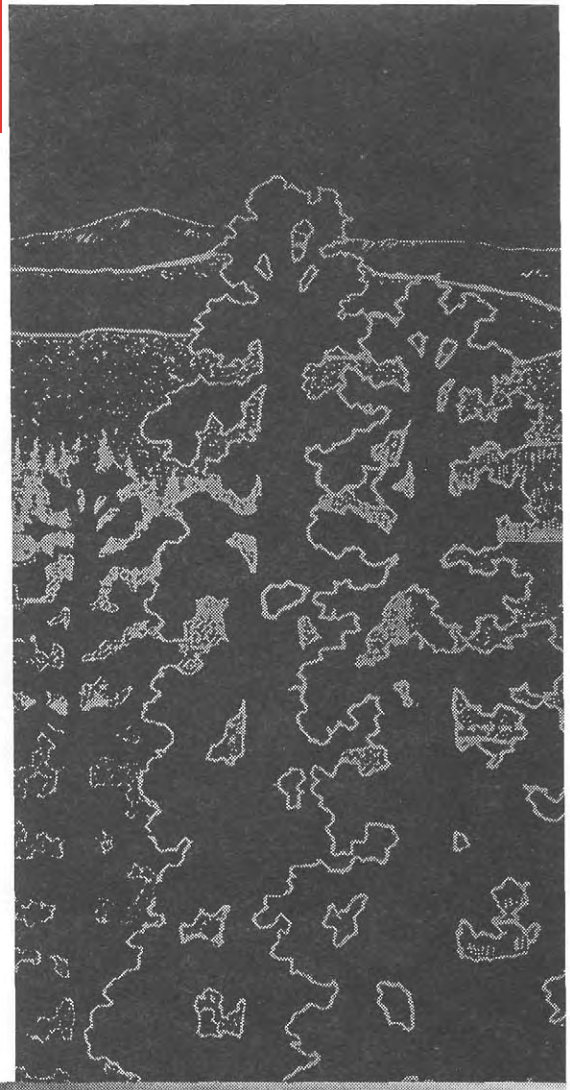
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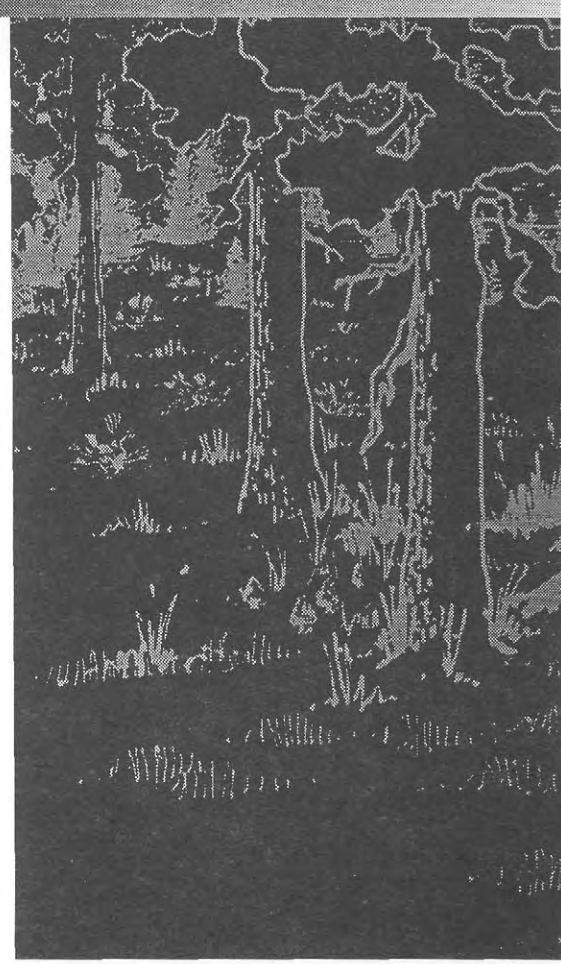
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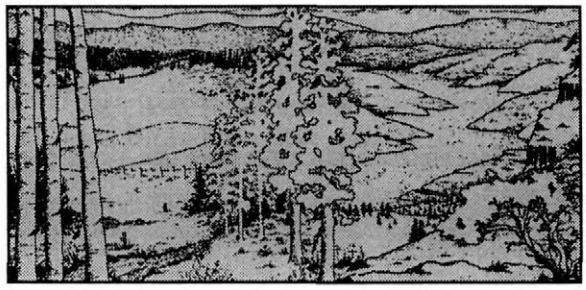


EXECUTIVE SUMMARIES





EXECUTIVE SUMMARY- BIOPHYSICAL ENVIRONMENTS



The Biophysical Environments chapter contains multi-scale descriptions of the following systems: geologic, geoclimatic, climatic, potential vegetation, soils, and hydrologic. The biophysical environments described are important to the ecological assessment of the Basin because they:

- Facilitate the delineation and description of terrestrial and aquatic ecosystems that behave in a similar manner given their potential ecosystem composition, structure, and function.
- Delineate areas with similar production potentials for management.
- Provide a basis for interpretations concerning hazards and limitations to management.
- Influence the natural disturbance processes that create finer-scale ecosystem patterns.
- Provide a needed context for the use and development of predictive models concerning future ecosystem pattern and process relations.

Ecosystem characterization is the process of appropriately relating pattern and processes at all scales of interest. It also entails the description and mapping of these patterns and processes. To accomplish this, ecological hierarchies of biotic processes, disturbance processes, and environmental constraints are superimposed. Biophysical environment descriptions and maps identify ecosystems that behave in a similar manner. They provide a useful template for interpretation of features that commonly display change following management or disturbance suppression (for example, existing vegetation). These maps and descriptions are based on landscape components that do not display high temporal variability (for example regional climate, geology, landforms). They often form the basis for delineation of environmental constraints for ecological pattern analysis. Regional, subregional, and landscape scales of biophysical environment maps were developed for use in this assessment. These maps and generalized descriptions of ecosystem components and processes such as geology, soils, climate, and hydrology are included in the Biophysical Environments Chapter.

Summary Characterization by Ecological Reporting Unit

An overview of the major biophysical patterns and hydrologic processes for each ERU within the Basin is presented to highlight differences among them.

Each of the ERU summaries contain:

- Statistics regarding characteristic subsection, lithology, and potential vegetation type composition, and basic climatic and morphometric descriptions.
- Descriptions of generalized soil characteristics and evaluation of productivity.
- Interpretations regarding stream type groups, valley bottom settings, and wetland complexes.
- Interpretations regarding upland erosion processes and sediment sources.

- Interpretations regarding predicted vulnerability of stream channels to disturbances, inherent channel recovery potential, and sensitivity to subwatershed disturbance within each ERU.

Listed below are brief descriptions of the ERU summaries.

ERU 1: Northern Cascades

Two subsection groups dominate:

- M242-01, characterized by glaciated mountains and foothills of igneous and sedimentary rocks modified by glacial and fluvial processes.
- M242-05, characterized by mountains and foothills covered by ash and pumice, frequently underlain by igneous extrusive rocks, and modified by fluvial, mass wasting, and aeolian processes.

This ERU has one of the lowest average elevations (1,216 m), one of the highest relative reliefs, and is in the highest slope class (27%). The area lies in the rain shadow of oncoming Pacific storms.

During the winter enough moisture spills over the Cascade crest to result in substantial snowfall. Overall, annual precipitation is in the highest class (95 cm) unevenly distributed between seasons. The major potential vegetation types are cool, moist; cold, moist; and warm, dry forestlands.

The dominant valley bottom settings are those with steeply sloping and highly to moderately confined valley bottoms and those having gentle slopes with low confinement. Stream types that are characterized by cascades and step-pool systems dominate; however, rapids-dominated B-stream types are very common (see fig. 1.2). Other locally important stream types that are important sources of sediment are braided-systems D types.

The erosion value is in the 65th percentile, the estimated median mass wasting index is at the 81st percentile, and the median sediment delivery hazard is about 78 percent, the highest across all ERUs. Stream channel sensitivity to increased flow and sediment is the lowest of all ERUs. The downstream transfer effects of increases in flow and

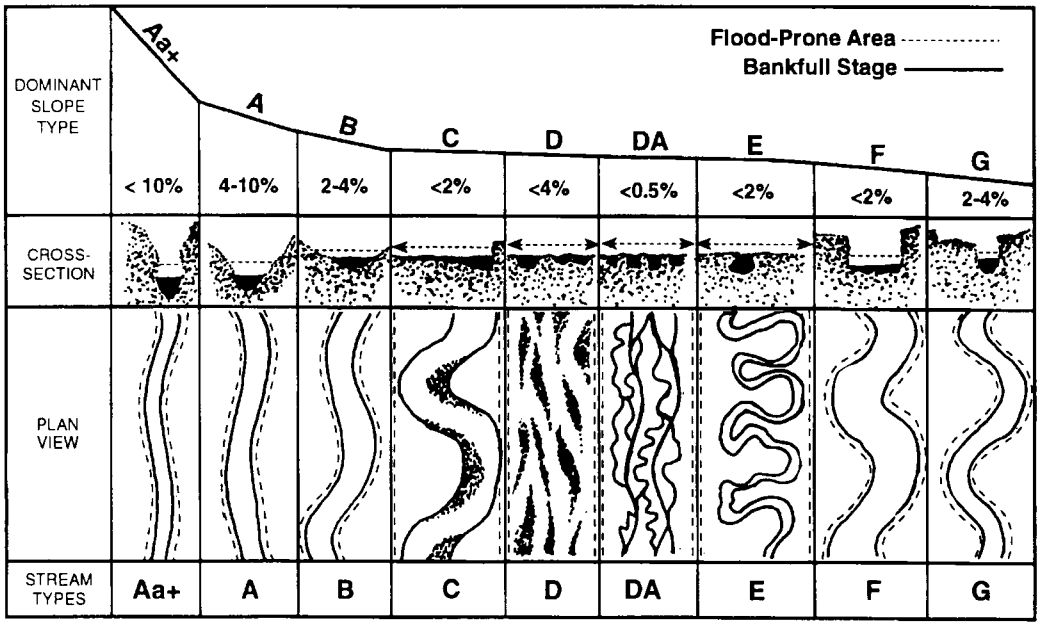


Figure 1.2—Longitudinal, cross-sectional, and plan views of major stream types.

sediment are average. Vegetation is relatively unimportant for maintaining the morphology of the A, B, and D stream types present. Overall, the potential for the estimated dominant stream types to recover from disturbance is among the highest of all ERUs.

ERU 2: Southern Cascades

Three subsection groups dominate:

- M242-05, characterized by mountains and foothills covered by ash and pumice, frequently underlain by igneous extrusive rocks, and modified by fluvial, mass wasting, and aeolian processes.
- M242-01, characterized by glaciated mountains and foothills of igneous and sedimentary rocks modified by glacial and fluvial processes.
- 342-07, characterized by foothills composed mainly of loess over basalt modified by fluvial and aeolian processes.

The lithologic mosaic for this ERU is dominated by mafic volcanic flows and calcic-alkaline volcanoclastics.

This ERU lies in the rain shadow of oncoming Pacific storms. During the winter enough moisture spills over the Cascade crest to result in substantial snowfall. Overall, ERU 2 has one of the highest annual precipitations (100 cm), unevenly distributed between seasons, and is in the highest class for maximum winter temperature. The major potential vegetation types present are warm, dry; cool moist; and cool, very dry forestlands.

The dominant valley bottom settings have steep slopes with low to moderate confinement; moderate slopes with moderate confinement; and gentle slopes with low confinement. Steep A stream types characterized by cascades and step-pool systems predominate, followed by rapids-dominated B stream types and significant numbers of E stream-type reaches with narrow, meandering channels and cool, swift water. Wetlands and lakes account for almost half of the valley bottoms described in subsampling.

The value for erosion is about 45 percent, the value for mass wasting is about 81 percent, and the sediment delivery hazard is in the mid-range (about 38%) of all ERUs.

The median index value for stream channel sensitivity to increases in flow and sediment is low (about 20%), downstream transfer effect of increases in flow and sediment is low, and the median value for potential bank erosion is moderate (about 38%). The importance of vegetation to maintaining the morphology of the dominant channel types is average (about 48%), and the median recovery potential is high (about 80%).

ERU 3: Upper Klamath

Three subsection groups dominate:

- M261-02, characterized by intermontane basins, foothills, and plateaus of igneous extrusive rocks overlain by ash, pumice, and alluvium modified by fluvial and volcanic processes.
- M242-02, characterized by plains of ash and pumice over volcanic rocks, mostly basalt, modified by alluvial and volcanic processes.
- M261-04, characterized by mountains composed of extrusive igneous rocks modified by fluvial processes.

Lake sediments, playas, and alluvium are important lithologic components in some areas.

This ERU has a high average elevation (1,560 m) and some of the lowest relative relief and average slopes (10%). This ERU also lies in the rain shadow of oncoming Pacific storms, but is less influenced by winter moisture that spills over the Cascade crest and results in snowfall. This combination results in the 5th lowest annual precipitation value (57 cm), and is in the highest class of winter solar radiation. The major potential vegetation types of this ERU are warm, dry; hot, moist; and hot, very dry forestlands. Cool, very dry forestlands are also common.

The dominant valley bottom settings are those having gentle valley slopes and moderate to unconfined side-slopes. Steep, confined valley bottoms and moderately steep, moderately confined valleys are also common. Steep, step-pool, A stream types are common, the majority of which are estimated to have unstable channels. Rapids-dominated B stream types are also common, and there is a comparatively high percentage of narrow, highly sinuous E stream types. There is a high percentage of channelized reaches; entrenched, low-gradient F stream types; and a moderate percentage of entrenched, gully G stream types.

This ERU is within the lowest class for upland erosion and has the lowest ranked sediment delivery hazard. It is in the second lowest class for mass wasting hazard and for downstream transfer effects of increased flow and sediment. This ERU ranks second highest in stream channel sensitivity to increases in flow and sediment, with only about 30 percent of the ERUs ranked higher for bank erosion potential. Riparian vegetation is fairly important to maintaining existing channel morphology. This ERU is ranked at the 40th percentile for inherent channel recovery potential.

ERU 4: Northern Great Basin

Three subsection groups dominate this ERU:

- M342-05, characterized by plateaus and foothills composed mainly of tuffs and basalts modified by fluvial and aeolian processes.
- M342-04, characterized by intermontane basins and valleys composed mainly of alluvium, ash, and lacustrine materials over basalt.
- M342-06, characterized by mountains composed mainly of tuffs and basalts modified by fluvial processes.

Lake sediments, playas, and alluvium are present in many subwatersheds.

This ERU occurs at higher elevations (average is 1,566 m), is within the lowest class of relative relief, and has the lowest average slopes. This ERU is in the driest part of the Basin with occasional marine intrusions both winter and summer; it is in the lowest class of annual precipitation, and is in the second highest class of winter solar radiation. The major potential vegetation type is warm, dry shrublands.

ERU 5: Columbia Plateau

Five subsection groups dominate:

- M342-07, characterized by foothills composed mainly of loess over basalt modified by fluvial and aeolian processes.
- M342-03, characterized by plateaus and high plains of fluvial and lacustrine sediments and ash deposits created by aeolian, fluvial, and lacustrine processes.
- M331-02, characterized by intermontane basins and valleys of valley fill, alluvium, and lacustrine materials overlying volcanic and sedimentary rocks.
- M331-04, characterized by glaciated mountains of volcanic and sedimentary rocks modified by colluvial, fluvial, residual, and glacial processes.
- M342-05, characterized by plateaus and foothills composed mainly of tuffs and basalts modified by fluvial and aeolian processes.

Mafic volcanic flows occur on 88 percent of the subwatersheds, and loess deposits occur on 48 percent of all subwatersheds.

This ERU has the lowest average elevation (486 m). It is within the lowest classes of relative relief and average slope (median slope value is about 8%). This ERU is in the driest part of the Basin with occasional marine intrusions both winter and summer; the annual precipitation is about 40 centimeters. This ERU is tied with ERU 2 for the highest average value for maximum winter temperature (about 4.5 degrees C) and is within the highest class of average August temperature (18 degrees C). The dominant potential vegetation types are warm, dry shrublands; warm, dry herbaceous lands; and cool, moist shrubland.

The dominant valley bottom settings are highly confined with steep valley slopes, moderately confined with moderate valley slopes, and moderately confined with gentle slopes. A stream types, characterized by step-pools, are dominant. About two-thirds of these are estimated to be unstable and thus are high sources of sediment. Also common are B and C stream types.

The erosion index is at the 70th percentile of all ERUs, the mass wasting hazard index is the third lowest, and the sediment delivery hazard is about average. The median index values for channel sensitivity to increases in flow and sediment and for bank erosion and downstream transfer effects are the second highest across all ERUs. The importance of vegetation for maintaining the width/depth ratio of the dominant channels is at the 58th percentile across all ERUs, and the recovery potential of streams is low.

ERU 6: Blue Mountains

Three subsection groups dominate:

- M332-08, characterized by mountains composed of igneous, sedimentary, and metamorphic rock modified primarily by fluvial and colluvial processes and secondarily by glaciation, frost churning, and mass wasting.
- M332-07, characterized by mountains composed of igneous and metamorphic rocks with lesser amounts of sedimentary rocks; all of which have been modified by fluvial, colluvial, mass wasting, frost churning, and glacial processes.
- M332-02, characterized by foothills of granitics and volcanics, with some metamorphic and sedimentary inclusions; all of these have been modified by glacial, fluvial, and residual processes.

This ERU falls within the mid-range class for most climatic and elevational data, except that it is within the lowest annual precipitation class. It is in the second highest classes for both winter solar radiation and average maximum winter temperature. A northward migration of a thermal trough during spring and early summer can increase precipitation and cause thunderstorms. The major potential vegetation types are warm, dry forestlands.

The dominant valley settings are highly confined with steep valley slopes, moderately confined on moderate valley slopes, and moderately confined on gentle valley slopes. The high-gradient A stream types and mid-gradient B types occur on over 74 percent of all subwatersheds while low-gradient C, D, and E stream types have moderate distribution. There is a high proportion of unstable, entrenched F types.

The value for erosion (65th percentile) is in the highest category. The median mass wasting index is about the 60th percentile, and the potential hazard for sediment to be delivered to streams is at the 50th percentile. Overall, the recovery potential of steams is low (20th percentile).

ERU 7: N. Glaciated Mountains

Three subsection groups dominate:

- M333-03, characterized by glaciated mountains of granitic and metasedimentary rocks modified by glacial and fluvial processes.
- M333-02, characterized by intermontane basins, valleys and till plains of lacustrine, outwash, alluvium and till.
- M333-04, characterized by mountains and breaklands of granitic and metasedimentary rocks that have been modified by fluvial and colluvial processes with some frost churning and alpine glaciation at high elevations.

Alluvium occurs in 73 percent of all subwatersheds, and open water occurs in 37 percent.

This ERU is in the second highest classes for relative relief: average slope 21%. Westerly flows can result in substantial precipitation, especially at higher elevations, with annual precipitation of about 87 centimeters. It is also in the highest class for summer precipitation (15 cm), and has among

the lowest maximum winter temperatures. The major potential vegetation types of this ERU are warm, dry; cool, moist; and cool, dry forestlands.

The dominant valley bottom settings are steep, confined valleys; broad, gently sloping valleys; and steeply sloping, moderate to unconfined valley bottoms.

The dominant stream types are steep, step-pool A stream types; rapids-dominated B stream types; and meandering, alluvial C stream types with well developed floodplains. Narrow, highly sinuous E stream types also occur. Wetlands and lakes are present in the majority of subsampled watersheds. The erosion potential is among the highest across all ERUs (about the 70th percentile). Median mass wasting hazard and potential delivery of sediment to streams is also high. The overall recovery potential following disturbance is generally good.

ERU 8: Lower Clark Fork

One subsection group dominates:

- M333-04, characterized by mountains and breaklands of granitic and metasedimentary rocks that have been modified by fluvial and colluvial processes with some frost churning and alpine glaciation at higher elevations.

This ERU is among those with the highest relative relief and has the highest average slope (26%). Westerly flows can result in substantial precipitation, especially at higher elevations. It has the highest annual precipitation (111 cm) and the lowest value for winter solar radiation. The major potential vegetation types present are cool, dry; cool, moist; and warm, dry forestlands.

Steep, confined valley bottoms occur in all subsampled watersheds, as do moderately confined and moderate-gradient valley bottoms and broad, unconfined valleys. Steep A stream types dominate. Alluvial, meandering C stream types also occur in all subsampled watersheds. Upland erosion potential is estimated as moderate relative to all other ERUs. Mass wasting potential is highest of all ERUs. The potential for sediment to reach streams is also very high, with most watersheds around the 90th percentile. Watersheds are fairly sensitive to increased streamflow and sediment, both on site and downstream, owing to transfer effects. Riparian vegetation is relatively insignificant in maintaining the channel morphology. Watersheds show the highest sensitivity to disturbance of all ERUs.

ERU 9: Upper Clark Fork

Four subsection groups dominate:

- M332-05, characterized by glaciated mountains and gneiss with lesser amounts of volcanic and sedimentary rocks modified by glacial, periglacial, fluvial, colluvial and mass wasting processes.
- M332-07, characterized by mountains of igneous and metamorphic rocks with lesser amounts of sedimentary rocks; all have been modified by fluvial and colluvial mass wasting processes.
- M332-08, characterized by mountains of igneous, sedimentary and metamorphic rocks modified by fluvial and colluvial processes with lesser amounts of glaciation, frost churning, and mass wasting.
- M332-04, characterized by intermontane basins and valleys of alluvium, lacustrine, and loess deposits modified by fluvial, mass wasting, glacial, and aeolian processes.

This ERU has the third highest average maximum elevation (2,432 m); the fourth highest average slope, and moderate relief. It is in the highest class for summer precipitation (15 cm) and in the lowest class for maximum winter temperatures (-0.3 degrees C). The major potential vegetation types are warm, dry; cool, dry; cold, wet; and cold, moist forestlands.

Steep, confined valley bottoms followed by moderate gradient, moderately confined valley bottoms, and steep, moderately confined valley bottoms occur in subwatersheds. Steep, step-pool A stream types

predominate; rapids-dominated B stream types, meandering-alluvial C stream types, and highly sinuous E stream types are decreasingly abundant. Wetlands and lakes occur in 61 percent and over 60 percent of the watersheds, respectively.

The upland erosion potential is average, and the mass wasting hazard and the potential for sediment to reach streams are ranked at the 60th percentile. Overall bank erosion potential is ranked at about the 30th percentile and the inherent recovery potential of these watersheds is quite high (70th percentile).

ERU 10: Owyhee Uplands

Three subsection groups dominate:

- M342-02, characterized by plateaus and high plains of basalts and tuffs modified by fluvial and aeolian processes.
- M342-06, characterized by mountains composed mainly of tuffs and basalts modified by fluvial and aeolian processes.
- M342-03, characterized by plateaus and high plains of fluvial and lacustrine sediments and ash deposits that have been created by aeolian, fluvial, and lacustrine processes.

Alluvium is present in 68 percent of the subwatersheds.

This ERU has relatively high elevation subwatersheds (1,442 m) and is in the lowest class for relief, average slope (9%). This ERU is in the driest part of the Basin with occasional marine intrusions both winter and summer. It has a low annual precipitation (30 cm) and some of the lowest summer precipitation values (4 cm). It is in the highest August temperature class (18 degrees C), the third highest winter temperature, and is in the highest class for winter solar radiation. The major potential vegetation types are warm, dry; warm, very dry; cool, moist; and cool, dry shrublands.

Gentle slopes in moderately confined valley bottoms and moderate slopes in confined to moderately confined valley bottoms occur in all or nearly all watersheds. Steep, confined valleys occur to a much lesser extent. Steep, step-pool A stream types and rapids-dominated B stream types occur most frequently. Meandering, alluvial C stream types with well-developed floodplains; braided channels; entrenched, gully-like G stream types; and entrenched, meandering F stream types occur as well.

Upland erosion potential ranks at about the 60th percentile. Mass wasting potential and sediment delivery hazard (20th percentile) are low. Potential bank erosion is quite high (70th percentile), with vegetation moderately important in maintaining width-to-depth ratios. Inherent recovery potential following disturbance is among the lowest of all ERUs.

ERU 11: Upper Snake

Two subsection groups dominate:

- M342-02, characterized by plateaus and high plains of basalts and tuffs modified by fluvial and aeolian processes.
- M342-06, characterized by mountains composed mainly of tuffs and basalts modified by fluvial and aeolian processes.

Alluvium occurs in 84 percent of the subwatersheds.

This ERU is characterized by high elevations (1,672 m), low relief, and low average slope (10%). It is in the driest part of the Basin with occasional marine intrusions both winter and summer. It is in the lowest class of annual precipitation (31 cm) and summer precipitation (6 cm), and has high winter solar radiation and high average daily August temperature. The major potential vegetation types present are warm, dry; warm, moist; and cool moist shrublands; and hot, very dry forestlands.

Moderately confined valley bottoms on gentle slopes and confined to moderately confined valley bottoms on moderate slopes are co-dominant. Moderate gradient, rapids-dominated B stream types occur in 93% of subsampled watersheds. Steep, step-pool A stream types occur in almost 80% of the subsampled watersheds. Channelized and entrenched streams occur to a lesser degree.

Upland erosion potential ranks at about the 60th percentile, but mass wasting and potential sediment delivery to streams is low relative to other ERUs. The overall sensitivity of these watersheds to increased flow and sediment is average. This ERU is distinguished by relatively high streambank erosion potential (65th percentile) and low channel recovery potential (40th percentile). Riparian vegetation is especially important for maintaining channel morphology (90th percentile).

ERU 12: Snake Headwaters

Four subsection groups dominate:

- M331-06, characterized by mountains of sedimentary and volcanic rocks modified by colluvial, fluvial, residual, glacial, and periglacial processes.
- M331-02, characterized by intermontane basins and valleys of valley fill, alluvium, and lacustrine materials overlying volcanic and sedimentary rocks.
- M331-03, characterized by glaciated mountains of volcanic and sedimentary rocks modified by colluvial, fluvial, residual, glacial, and periglacial processes.
- M331-04, characterized by glaciated mountains of volcanic and sedimentary rocks; all have been modified by colluvial, fluvial, residual, and glacial processes.

Alluvium is present in 88 percent of the subwatersheds.

This ERU has the highest average elevation (2,191 m), high winter solar radiation, a moderate level of summer precipitation, and low maximum winter temperatures. Relief and average slope (18%) are in the mid-range for all ERUs. The major potential vegetation types are cool moist, and warm dry shrublands; and cool dry, and warm dry, forestlands.

Steep, moderately confined valleys dominate followed by moderately confined valleys on moderate slopes and broad, gently sloping valleys. Steep, step-pool A stream types occur in all subsampled watersheds, as do meandering, alluvial channels with well-developed floodplains. Braided channels also occur over small areas in a majority of watersheds. The mass wasting index is high (80%), but the potential for sediment delivery to streams is only moderate because of low drainage densities. Maintenance of riparian vegetation is fairly important relative to other ERUs.

ERU 13: Central Idaho Mountains

Three subsection groups dominate:

- M332-07, characterized by mountains of igneous and metamorphic rocks with lesser amounts of sedimentary rocks modified by fluvial, colluvial, and mass-wasting processes.
- M332-05, characterized by glaciated mountains and gneiss with lesser amounts of volcanic and sedimentary rocks modified by glacial, periglacial, fluvial, colluvial, and mass-wasting processes.
- M332-01, characterized by breaklands and foothills of granitic rocks modified by fluvial, colluvial, and mass-wasting processes.

This ERU is within the second highest elevation class. It is in the highest relative relief (average slope 26%) and winter solar radiation classes. It is less influenced by precipitation from westerly flows than are the ERUs further north. The major potential vegetation types present are warm, dry; cool, dry; and cold, dry forestlands; and cool, moist shrublands. Steep, confined valleys dominate this ERU.

Moderately confined valleys with moderate slopes and steep slopes are common. Steep, step-pool and cascade streams (Stream type A) occur in all subsampled watersheds. On more moderate slopes, rapids-dominated B stream types, and localized occurrences of braided D stream types are common (93% and 45% constancy respectively). Highly sinuous, narrow, riffle-pool streams (E types) occur in 45% of all subsampled watersheds. Unstable, entrenched F types occur to a lesser extent.

Upland erosion potential is average. Potential for mass wasting and delivery of sediment to streams is quite high (both are at the 65th percentile). Overall sensitivity to increased sediment and streamflow is fairly low (25th percentile), and potential downstream transfer effects caused by increased streamflow and sediment are moderately high (60th percentile).

Hydrologic Integrity

An analysis of hydrologic integrity across the Basin was complicated by a lack of consistent finer-scale data. Stream parameters such as bankfull width, depth, streambed gradient, and substrate composition were generally lacking for most watersheds. As a result, a generalized probabilistic approach was used to estimate subbasin hydrologic integrity. In this approach, information on the resiliency and sensitivity of watersheds to disturbance were combined with estimates of past disturbance to provide an overall hydrologic integrity estimate. Rangeland and forested watersheds were assessed independently in this analysis to facilitate characterization of these environments separately at the subbasin level (maps 1.5 and 1.6). The integrity values reflect probabilities of finding altered hydrologic functions within 4th-field hydrologic units (subbasins) based on relative differences between subbasins.

Values were derived for rangelands and forestlands by subbasin and assigned to high, moderate, and low classes. These integrity values assume that areas with high effect (disturbance) and low recovery potential (resiliency) have higher probabilities of containing altered hydrologic functions than other areas; consequently, they are described as having low integrity. Conversely, areas with low relative effect from mining, dams, roads, cropland conversion, and grazing and that also have high recovery potentials are considered to have the highest probable hydrologic and riparian integrity. More specific descriptions of subbasins with high and low forest and rangeland integrity are shown below. Forest and rangelands with moderate integrity are likely to have some aspects of each of the high and low categories.

Forest lands with high hydrologic integrity have had little disturbance of their hydrologic functions from past activities. In addition, the potential for streams to recover following disturbance is generally moderate to high. Forest lands with low hydrologic integrity have experienced a great deal of disturbance to their hydrologic functions from past activities, which primarily include roads, dams, and cropland conversion of the lower elevation valleys. The potential for streams to recover following disturbance is low to moderate, and sediment hazards associated with roads are moderate to high.

Rangelands with high hydrologic integrity have had relatively little disturbance to their hydrologic functions from past activities; grazing effects on riparian areas are assumed to be generally low. The potential for streams to recover following disturbance is high. Stream sensitivity to increased flow and sediment is relatively low. Stream channel function has a low dependence on the maintenance of riparian vegetation. These subbasins support some of the riparian environments that are most resilient to livestock grazing. Rangelands with low hydrologic integrity have experienced high disturbance of their hydrologic functions from past activities (primarily cropland conversion of valley bottoms and roading). The potential for streams to recover following disturbance is low. Stream channel sensitivity to increased sediment and flow is moderate to high, and streambank sensitivity to disturbance is high.

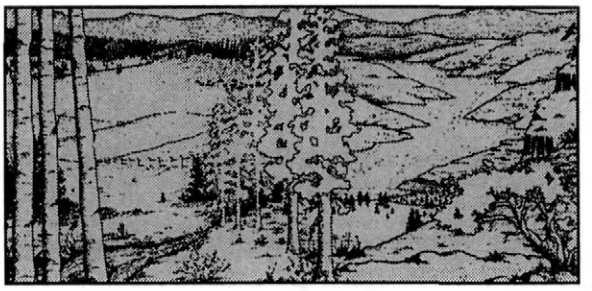
Map 1.5—Relative hydrologic integrity ratings of forest environments within subbasins.

Map 1.6—Relative hydrologic integrity ratings of rangeland environments within subbasins.

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EXECUTIVE SUMMARY: LANDSCAPE DYNAMICS

Introduction

We address this summary to the stewards of the Basin. We consider stewards to be people that make decisions about landscape dynamics that affect the Basin. This includes public land managers with the Forest Service and Bureau of Land Management and other involved agencies. It also includes other people that influence landscape dynamics on public lands. For example, if you turn on a faucet that runs water that comes from public land watersheds of the Basin, there is an associated effect. If your input to public officials or elected officials influences whether a tree is cut or not cut, a fire is lit or put out, a road is closed or not closed, or a species is recovered or not recovered, you have affected the landscape dynamics of the Basin. From a scientific perspective these associated, and often far-reaching effects, are neither good nor bad. They are the consequences of how society chooses to manage public lands. We hope that the Landscape Dynamics Assessment (Chapter 3) and this summary help the people that influence this "cumulative consensus" to make better decisions about the collective outcome for the land and people of the Basin.

In this summary we move directly to some of our key points and then follow with a synthesis of findings and a summary of results.

Key Points

Landscape ecology has often been misconstrued as vegetation ecology. This is not the case. Landscape ecology is about understanding the interrelationships between human land use, species diversity, ecosystem health, and the inherent disturbance processes and biophysical capabilities of the land (fig. 1.3). The lack of such an emphasis in past analysis has resulted in land management patterns that emphasize individual components rather than the way these components effect one another. *We hypothesized that understanding of these relationships is as important, or more important, than understanding the individual components. Our landscape assessment found this to be true.*

Recovery efforts for species at risk (such as threatened, endangered, candidate, or sensitive species) have been the source of considerable conflict within the past decade, because they have been perceived as placing restrictions on forest or range restoration by limiting management in reserve and buffer areas. In our analysis we *hypothesized that areas with reserve landscape patterns would have higher departure from the historical range of variability (HRV) in disturbance regimes, composition, and mosaic patterns than areas with traditional management. We found this to be false. In fact, we found that areas with the highest levels of traditional management had the highest departure in these characteristics and the highest probability for severe events.*

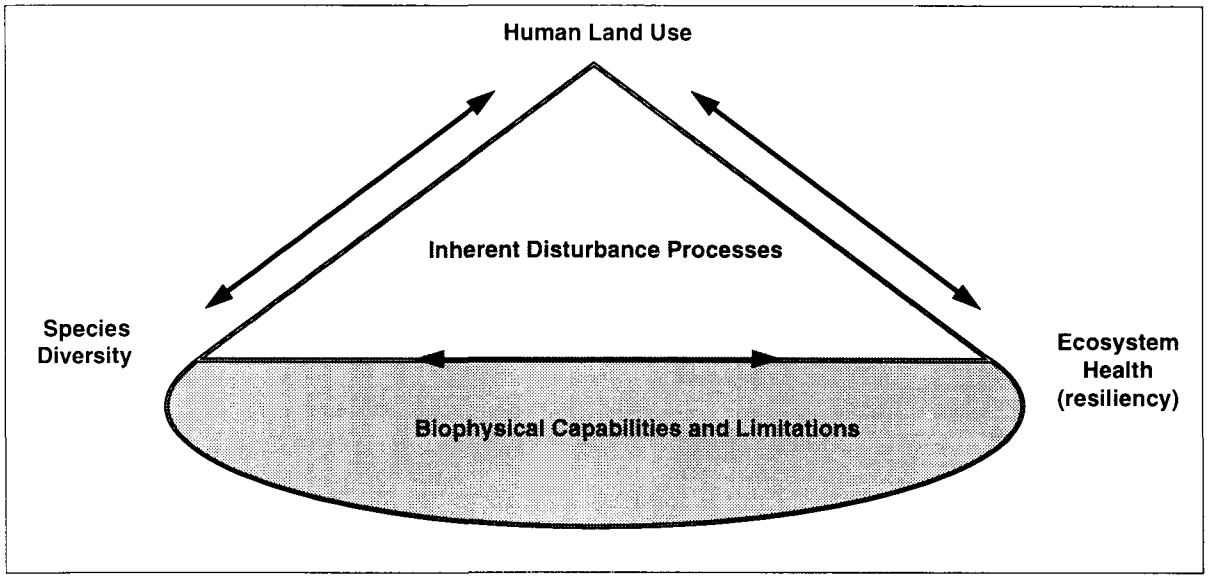


Figure 1.3— Landscape dynamics involves the relationships of human land use, species diversity, and ecosystem health in relation to inherent disturbance processes and biophysical capabilities. Healthy (properly functioning) landscapes provide a "best fit" of the human land uses, species and habitats, and ecosystem conditions that are adapted to the inherent disturbance processes. Outcomes have a high probability for sustained site productivity, a diversity of species consistent with the diversity of habitats, and ecosystem conditions that are adapted to the succession/disturbance regime.

In the assessment we found that most patterns of current forest and range land use activities, habitats for native species, and processes and functions critical to ecosystem health were not consistent with inherent disturbance and biophysical capabilities. We *hypothesized that traditional patterns of land use, whether commodity or reserve, disrupted the inherent disturbance processes and caused a concurrent decline in ecosystem health and native species that depend on such connected relationships. In the assessment this proved to be true* (photos 1.1, 1.2, 1.3, 1.4, and 1.5).

These findings caused us to ask why traditional land management practices caused such high disruption and departure from the native landscape patterns when the traditional objective of each discipline has been to conserve these native characteristics. We *suggest that there is a lack of connectivity between disciplines* (such as forestry, range, fire, watershed, wildlife, fisheries, engineering, recreation) that precludes achieving a landscape perspective. We also *suggest there is a lack of connectivity between management regions* (ownerships and administrative areas) which precludes achieving a landscape perspective.

Native landscape systems, or properly functioning (healthy) landscapes, have relationships between land use, ecosystem health, and species diversity that are in balance with inherent disturbance processes and biophysical capabilities (see fig. 1.3). When relationships between land use, ecosystem health, and species diversity are out of balance with the inherent disturbance processes and biophysical capabilities the landscape system tends towards disequilibrium. We *hypothesized that the disturbance processes of disequilibrium landscapes eventually recalibrate through reduction of productivity and loss of species the biophysical capability and species diversity to a new equilibrium with attendant reductions in land use options. This proved true in both our assessment of management scenarios and our review of the literature.*



Photo 1.1—Commodity landscape patterns have high departure from native patterns because of systematic fragmentation or homogenization of disturbance processes and biophysical mosaics.



Photo 1.2—Wildfire events on commodity landscape patterns in severe fire weather conditions can result in blow-up fire behavior and fire effects.



Photo 1.3—Flood or erosion events are much more severe on commodity pattern landscapes because of cumulative relationships between landscape pattern departure and extensive road networks.



Photo 1.4—Reserve landscape patterns have high departure from native patterns because of homogenization of disturbance processes and biophysical mosaics.



Photo 1.5—Severe fire events and associated erosion in reserve pattern landscapes result in shifting large blocks of late-seral conditions to early-seral and fragmenting biophysical linkages, such as riparian corridors.

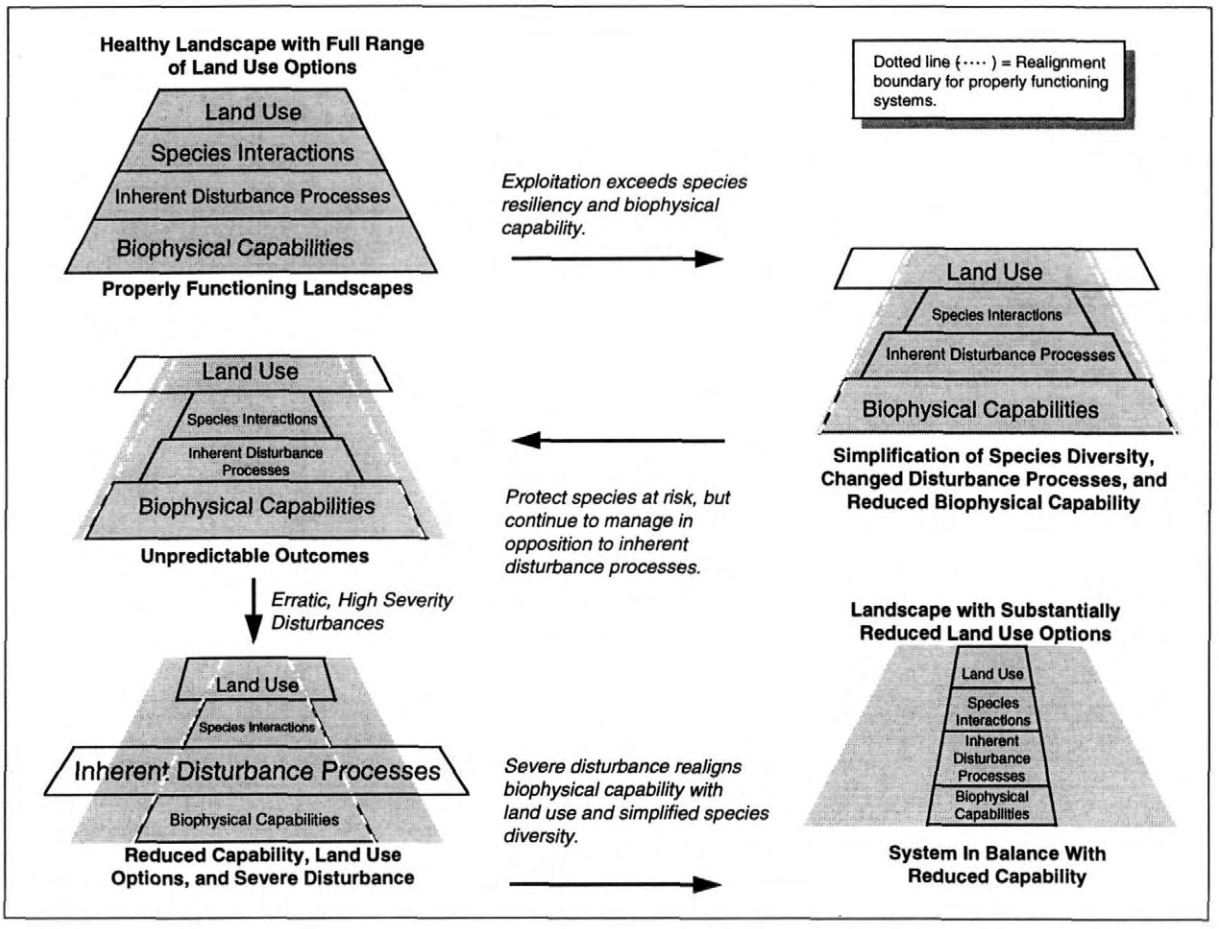


Figure 1.4—Stages in degradation of landscape health in response to land uses that are incompatible with system relationships.

The "stages" in this recalibration can be illustrated as in figure 1.4. In a native or "properly functioning landscape" land use is in concert with the other factors. This stage existed in the Basin during the pre-Euro-American settlement period. Exploitation of species and the biophysical capabilities of land heightened in the Basin during the late 1800s, resulting in simplification of species, changes in the inherent disturbance processes, and a concomitant reduction in biophysical capability. A protection emphasis began in the Basin during the early 1900s with an increasing shift toward protection of individual species by the 1970s. Land use, however, continued to occur in opposition to inherent disturbance processes, disrupting system equilibrium and resulting in continued loss of biophysical capability and system responses that are unpredictable. Many landscapes in the Basin are now entering this stage. This unpredictability can be manifested in high severity disturbances that substantially reduce biophysical capability and land use options. Continued severe disturbances eventually realign biophysical capability with simplified species diversity and a reduced set of land use options. *This process of reduction in biophysical capability and simplification of species diversity, however, can be stabilized at any stage* through change in land use to practices that work

with the land's inherent disturbance processes and are in balance with species adaptations and biophysical capability. Such change would help to restore the system to equilibrium before severe disturbance greatly reduces system potentials.

Our modeling of future scenarios indicates that both traditional reserve (passive management) and commodity (consumptive management) landscape patterns will result in a substantial reduction in biophysical capability, species diversity, and associated land use options. Reduced diversity will be related to exploited elements (such as large trees, native bunchgrasses and predators) or with those species adapted to complex habitat relationships (such as tree cavity nesting/shrubland feeding birds, or species with large migrational patterns). Decline in biophysical capability will occur in the form of reduced productivity (such as from loss of soil, nutrients, or species diversity) and loss of resiliency (in response, for example, to insects, disease, drought stress, competition from exotics, fire or flood). As a result, *landscapes of the Basin will shift to the point where land use will be forced into a new equilibrium, with substantially reduced options, for species diversity and production of human values.*

Our scenario projections of ecological (active management) patterns indicate that current landscapes can be managed with ecological restoration, conservation, and production treatments designed to be consistent with the inherent disturbance processes and biophysical capabilities (photo 1.6). This type of management could shift landscapes at any stage along this continuum back into alignment with the biophysical capability. The native regime and historical range of variability (HRV) provides a sound baseline for understanding ecological restoration, production, and conservation disturbance treatments that can mimic patterns under which the biophysical system and native species have evolved. *However, native patterns or HRV do not provide a sound basis for design of land management objectives or desired conditions.*



Photo 1.6—Native or properly functioning landscape patterns have a balance of land use, ecosystem health, and species diversity that are consistent with inherent disturbance processes and biophysical capability.

Humans are intermingled with wildland mosaics and have different expectations of wildland values than can be produced by mimicking HRV. Landscape response potentials have also been altered by past land use practices which resulted in systems strongly influenced by exotic species, pollution, erosion, and other effects. *However, within the limitations of altered landscapes, ecological restoration, conservation, and production treatments can be designed to provide effective habitats as well as produce other human resource values (photo 1.7). The designs of these treatments are benefitted by concurrent designs of spatially and temporally connected landscapes that support humans, terrestrial and aquatic species, and healthy ecosystems (photo 1.8).*

While we found modeling HRV and analysis of current and future departures from HRV useful at the broad scale, we found that statistical extrapolation of departure of mid-scale landscape mosaic and succession/disturbance regime patterns and fine-scale elements such as snags, fuels, stand density, and species composition

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Photo 1.7—Management for native or HRV patterns is not possible in landscapes with altered potentials or complex mosaics of human and wildland conditions. However, management for properly functioning landscapes can be achieved by using an active ecological approach to management of succession/disturbance regimes.



Photo 1.8—Concurrent design of habitats for terrestrial and aquatic species (such as large snags and trees) in connected landscapes (such as for birds that nest in forests and feed in rangelands) restores habitat linkages.

were of equal value in testing hypotheses. From a mid-scale perspective it appears that identification of the range in variability of native (or proper functioning) landscape mosaic patterns across similar geographic areas (regionalization) is the most useful analysis. Such analysis is enhanced when it is coupled with modeling of various options for shifting landscapes to different scenarios of patterns, while protecting critical elements (such as aquatic or terrestrial rare population strongholds, remnant native range, or large trees) and producing or maintaining desired socioeconomic resource values. At the fine-scale, mapping and fitting of landscape management patterns to the biophysical pattern of succession/disturbance regime (hierarchical to the mid scale) that is consistent with the native (or proper functioning) pattern, will likely produce the "best fit" of aquatic/terrestrial habitats and socioeconomic resource values that are consistent with broad-scale objectives.

Synthesis of Findings

Although the conversion of forest and rangeland potential vegetation groups (PVGs) to agriculture (photo 1.9) and other land use is substantial (fig. 1.5) this decline in itself would not be sufficient to cause major disruption in Basin landscape systems. Decline in similarity of physiognomic types, broad-scale and mid-scale fragmentation, increased soil disturbance, and altered forest and range potential vegetation group response is substantial when considered in aggregate. Almost two-thirds of the area across the Basin are restorable to functioning systems, and based on the indices (fig. 1.5) it would appear that landscapes of the Basin are in a moderately healthy condition.

However, the broad-scale data alone do not reflect the gravity of the multi-scale simplification of species diversity, disruption of disturbance processes, decline in ecosystem health, and reduction in land use options (figs. 1.6 and 1.7). The Broad-



Photo 1.9—Considerable area of forest and rangeland has been converted to agricultural and other forms of land use. These systems can be managed to sustain biophysical capabilities and provide habitats as well as sustained flow of human resource values.

scale Assessment of Aquatic Species and Habitats and the Terrestrial Ecology Assessment (Chapters 4 and 5) indicate substantial declines in native species and habitat quality. We found this to be somewhat correlated with terrestrial community departure, particularly when evaluated spatially using subbasin stratification and other landscape indices. But this broad-scale index of departure does not adequately explain the combined levels of affects on ecological processes and production of human resource values (both commodity and amenity).

We concluded that the broad-scale changes in landscape indices are not adequate indicators of effects on species diversity, forest and rangeland health, disturbance processes (such as wildfire, severity of fire effects, insect/disease mortality, and exotics), and land use resource values that are multi-scale in nature (figs. 1.6 and 1.7). The highest departure in landscape indices is occurring in predictions of mid-scale landscape patterns and succession/disturbance regimes (fig. 1.8). These landscape indices are in almost total departure from patterns that would be in concert with biophysical patterns. Across all ownerships the succession/disturbance regimes and landscape patterns have very low (3%) similarity to the native regime. This includes agricultural and urban lands. Bureau of Land Management- and Forest Service-administered lands have only slightly higher (5%) similarity of these multi-scale indicators. When we compare current land use to native succession/disturbance regimes we find substantially higher departure in the current period. *Combining this low compatibility between land use and succession/disturbance regimes with the generic application of standardized (one-size-fits-all) commodity treatments or reserve protection buffers on variable landscapes has resulted in the current high departure of landscape patterns and succession/disturbance regimes.*

A good example of combined departures is roads on BLM- and FS-administered lands. Road surface area in itself only accounts for 2 percent of the BLM- and FS-administered lands. However, because of the linear pattern across the contour and connected effects on aquatic and terrestrial systems the affected area is approximately 65 percent.

We project that landscape patterns of succession/disturbance regimes could be restored with an active ecological management strategy on a substantial portion of the public lands within the foreseeable future (photos 1.10, 1.11, 1.12, and 1.13). It is *highly probable that this type of strategy could stabilize current declines in terrestrial and aquatic species, ecosystem health, biophysical capability, and land use options, with an associated reduction in erratic and severe disturbance events (fig. 1.9). However, achievement of this future will require change in the kinds and coordination of land use activities, connectivity of disciplines, agency and public collaboration, monitoring, and associated adaptive management.*

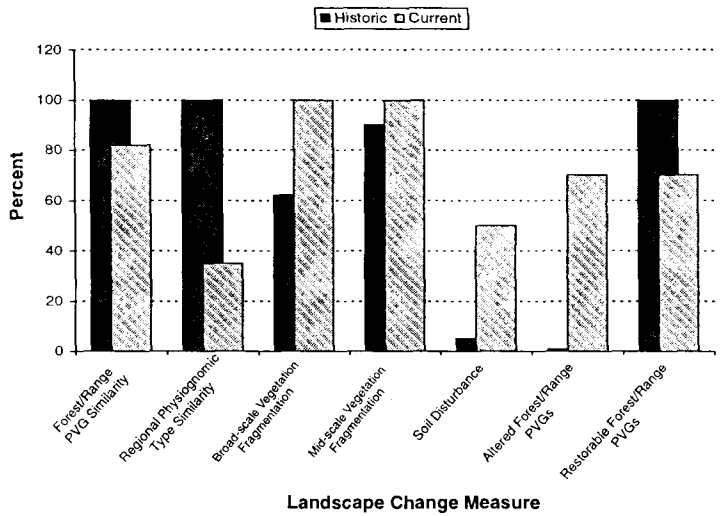
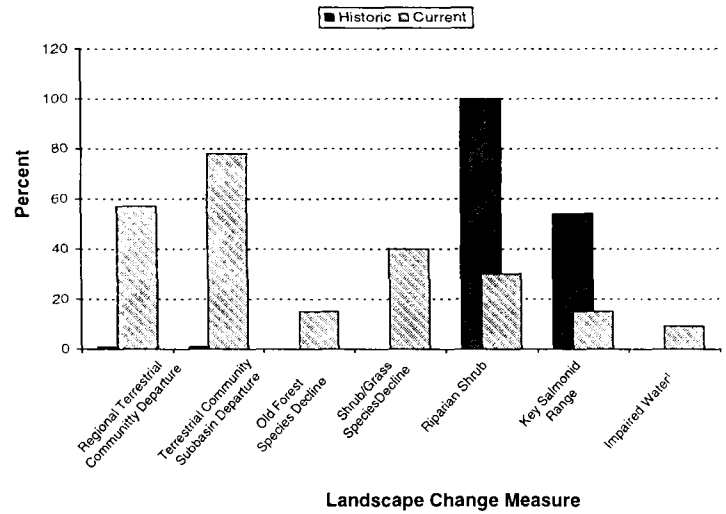


Figure 1.5— Changes from historic or recent historic to current in landscape composition and pattern indices in relation to terrestrial and aquatic conditions.



[1]Impaired water is a legal designation rather than an ecological measure. However, the current amount of impaired water compared to historical water quality is of concern.

Figure 1.6— Changes from historic or recent historic (circa 1960s) to current in landscape composition and pattern indices in relation to landscape health indices and human resource values.

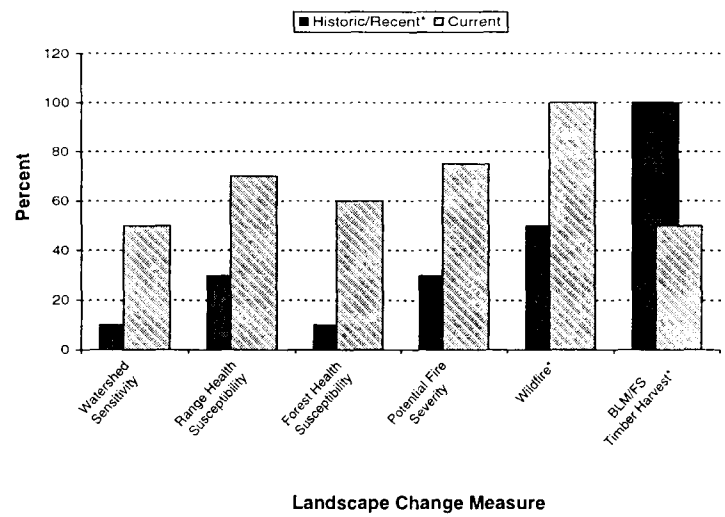


Figure 1.7— Changes from historic or recent historic (circa 1960s) to current in landscape succession/disturbance regime, patterns, correlate with roads, and potentials for ecological restoration. (Note: recent=1960's)

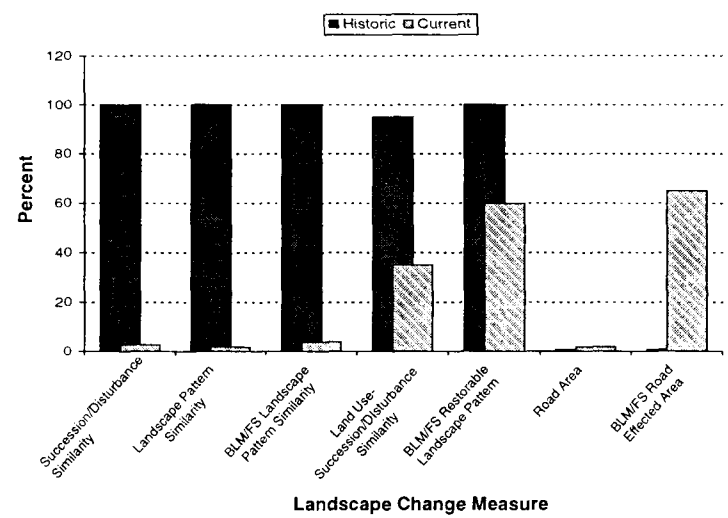


Figure 1.8— Changes from historic or recent historic to current in landscape succession/disturbance regime, patterns, correlate with roads, and potentials for ecological restoration.



Photo 1.10—Invasion of exotic species, such as yellow starthistle, preclude the option of mimicking native patterns. However, active ecological restoration and management to reduce spread can sustain rangelands in patterns that somewhat represent native conditions.



Photo 1.11—Current fuel conditions, concerns about smoke, and urban-rural/wildland interface areas preclude the option for fires of similar size as those that occurred in HRV. However, prescribed fires, thinning, and harvesting planned strategically can be used to produce landscape mosaics and stand structures that represent native systems.



Photo 1.12—Considerable area in forest potential vegetation has shifted to reserve or commodity patterns that do not represent the native pattern. These systems can be managed in the context of properly functioning landscapes and produce desired benefits. A composite regional landscape managed in a properly functioning context could reverse the decline in forest health, forest dependent species, and human resource values.



Photo 1.13—Considerable area in rangeland has shifted to reserve or commodity patterns that do not represent the native pattern. These systems can be managed in the context of properly functioning systems and produce desired benefits. A composite regional landscape could reverse the decline in rangeland health, rangeland dependent species, and human resource values.

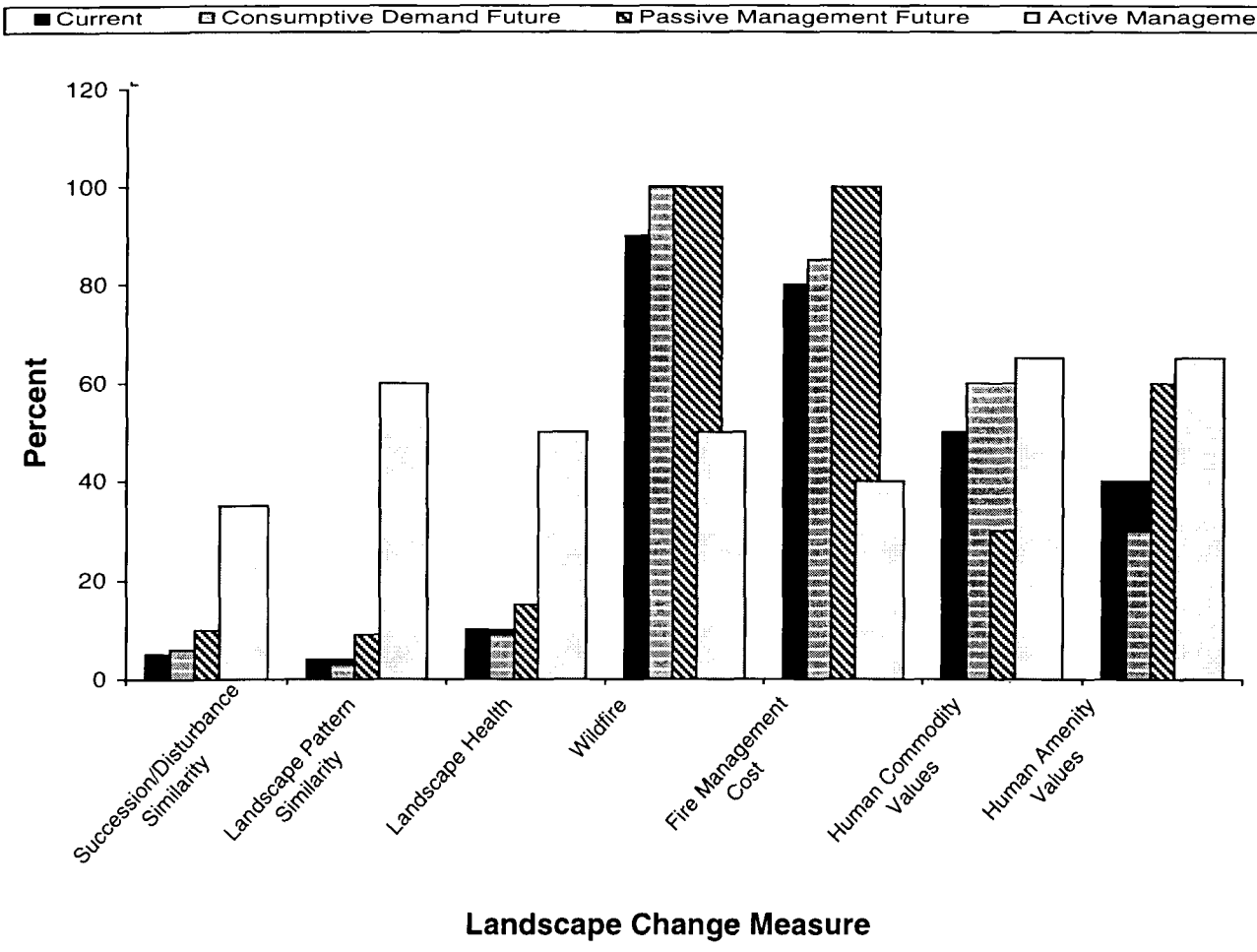


Figure 1.9–Traditional flow of changing outcomes for landscape health.

Summary Overview

We conducted a multi-scale evaluation of the integrity, resiliency, and sustainability of forestland, rangeland, and riparian system functions and processes as part of the overall effort to assess the ecological condition and trends of the Basin. Consequently, our assessment used a regional and landscape perspective to assess biogeochemical, successional, and disturbance processes; vegetation conditions; and landscape patterns across the Basin. We used the concepts of a biophysical template (or biophysical setting) and the historical range of variability as a framework to facilitate understanding of the complex spatial and temporal relationships of these processes and conditions.

Broad-scale Changes of Biophysical Templates

The biophysical template is the current expression of evolutionary processes, and can be perceived as the biological, physical, and disturbance characteristics of a spatially and temporally explicit environment. We used potential vegetation types, in an aggregate form (potential vegetation groups), as a surrogate of the biophysical environment and site potential.

The Basin contains a complexity of biophysical environments and associated succession and disturbance dynamics. The complexity of biophysical settings is strongly correlated to the interaction of geomorphologic processes and climatic regimes within the Basin. Vegetation patterns, which are subsequently tied to the variety of biophysical settings, also vary widely across the Basin.

As biophysical conditions change as a result of altered topography, soils, or composition of biotic communities, the succession/disturbance regimes are altered as well. Society has expended energy to control or suppress disturbance regimes and successional processes, thereby altering many key

ecological relationships that developed over evolutionary time. Fire suppression; the extensive application of fertilizers, insecticides, and herbicides; the construction of dams; and efforts to produce commodities and values such as timber products, livestock forage, visual conditions, and habitats oriented to specific species (for example, big game cover), are just a few examples of practices humans employ that change the relationships between the biophysical environment and succession/disturbance regimes. In many cases, the alteration of these ecosystem processes has been so extensive that many biophysical settings within the Basin are currently in a state of disequilibrium. Systems in disequilibrium are less resilient to disturbances, and their disturbance responses are less predictable than the responses of systems existing in equilibrium.

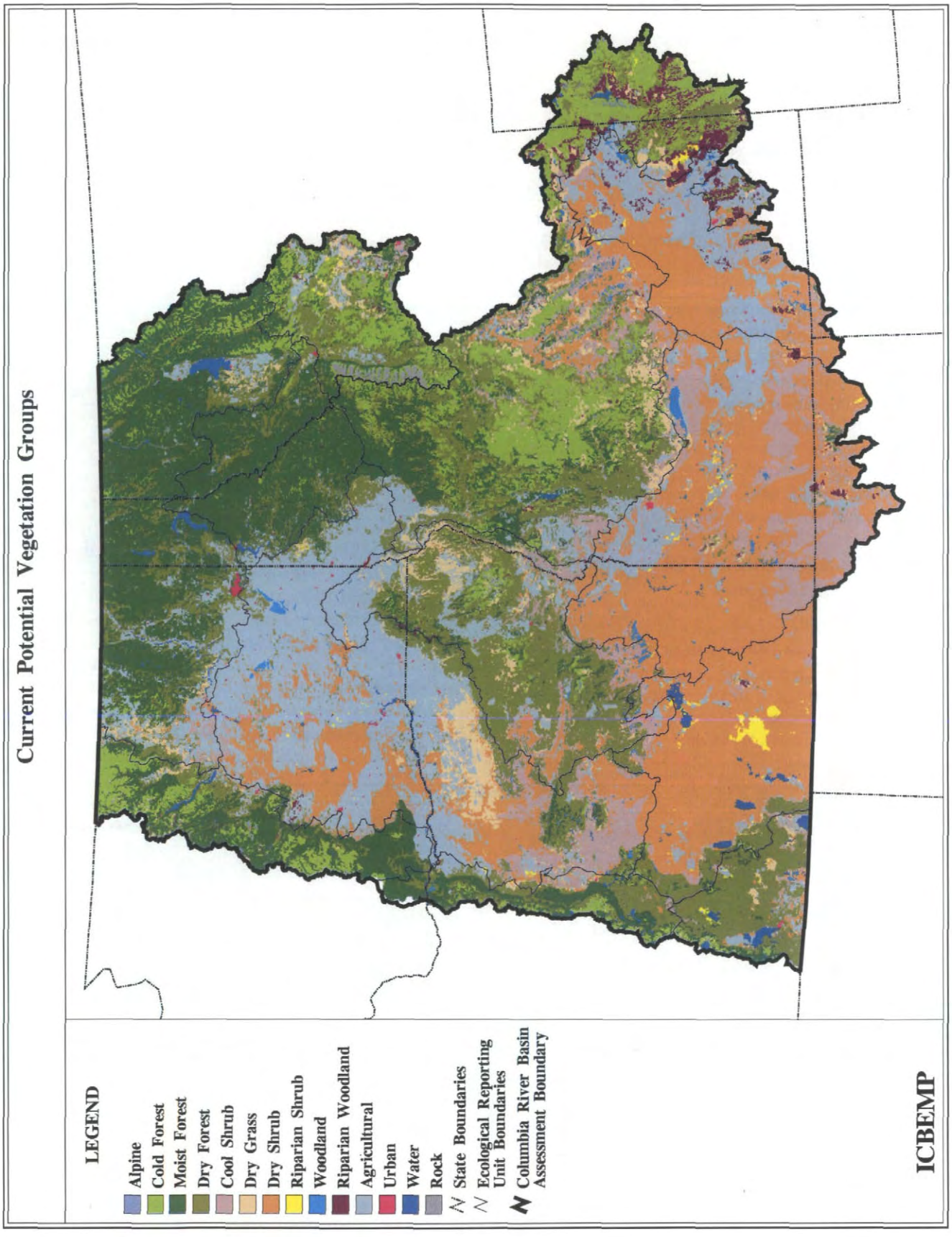
Potential vegetation groups (PVGs; that is, aggregations of potential vegetation types) and landforms were used to characterize and stratify broad-scale biophysical environments. We evaluated the trends of PVGs and succession/disturbance regimes to indicate change of biophysical environments. The areal extent and composition of PVGs changed substantially between the historical and current periods (maps 1.7 and 1.8).

Basin-wide, the most intensive alteration of PVGs was attributable to the agricultural development of 17 percent of the Basin between historical and current periods. Less intensive, but more extensive change to the succession/disturbance regimes of biophysical settings occurred as a result of livestock grazing, timber harvest, fire exclusion, flood control, road construction, and the introductions of exotic plants and pathogens. For example, exotic plants have altered the succession/disturbance regimes, productivity, and in some cases, the biophysical setting, of nearly 47 percent of the Basin. Exotic plants are particularly problematic within the rangeland and dry forest PVGs. In forest settings, introduced pathogens have altered the successional pathways and community composition of moist and cold forest PVGs across nearly 22 percent of the Basin.

Within the Basin, the rangeland biophysical environments have changed to the greatest extent. Agricultural development, primarily on the dry shrub, cool shrub, dry grass, and riparian PVGs, is the most intensive change within rangeland systems. Most agricultural practices have substantially altered key ecological processes such as geomorphologic development (that is, soil development and erosion), hydrologic and carbon-nutrient cycles, composition of floral and faunal communities, and ecological food webs. Excessive livestock grazing pressure and the invasion of exotic plants have affected much of the remaining rangelands. Excessive livestock grazing pressure has been implicated in the spread and establishment of exotic annual grasses, which shorten fire-return intervals and dramatically change vegetation composition and structure. Not only has the resilience of these systems declined, but in some cases, the succession/disturbance regimes are still evolving and disturbance responses cannot be easily forecast.

Because of their inherently higher productivity, forest systems seem to be more resilient than rangeland systems. Thus, the biophysical settings within forests have been altered less than those within rangeland systems. In forest systems, fire exclusion, timber harvest practices, and introductions of white pine blister rust within the moist forest PVGs have (1) nearly eliminated western white pine as a dominant species, (2) increased intervals between fires, and (3) increased fire severity. Fire exclusion and blister rust have had a similar effect on biophysical conditions within the cold forest PVG, except that whitebark pine is the dominant species in decline. Although the changes within the cold forest PVG have been less extensive in area, the effect is likely more severe compared to the moist forest PVG. To date, whitebark pine composes the entire forest physiognomy within many cold, high-elevation settings where it dominates the early- as well as late-seral communities. Potentially, this entire forest physiognomy may be replaced by shrubland or herbland physiognomies which could disrupt snow accumulation and hydrologic systems as well as associated terrestrial species.

Map 1.7— Historical (circa 1850-1900) period potential vegetation groups (PVGs). PVGs reflect the vegetation potentials (without disturbance) in relation to climate and other physical characteristics. This map represents average conditions at the time of Euro-American settlement.



Map 1.8— Current period potential vegetation groups (PVGs). PVGs reflect the vegetation potentials (without disturbance) in relations to climate and other physical characteristics. This map represents average current period (circa 1990) potentials.

Road density classes were found to be strongly correlated with the observed changes of extant PVGs because roads were closely associated with modern anthropogenic activities. Road density was found to be indirectly correlated with: (1) the distribution and spread of exotic plants, (2) many forest composition and structural changes, (3) efficacy of fire suppression activities, and (4) the probability of fire occurrence due to human-caused ignitions. In forest systems, roads were associated with timber-management practices and thus correlated with the transition of shade-intolerant to shade-tolerant species, the loss of late-seral structures, reduced densities of large trees and snags, and increased fuel loadings. In rangeland systems, roads appear to function as vectors for dispersing exotic species. Regardless of the biophysical setting, roads appear to increase the efficacy of fire-suppression activities.

Broad-scale Changes of Succession/ Disturbance Regimes

We found little (less than 25%) similarity between the historical and current succession/disturbance regimes within forest and rangeland systems. With few exceptions, disturbance frequency declined as the severity of disturbance increased. Exceptions to this general trend are the dry grass and dry shrub PVGs that have been invaded by exotic annual grasses. In these instances, fire disturbance has become more frequent. Not surprisingly, the departure of succession/disturbance regimes on BLM- and FS-administered lands was less dramatic than the changes that occurred on other ownerships.

Fire Regimes

The resemblance between historical and current fire regimes within forest and rangeland systems ranged from low to moderate depending on the PVG. In forest settings, the current fire regimes of cold forests were most similar to the historical regimes. The current fire regimes of dry forests were least similar. Of the rangeland settings, the current fire regimes of the dry shrub PVG had the least similarity with the historical regimes, primarily because of the effects associated with the invasion of exotic annual grasses and excessive livestock grazing. The current fire regimes of the cool shrub PVG were the most similar to historical regimes within rangeland systems. As with succession/disturbance regimes, the departure of fire regimes that occurred on other land ownerships was more dramatic than that which occurred on BLM- and FS-administered lands.

The changes in vegetation composition and structure of forests and rangelands that occurred between the historical and current periods have substantially increased the risks of wildland wildfires at both the landscape and regional levels. Although wildfire-suppression activities have been successful in reducing the areal extent of wildfires since the early- to mid-1900s, it now appears that the more recent trends may be changing and firefighters may be losing the battle. That is, even though land managers have been allocating increasing amounts of resources to wildfire suppression, suppression efficacy seems to be declining. In fact, the current areal extent of wildfires is approaching that experienced in the early 1900s. Fuel loadings have steadily increased as a result of suppression efforts and the subsequent decline of fire frequencies. As a result, fire severity has increased, as have suppression costs and the associated hazards to life and property. The average costs of wildfire suppression, number of firefighter fatalities, and areal extent of high-intensity fires during the last 25 years have exceeded the corresponding levels that occurred between 1910 and 1970.

Further complicating matters, human populations within the wildland/urban interface have substantially increased within the last few decades. These areas of rapidly-growing human populations are commonly associated with high fire risks.

Broad-scale Changes of Biogeochemical Relationships

The observed transitions of succession/disturbance regimes and vegetation structure and composition were directly associated with changes of biogeochemical processes. Biogeochemical processes are the basic chemical responses of biota to their environment measured in the form of growth, stress, and nutrients. Net primary productivity increased in forests that experienced transitions from shade-intolerant species to shade-tolerant species. In rangeland settings, net primary productivity declined in areas invaded by exotic grasses and forbs, whereas net primary productivity increased in areas converted to agricultural uses. Although carbon stress is inherently associated with moisture availability, it fluctuated with observed transitions of vegetation conditions. In forest settings, carbon stress increased as single-layered stands developed multi-layered canopies, but decreased as the ratio of shade-tolerant to shade-intolerant species increased. Water stress increased in association with successional development, due to increasing amounts of live biomass respiration. Nutrient availability declined with successional development, and as single-layered forests developed multiple layers. Nutrient availability also declined as herblands developed into shrublands, and as herblands or shrublands transitioned to woodlands and forests.

General Landscape Patterns

Landscape patterns at a subbasin level were dependent upon type of landscape mosaic, landform, and the composition of biophysical settings, vegetation conditions, succession/disturbance regimes, and historical land uses. We compared current landscape patterns with those expected in systems dominated by native processes, and to those expected to result from traditional commodity or reserve management strategies. Succession/disturbance regimes resulting from traditional commodity and reserve management strategies would likely change vegetation conditions, and consequently, landscape patterns. Further, intervals between disturbances would increase, but so would the severity of these disturbances. The effects of disturbances could be more acute or more chronic than those associated with native systems.

An examination of current landscape patterns revealed that only 2 percent of the Basin had landscape patterns similar to native patterns, whereas 16 and 64 percent had patterns similar to those expected from traditional reserve and commodity management strategies, respectively. Current landscape patterns of BLM- and FS-administered lands were comparable to the patterns of the Basin as a whole, except that these lands had substantially more area (29%) resembling the patterns expected from a reserve management strategy.

Regional Cover Type Trends

Few cover types occurred within their median 75-percent historical ranges during the current period. In rangeland settings, agricultural development was primarily responsible for areal declines of the fescue bunchgrass, wheatgrass bunchgrass, big sagebrush, and native forb cover types. Areal transitions indicated that the invasion of exotic species occurred predominantly in the big sagebrush cover type, and to a lesser extent, the wheatgrass bunchgrass, mountain big sagebrush, and fescue bunchgrass cover types.

Forest settings were dominated by transitions of shade-intolerant tree species to shade-tolerant tree species. For example, within the dry forest PVG, the areal decline of interior ponderosa pine was mostly attributable to increases in the grand fir/white fir, and interior Douglas-fir cover types. Similarly, the composition of moist forests composed by early-seral, shade-intolerant western larch and western white pine became dominated by Douglas-fir, lodgepole pine, or grand fir/white fir cover types. Lastly, cold forests were affected by the conversion of the whitebark pine cover type into the Engelmann spruce/subalpine fir cover type.

Regional Trends of Terrestrial Communities

The areal extent of most (83%) terrestrial communities occurred outside of their median 75-percent historical range. No terrestrial community within rangeland settings occurred within its historical mid range during the current period. The flux of forest communities was dominated by the transitions of early- and late-seral communities into mid-seral communities. Forest transitions were attributed to the synergistic influences of fire exclusion and timber harvest practices. Timber management practices reduced the areal extent of late-seral communities, and limited the regeneration period of early-seral stands, whereas fire exclusion limited the recruitment of early-seral communities. The departures of community composition from the historical systems seemed to be the greatest in dry forests, and least in cold forests.

Forest and Rangeland Integrity

We characterized the ecological integrity of forests and rangelands at the subbasin level. Because ecological integrity could not be measured directly, relative integrity values were estimated from the departures of broad-scale indicator variables. Both direct and indirect indicator variables were used including PVGs, cover types, changes of fire disturbance regimes, and road densities.

Subbasins having the highest forest integrity values were largely unroaded, and composed of cold forest PVGs, or a mixture of moist and cold forest PVGs. Conversely, subbasins composed of a relatively large proportion of the dry forest PVG that had been intensively roaded, typically had the lowest forest integrity. Forest integrity was thus strongly associated with the efficacy of fire exclusion, the intensity of timber management, and the degree to which succession/disturbance regimes have changed within a subbasin. Most (59%) of the forested subbasins were characterized as having low forest integrity, whereas substantially fewer (23%) were characterized as having high forest integrity.

Most (69%) of the rangeland subbasins were characterized as having low rangeland integrity. In contrast, few (8%) rangeland subbasins had a high rangeland integrity. In general, the subbasins characterized with low rangeland integrity had high compositions of agricultural development or dry grass and dry shrub PVGs, which were indicative of their susceptibility to exotic plant infestations and their lack of recovery potential from excessive livestock grazing.

Modeling Scenarios

We modeled future (100-year) projections resulting from three management scenarios: (1) consumptive demand (that is, traditional commodity production); (2) active ecological management; and (3) passive management (that is, traditional reserve management). Overall, an active management strategy seemed to result in outcomes most beneficial to both humans and native systems. The consumptive demand scenario resulted in outcomes that were typically least similar to the native regime. Ironically, although the passive and consumptive demand scenarios had radically different objectives, their outcomes were surprisingly similar because the passive scenario also has disturbance processes that are inconsistent with biophysical capabilities and species adaptions.

Proper Functioning Landscape Systems

Proper functioning landscapes are "those landscapes whose processes are in a dynamic equilibrium (including the production of human values), such that the rates and routes of key processes and disturbances are resilient and have predictable responses to disturbance. The assessment of proper functioning landscape systems (PFS) is a process which strategically links the "driving variables" of the key ecological processes and predicts responses at hierarchical landscape scales. This provides a process for integration of ecosystem health assessment based on complex relationships between land use, species interactions, inherent disturbance processes, and biophysical capabilities.

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EXECUTIVE SUMMARY: BROAD-SCALE ASSESSMENT OF AQUATIC SPECIES AND HABITATS

The Broad-Scale Assessment of Aquatic Species and Habitats addresses the aquatic resources within the Interior Columbia Basin Ecosystem Management Project assessment area. It is directed along four primary themes: a broad characterization of the geophysical and biological settings that define the natural potential of the Basin to provide for aquatic resources; anthropogenic factors that affect aquatic habitats and species, with special emphasis on effects of Federal land management; a broad-scale assessment of the current condition of aquatic habitats and species, primarily fishes; and a synthesis of information in order to provide a regional context for Federal management strategies to protect and restore aquatic and riparian habitats.

Geologic and geomorphic processes formed and continue to affect the Basin. These processes, in concert with the underlying physical environment, establish the template and constrain the successional pathways for aquatic habitats and their associated communities. Similarly, natural fluctuations in the marine environment due to variation in atmospheric and oceanic circulation patterns influence the productivity of anadromous fish stocks. They may temporarily mask changes in freshwater habitats.

Human effects predated Euro-American settlement but increased dramatically with technological development. By the mid-1800s, Euro-American settlers had begun to substantially alter the Basin's landscape and aquatic habitats. Large dam construction began about 1900. The dams have greatly reduced the range of migrating fish. Fish spawning and rearing areas in the upper Columbia River Basin were isolated after the Grand Coulee (1941) and Chief Joseph (1955) dams were completed. Since 1967, Hells Canyon Dam has blocked anadromous fish access to the Snake River and tributaries above the dam. A similar loss of most spawning and rearing habitats followed the construction of Cabinet Gorge Dam on the Clark Fork River above Lake Pend Oreille. Today there are at least 1,239 large dams in the assessment area, each with storage capacity in excess of 62,000 cubic meters. If small dams are included, the total storage capacity could be several times larger. There are thousands of small dams in the Basin, and most do not have fish passage facilities. The full extent to which these dams impede migration or affect spawning and rearing habitats of fishes has not been documented. Even though the rate of increase in storage volume has leveled since the mid-1970s, the total number of dams continues to increase, suggesting that new construction is focused on smaller dams. Even with fish passage facilities, detrimental effects from dams occur. Direct mortality of juveniles continues in turbines and bypass systems. Indirect mortality is caused by physiological stress, increased susceptibility to predators, and the inability to find routes around dams and through slack water.

According to U.S. Environmental Protection Agency estimations, overall water quality impairment within the Basin appears to be modest compared with total length of streams. Because these

estimates are based on existing and accessible data from locally specific State and Federal monitoring programs, they likely do not reflect the real extent and distribution of impairment. Many streams identified by the Forest Service as having elevated temperatures were not identified in Environmental Protection Agency assessment reports. In addition, water withdrawals for offstream uses can reduce instream flows significantly. This can alter or eliminate habitat and affect water quality. Most streams in the region are now fully or over-appropriated. Irrigation is the primary offstream use of water in the Basin.

To look at changes in riparian vegetation we conducted a mid-scale, Basin-wide analysis. The analysis showed significant changes. There was a decline in shrublands in the riparian zones in more than half of the ERUs. Shrublands predominantly shifted to forests and herblands through succession or disturbance. Forests, woodlands, and herblands increased in area or stayed approximately the same. Cottonwood, aspen, and willow, typically riparian-associated species which are known to have significant declines, are included in the forest class. However, they are likely masked by the dominance of other species in this class. These cover types decreased in 6 of the 13 ERUs. Significant decreases occurred in the Snake Headwaters and Columbia Plateau. Significant increases in woodlands occurred in the Northern Great Basin, Blue Mountains, and Columbia Plateau. This increase is attributed to shrubland conversion to juniper stands. The integrity of riparian vegetation and its extent along rivers has been changed and fragmented throughout the Basin in response to forest conversion and streamside disturbance.

Stream Habitat Features

We used stream-inventory data and landscape information to detect and characterize land use effects on aquatic habitats. For decades various agencies have routinely inventoried streams within their jurisdictions in order to monitor key aspects of stream-channel conditions. These inventories provide a rich source of information for comparison across broad geophysical settings and management regimes. They also permit historical comparisons in some areas. Many historically surveyed streams were resurveyed recently throughout the Columbia River Basin. Changes in habitats were analyzed using the information from the resurveyed streams.

Results of survey information and tests of relationships among habitat features, landscape features, and disturbance variables reinforce the evidence that streams within the assessment area have been significantly affected by human activities. Major decreases in pool habitat have been caused by two factors: the loss of riparian vegetation, and road and highway construction accompanying human activities (such as timber harvest, grazing, and farming). Most notably, pool frequency (large pools and all pools) is inversely correlated with road density and management intensity. The losses appear to have been the greatest in the lower-gradient, biologically-productive areas of river basins most disturbed by humans. The magnitude of decreases in deep pools is substantial and extensive regardless of ERU. The unmanaged streams that were resurveyed generally are in steeper and more highly dissected landforms within the Columbia River Basin and therefore would have had fewer large or deep pools. Most unmanaged streams either have retained pools or have improved pool habitat during the last 55-60 years.

A factor likely to be important in controlling pool frequency in the Columbia River basin is the abundance of in-stream wood. There is a correlation between wood frequency and pool frequency throughout the assessment area. This occurs most notably between large-wood and large-pool frequencies on low-gradient streams. Wood effectively stabilizes channels, influences sediment routing, provides a major component of the in-stream organic matter, provides cover for fish and habitat for invertebrates, and increases overall channel complexity. Protecting sources of in-stream wood for streams is important because:

wood is not readily available in many areas; it plays a critical role for pool formation and habitat conditions; and wood frequency is sensitive to management practices.

The amount of fine sediment (sediment less than 6 mm) on channel beds is another important aspect of habitat quality that apparently is influenced by management. The results of our analysis indicate road density significantly affects surface fines and corroborates the link between forest management practices and channel sediment characteristics.

The role that low-frequency events have in controlling channel morphology, is an aspect of channel conditions in the assessment area that has not been explicitly evaluated in this analysis. Events such as large floods, mass movements, and fire can profoundly affect stream channels by introducing and/or mobilizing large quantities of sediment, thereby altering bed structure and channel form in manners that can persist for decades to hundreds of years. Past human activities can strongly influence the timing and magnitude of natural events. Clearcutting and watershed disruption are linked to increased water yields, bedload movement, more frequent flooding and scour events, and channel instability. Long-term risk to fish and fish habitat on a regional scale is affected by potential long-lasting perturbations to channel conditions.

Status and Distribution of Fishes

A total of 142 fish taxa were reported within the Basin. We considered the fishes at three levels listed in order of increasing detail: 1) fish species assemblages, 2) sensitive native species, and 3) key salmonids. We summarized the known occurrence of all native and introduced fish taxa, defined species assemblages, and calculated richness and diversity indices. We compiled information for 38 taxa considered sensitive, threatened, endangered, or of special concern. We then considered seven select salmonids in the greatest detail: bull, westslope cutthroat, Yellowstone cutthroat, and redband trout; steelhead; and ocean-type (age-0 migrant) and stream-type (age-1 migrant) chinook salmon.

Our analysis was based on both a summary of known distributions and the prediction of distributions and status for select species throughout the entire assessment area. Classification of status for key species and distribution for all species, native and introduced, was supported by information collected through more than 140 biologists working throughout the region. We organized our conclusions along four major themes: 1) composition, distribution, and status of fishes; 2) areas with strong populations; 3) system integrity; and 4) intensively managed areas.

Composition, Distribution, and Status of Fishes

The composition, distribution, and status of fishes within the Basin is very different than it was historically. The overall changes are dramatic and extensive, and in many cases irreversible. Some forms are extinct. Many others, especially anadromous fish, are extirpated from large portions of their historical range. Our clearest understanding of fish status comes from the analysis of the seven key salmonids and is supported by our analysis of species assembages. Although several of the key salmonids remain distributed through much of their historical ranges (notably the cutthroat trouts and interior redband trout), declines in abundance, the loss of important life histories, local extinctions, and fragmentation and isolation of high-quality habitats are apparent. Wild chinook salmon and steelhead are approaching extinction in a major part of the remaining distribution.

If current distributions of the key salmonids are good indicators of aquatic ecosystem health, many systems are only remnants of what were larger and more complex, diverse, and connected systems. Even with no further habitat loss the fragmentation and isolation may place remaining populations at risk. With the exception of the Central Idaho Mountains, Snake Headwaters, and perhaps the Northern Cascades, most of the important areas for the key salmonids exist as patches of scattered watersheds. Many are not well connected or are restricted to much smaller areas than historically.

Many of these important watersheds are associated with high-elevation, steep, and more erosive landscapes. These areas may have more extreme or variable environments contributing to higher variability in the associated populations and higher sensitivity to watershed disturbances. Risks could be aggravated by further development.

The patchwork of important watersheds also suggests that remaining populations are not well distributed within the subbasins. Watersheds that were once likely to support a complex of life-history patterns and subpopulations within larger regional or metapopulations are now often fragmented. The loss of spatial diversity in population structure and of the full expression of life-history pattern may lead to a loss of productivity and stability important to long-term persistence.

Although we know less about the rare and sensitive fish taxa than about the seven key salmonids, analyses of existing distribution and reviews of available literature provide important insights about common threats and appropriate management needs. Many of these taxa occur in isolated areas of the Columbia River basin, in isolated subbasins of the Great Basin, or are restricted to the Upper Klamath Basin. They typically occur in relatively depauperate subbasins, perhaps with only one or two native fish species present and in very restricted areas, often occupying one or two small habitat patches within subwatersheds (averaging 8,000 ha in size). Consequently, broad- or mid-scale assessments that focus on high native species diversity may not adequately describe their distributions.

Areas with Strong Populations

Though much of the native ecosystem has been altered, core areas remain for rebuilding and maintaining functional native aquatic systems. Even though they are reduced in numbers and distributions, native trout remain one of the most widely distributed taxa within the Basin. These indicators of environmental quality suggest that although we have serious problems, particularly in the larger rivers and in the low-elevation agricultural and range lands, the situation is somewhat better in the forested lands. Conditions remain the best in those areas that have experienced the least human-caused disturbance. We see a higher proportion of strong populations in higher-elevation forested lands than others, and the proportion declines with road density. Most of the areas exhibiting high aquatic integrity fall within forested areas, with the exception of areas inherently high in native species richness near the southern edge of the Basin.

The largest areas of contiguous watersheds supporting strong populations of key salmonids are associated with the major river subbasins found in the Central Idaho Mountains, the Snake Headwaters, and the Northern Cascades ERUs. Important but more restricted areas are also found in the Blue Mountains, Upper Clark Fork, and the Northern Glaciated Mountains. Each of the key salmonids had some known or predicted strong populations. Strong areas for salmonids occurred in from less than 1 percent of available subwatersheds for stream-type chinook salmon to 34 percent of available subwatersheds for Yellowstone cutthroat trout (table 1.5). There are few clusters of subwatersheds likely to provide highly productive habitat for multiple species, but collections of watersheds still exist within larger subbasins. However, the core for maintaining and restoring much of the biological diversity associated with fishes still exists.

System Integrity

Protection and maintenance of system integrity and functioning will require innovative approaches. Simple solutions such as setting aside small, scattered watersheds probably will not be adequate for the persistence of even current distributions and diversity. The problems are too complex and too pervasive. If maintenance or restoration of aquatic ecosystem integrity is an important goal, dramatic and decisive action is required to stop further alterations and restore areas that are degraded. Aquatic diversity and resilience are dependent on the maintenance of complex habitats and networks of those habitats at multiple scales.

Table 1.5—Current population status of seven key salmonids in the Basin and its relationship to lands administered by the Forest Service (FS) and Bureau of Land Management (BLM). Data are based on counts of subwatersheds.

Species	Percent of Historical Range Occupied	Percent of Occupied Range Classed as Strong	Percent of Strongholds in Wilderness	Percent of Strongholds on FS/BLM	Percent of Depressed on FS/BLM	Sensitive to FS/BLM Land Uses
Bulltrout	45	13	55	95	82	Yes
Westslope cutthroat	85	25	44	94	65	Yes
Yellowstone cutthroat	66	35	19	70	46	Yes
Redband	69	22	8	56	58	Yes
Steelhead	46	1	9	70	61	Yes
Stream-type chinook	28	<1	50	88	77	Yes
Ocean-type chinook	30	15	0	20	25	minor influence

Conserving the remaining watersheds and habitats that have high intrinsic value or condition for aquatic species is the key to maintaining system integrity. Focus areas include those areas supporting strongholds for one or multiple species, areas of high genetic integrity or fringe distributions, and areas that support narrowly distributed endemic or listed species. For example, many narrowly distributed endemic species are associated with small isolated systems of the interior Oregon Lakes and Klamath basins and illustrate the special significance of these areas. Reconnecting and expanding the mosaic of strongholds for widely distributed species such as the key salmonids would help improve system integrity. For wide-ranging fishes such as the salmon, steelhead, and other migratory trouts, this includes protection of water quality and passage in migratory corridors as well as protection of spawning and rearing areas. Conservation and restoration of important habitats for key salmonids could provide habitat for associated species and will sustain important processes that influence structure and function within these systems.

Restoring or maintaining the integrity of migration corridors will be challenging. Restoration and management of watersheds on Federal lands only will not be sufficient. River corridors surrounded largely by private lands are a particularly important part of fish habitat networks. The connections and habitat provided by larger river systems are critical to the maintenance of anadromous populations. The construction of dams and reservoirs and their complex effects on migration is viewed as the single greatest threat to the persistence of salmon and steelhead in the upper basins. Although much of the highest-quality habitat for these anadromous fish probably remains in the Central Idaho Mountains, no strong populations persist there due largely to passage mortality in migration corridors. These corridors provide a critical link that maintains the complex life histories of other species as well. For example, there are non-anadromous species that retain migratory life-history patterns. Species such as bull, redband, Yellowstone cutthroat, and westslope cutthroat trout may move repeatedly between small rivers and headwater streams used for spawning and initial rearing and large rivers or lakes used for subadult rearing, overwintering, or seasonal foraging.

Aquatic community composition has been influenced by the introduction of non-native species and hatchery-propagated native species. Non-native species containment would also increase system integrity. We found large numbers of introduced species throughout all major river systems. The changes are most severe in the

warmer mainstems, but higher-elevation tributaries are also affected. Land management agencies could cooperatively work with State fishery management agencies to reduce or eliminate stocking of non-native and hatchery-reared fish in areas capable of supporting self-sustaining native species. Containing non-natives will provide benefits that go beyond system integrity.

Intensively Managed Areas

While watershed protection is an effective management approach, evidence suggests that system integrity can be maintained in some intensively managed areas. We found robust fish populations in areas with minimal disturbance. We also found that intensive land use did not necessarily eliminate all strong populations or areas with high integrity. We could not discern, however, whether intensively managed areas with high integrity are anomalies, regions where the effects on streams lag behind the changes on land, or are areas where intensive management and fish can coexist. A more careful examination of these areas may provide useful guidance for future management of disturbance in important watersheds.

Ecosystem Management and Fishes

Six major issues involved with ecosystem management and fishes were examined: 1) catastrophic wildfire and active forest restoration; 2) the role of federal land management in managing for anadromous fishes; 3) the effect of roads on sedimentation and fishes; 4) the function of special emphasis watersheds relative to unroaded areas; 5) subbasin classification to provide a spatially explicit description of aquatic needs and opportunities; and 6) riparian habitat conservation area ecological requirements.

Wildfire and Forest Restoration

Refounding of populations through dispersal from local refuges and through complex life history and overlapping generations are two primary factors important in fish population recovery following a large wildfire. Spatially diverse and complex habitats are important to both types of population recovery. Complex landscapes not only produce a mosaic of burn effects, they also create a mosaic of pre-fire stream habitat conditions that provide important refuges within the burn perimeter. That same pattern of stream habitats, the size of the watersheds, and the connection of the watersheds to a larger river basin are likely important in the full expression of life history. Strong, well-distributed populations appear to have a high potential for recovery following intense wildfires. Depressed populations inhabiting marginal or degraded habitat may lack the resiliency to adequately deal with catastrophic disturbance.

The use of intensive forest management to reestablish more natural landscape patterns and disturbance regimes has variable risks and benefits across the landscape. However, the consequences of large fires are dependent on habitat conditions and the inherent resiliency of local populations. Risks to aquatic ecosystems from fire may be most important where they have been seriously degraded and fragmented. Watersheds that support healthy populations may be at greater risk through disruption of watershed processes and degradation of habitats caused by intensive management than through the effects of fire.

Role of Federal Land Management

There is no question that Federal land management has an effect on anadromous salmonids; however, it is not known to what extent efforts to improve and/or protect habitat will aid in the recovery of depressed populations, given the other factors affecting these fishes. With current conditions in migrant survival, many stocks are at serious risk. Rehabilitation of depressed populations cannot rely on habitat improvement alone. It requires a concerted effort to address causes of mortality in all life stages. These include freshwater spawning and rearing, juvenile migration, ocean survival, and adult migration. Thus, to realize the benefits of improved migration and ocean survival, good-quality freshwater habitats and populations

must be maintained, and the distribution of high-quality spawning and early rearing habitats must increase. Improved federal land management is crucial to this task.

Roads and Associated Activity

Roads contribute to the disruption of hydrologic function and increase sediment delivery to streams. Roads also provide access, and the activities that accompany access magnify their negative effects on aquatic habitats. Activities associated with roads include fishing, recreation, timber harvest, livestock grazing, and agriculture. Roads also provide avenues for stocking non-native fishes. Unfortunately, we do not have adequate broad-scale information on many of these attendant effects to accurately identify their component contributions. Thus we are forced to use roads as a catch-all indicator of human disturbance.

The discussion of the relationship of roads to fishes often centers around three themes: 1) the belief that road-building practices have improved enough in the last decade that we should not worry about their effects on aquatic systems; 2) the legacy of past road building is so vast and road maintenance budgets so low that the problems will be with us for a long time; and 3) the belief that there is not a strong correlation between road density and fish habitat and population.

From an intensive review of the literature, we conclude that increases in sedimentation are unavoidable even using the most cautious roading methods. Roads combined with wildfires accentuate the risk from sedimentation. The amount of sediment or hydrologic alteration from roads that streams can tolerate before there is a negative response is not well known. It is not fully known which causes greater risk to aquatic systems: building roads to reduce fire risk or realizing the potential risk of fire. More research is needed in this area.

The ability of the Forest Service and Bureau of Land Management to conduct road maintenance has been sharply reduced because of declining budgets. This is resulting in progressive degradation of road drainage structures and a potential increase in erosion. Most problems are with older roads that are located in sensitive terrain and roads that have been essentially abandoned, but are not adequately configured for long-term drainage. Given the magnitude of the area of federal forests with moderate to high road densities, the job of road maintenance will be expensive. Most road networks have not been inventoried to determine influence on riparian or aquatic resource goals and objectives.

We conducted two analyses examining the correlation of roads to habitat and fish population status. Each of these analyses support the general conclusion that increasing road density correlates with declining aquatic habitat conditions and aquatic integrity. Our results clearly show that increasing road densities (combined with the activities associated with roads) and their attendant effects are associated with declines in the status of four non-anadromous salmonid species. Those species are less likely to use moderate to highly roaded areas for spawning and rearing, and if found are less likely to be at strong population levels. There is a consistent and unmistakable pattern based on empirical analysis of thousands of combinations of known species status and subwatershed conditions. The analysis is limited primarily to forested lands managed by the Forest Service and Bureau of Land Management.

Special Emphasis Watersheds

We examined several efforts to identify special emphasis watersheds for conservation of aquatic resources and ecosystem function in the Basin in order to address whether habitat criteria or population presence and status are better indicators for such special fish emphasis watersheds. We used fish population strength to identify the best remaining habitats within the Basin by focusing on subwatersheds with designated strong populations of seven key salmonids. This approach has the distinct advantage of recognizing the biological building blocks necessary to maintain and rehabilitate fish

populations in the Basin. The population status watershed approach incorporates excellent habitat, strong populations, and unroaded areas.

Designated wilderness and potentially unroaded areas are important anchors for strongholds throughout the Basin. More than 8 million hectares (27%) of Forest Service and BLM lands in the Basin contain strongholds (40% of Forest Service and 4% of BLM). These stronghold subwatersheds contain large areas of unroaded land (about 4.7 million hectares), averaging 58 percent of the area of an individual subwatershed.

Subbasin Classification

We developed a simple classification of subbasins (approximate area of 280,000 hectares) throughout the Basin. The classification scheme provides a spatially explicit description of aquatic issues, needs, and opportunities that can be associated with similar descriptions for terrestrial ecosystems. We grouped the subbasins into three classes based on contiguous, well-connected subwatersheds with high aquatic integrity and strong populations. The categories range from the best connected to the most isolated and fragmented populations with few or no strongholds within a subbasin.

RHCA Ecological Requirements

We examined recent literature to look at the sufficiency of interim riparian habitat conservation areas (RHCAs) to maintain ecological functions and prevent cumulative effects. Forest plans and forest practice rules regulate two major features of RHCA: 1) width; and 2) the type and amount of activities that can take place within them. By design, a RHCA is to be wide enough to maintain ecological function at the small watershed level and limit disturbance near streams. Interim RHCAs in the range of anadromous fishes and bull trout are prescribed at 90-meter minimum widths for fish-bearing streams in order to maintain stream function and prevent sediment inputs from non-channelized sources. A review of the literature indicates that this width is likely to be sufficient to provide for most riparian functions with a margin for error depending on the intensity and extent of activities within a RHCA.

The likelihood of disturbance resulting in discernable in-stream effects increases as adjacent slopes become steeper. Thus, greater protective measures to protect or rehabilitate riparian function and structure on steeper slopes may be required to prevent or reduce in-stream effects. The specific width necessary to protect a given stream and riparian area structure and function can be determined based on watershed and site-specific analysis.

Taken in aggregate, the standards for management of stream and riparian systems on forest lands are more restrictive and ecologically more effective than requirements for riparian areas where agriculture and urban or industrial land uses are dominant. No state within the Basin has enacted an agricultural practices act explicitly protecting riparian vegetation. Improved protection of riparian areas in agricultural lands is essential if salmon and many native fishes are to survive in the long term.

Research Needs

Our collective knowledge of status, distribution, and habitats for fishes is incomplete. The classifications of status were incomplete for 12 percent to 15 percent of the historic range for anadromous key salmonids, and 33 percent to 67 percent of the presumed range for non-anadromous key salmonids. Classification of status was most complete for chinook salmon and least complete for redband trout. Our knowledge reflects the historical focus of fish-management and research agencies on production and yield, recreational fishing opportunity, and high-profile species rather than on biotic integrity or species conservation. Limited information is available for most fishes. Sampling methodologies are poorly developed, inventories are incomplete, and reference standards are virtually nonexistent.

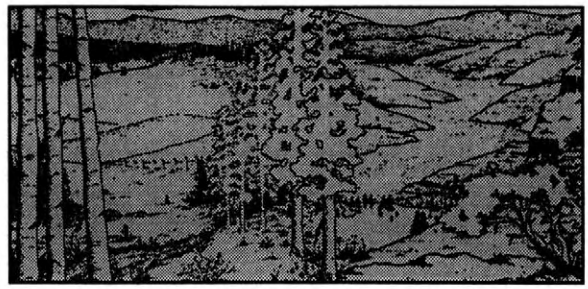
The development of consistent, reliable, large-scale species inventories and databases will be critical for long-term management and evaluation of aquatic ecosystems. Continued research to define critical habitat requirements and predict distributions at multiple scales will be a key element in understanding both current and potential distributions.

Many of the 38 special concern taxa are poorly understood and in need of study and rigorous monitoring efforts. Habitat and population monitoring is essential if management is to respond to factors threatening the persistence of the narrowly distributed endemics.

Evaluation of the roles of riparian buffer zones and corridors of variable structure, size, shape, and connectivity will improve integrated aquatic-land management. Field experiments can be developed to assess the potential role of riparian management areas in watershed management. These experiments may answer fundamental questions necessary for knowledgeable watershed management. They may provide information on the spatial dimensions (that is, width, length, depth, space, and continuity) necessary to achieve single and multiple ecological and/or social objectives and on how well these areas function through time.

It is important to evaluate the role of hydrologic and geomorphic disturbance from extreme events on the biological structure and function of streams, lakes, and riparian management areas. Three types of studies can contribute to this evaluation. First, field surveys are needed to assess the effect of historical events such as fires and large floods. Second, intensive, opportunistic surveys could be undertaken during and following such rare events. Third, the resilience of riparian and aquatic ecosystems to changes in the magnitude and frequency of extreme events could be tested using human-caused events (such as regulating levels of dams and reservoirs).

EXECUTIVE SUMMARY- TERRESTRIAL ECOLOGY OF THE BASIN



A first-ever catalogue of biodiversity of the Basin revealed diverse communities of plants, invertebrates, and vertebrates. However, many species groups are largely unstudied. Over 43,000 species of macro-organisms are estimated to occur within the assessment area and 17,186 species are known to occur. Micro-organisms, critical to ecosystem health and function, probably tally at least several hundred thousand species. This biodiversity results from the wide variety of habitats, topographic conditions, and prehistoric events within the study area. For this assessment we evaluated 14,028 species of macro-organisms. We explicitly included 1,339 individual species and 143 species groups in a database on species-environment relations (SER). We also identified 296 species (excluding fish) that are of particular interest to American Indian tribes.

Some 264 taxa (species, subspecies, or fish stocks) have Federal listing status (table 1.6). Among non-fish taxa, these include 184 Category 2 Candidate, 31 Category 1 candidate, 11 endangered, 6 threatened taxa, and 1 taxon federally proposed as endangered. The Forest Service and Bureau of Land Management list 538 species (excluding fish) as sensitive. Some of the threatened and endangered species and many of the additional species of potential conservation concern are dependent on environmental or habitat components not evaluated at the broad scale.

We do not project species' viability in this assessment. Rather, this assessment sets the stage and provides base information including species distribution, habitats and key environmental correlates, and management actions and effects, as a basis for subsequent viability evaluation. Species' viability under various planning alternatives is presented in another document.

Our work provides an ecosystem context for managing and restoring habitats and environments for terrestrial species and communities. We provide a classification system for environmental correlates and for ecological functions of species and identify functional species groups based on their ecological roles. Although the FS and BLM are charged primarily with habitat management, knowledge of species' ecological roles and the dynamics of plant and animal communities provides a stronger knowledge base. It creates an ecological foundation for ecosystem management. We discuss selection of bioindicators for monitoring environmental changes and for assessing grassland deterioration problems. We examine possible actions for mitigation and restoration.

Land managers will probably be most interested in the following products: (a) lists of habitats and associated species with the greatest declines in area or distribution since historic times; (b) Species-Environment Relations (SER) databases listing species by habitats and ecological functions. The databases are used to determine the potential effects of ecosystem management activities. They can be used to proactively craft activities which emphasize or restore specific habitats or functions; (c) over 520 species distribution GIS maps and additional maps showing areas of high biodiversity and species rarity and endemism; and (d) descriptions of how fungi, lichens, bryophytes, and invertebrates have key ecological roles in maintaining ecosystem health, long-term productivity, and sustainable resource use.

Table 1.6— Numbers of taxa (species, subspecies, fish stocks) by Federal listing status, extirpated, and of special interest to American Indian tribes. Listing status classes: C1 = Category 1 candidate ; C2 = Category 2 candidate; Forest Service sensitive (in at least one state within the assessment area); Bureau of Land Management sensitive (in at least one state within the assessment area); Joint FS/BLM sensitive = same species listed by both FS and BLM as sensitive; Tribal = species identified by the ICBEMP Science Integration Team as of particular interest to American Indian tribes.

Class	U. S. Fish and Wildlife Service						Forest Service and Bureau of Land Management				Tribal
	C 1	C 2	Threatened	Endangered	Federally proposed threatened	Federally proposed endangered	FS sensitive	BLM sensitive	Joint FS/BLM	Total FS/BLM	
Nonvascular Plants	0	1	0	0	0	0	3	10	1	12	4
Vascular Plants	31	111	1	3	0	1	371	113	45	439	205
Invertebrates	0	38	1	4	0	0	0	25	0	25	16
Fish	2	19	5	5	0	0	(...see Aquatic Species and Habitats chapter...)				
Amphibians	0	6	0	0	0	0	2	5	2	5	0
Reptiles	0	1	0	0	0	0	1	5	0	6	2
Birds	0	13	3	2	0	0	22	23	12	34	34
Mammals	0	14	1	2	0	0	11	12	6	17	35
TOTAL	33	203	11	16	0	1	410	193	66	538	296

Species at Risk

The Assessment contains a complete catalogue of all federally listed threatened, endangered, and candidate species. The database also includes information on The Nature Conservancy and Heritage Program rare plant categories, and state- and agency-specific listing categories of all species. Summaries of conservation plans and useful management actions for federally listed species are provided.

The assessment also identifies a number of additional taxa, especially plants and invertebrates, worthy of additional attention. These include: 394 fungi species; 40 functional groups of lichen species; sundry types of microbiotic crusts (not classified); at least 400 apparently regionally rare bryophyte species; 280 individual vascular plant species and 82 rare plant communities; 144 rare and endemic invertebrates (gastropods and insects); and various vertebrates. Among the vertebrates are the more aquatic-dwelling amphibians, reptiles susceptible to ground-disturbing management activities, and birds and mammals associated with habitats that are now scarce, declining, or increasingly fragmented. These include native grasslands, sagebrush, and old low- and mid-elevation forests. Basic inventories are needed for many of these species to determine their true rarity.

We do not advocate a species-by-species approach to management of all such species at risk. Many of the species on these lists can be assessed in groups. Inventories, where desired, could aim at gathering information for many species simultaneously, and management guidelines could address their collective habitat and environmental requirements or locations of joint occurrence.

Species Environment Relations

Native grasslands (Fescue bunchgrass, *Agropyron* bunchgrass), shrublands (big sagebrush), and old single-story and multi-story stages of many forest types, especially lower montane forests, have declined in total area and shifted in distribution since historical times. Most declines have occurred on Federal lands, although non-Federal lands have also experienced declines. Many species of plants and allies, invertebrates, and vertebrates are associated with these types. Vertebrate species associated with the decline of old-growth forests included primary cavity excavators and species with large home ranges. Other vegetation types, including young successional stages of forests, conifer-encroached sagebrush and disturbed riparian conditions, have increased in total area and distribution since historical times.

Major ecological species functions are summarized from the SER databases. Understanding functions is critical to crafting appropriate ecosystem management guidelines; the fate of individual species is only one facet of terrestrial ecology conservation. The major ecological functions we addressed were: species contributing to major biomass; herbivory; nutrient cycling relations; interspecies relations; soil productivity; wood decomposition; and water quality. As a land management tool, Federal managers will probably find these ecological/functional species groupings more useful than a list of individual keystone species.

Probably no vertebrate became regionally extinct in historical times; information on other taxa is lacking. Small-bodied, less widely-vagile species may be at greater risk for declines or local extirpations. Range edges are important for species conservation. Using the SER model, we identified species closely associated with conditions affected by management including: forest canopy; mistletoe brooms; dead parts of live trees; trees with exfoliated bark; snags; down wood; litter and duff; fire processes and insect outbreaks; recreation; roads; and trails. This information may be useful for managers predicting potential activity effects. The information will help identify specific conditions for the conservation of species functional groups.

Fungi

Fungal flora and management activities, effects on fungi are poorly known. Some species are important to recreational and commercial gatherers. Many kinds of fungi occur, including species with narrow distributions, species that fruit after fire, species

that fruit in dung, and species that are mychorrhizal and saprophytic and thus depend on host plants. Fungi conservation can include protection of type localities in small, site-specific mycological preserves and further study of species biology and ecology.

Lichens

Lichens play key ecological roles in ecosystems. These include contributing mass and nutrients to litter and duff, increasing canopy and soil moisture-holding capacity, fixing atmospheric nitrogen, serving as food for animals, and acting as bioindicators for air quality. They may also have significance for some American Indian tribes. The 736 lichen species were divided into 40 functional groups based on ecological relationships. The groups occur on four main substrates: dead organic matter, corticate and decorticate wood, rock, and soil. Lichens are major components of native rangelands and provide critical soil functions. They have been threatened by exotic grasses, increased fire frequency, rangeland conversion, and livestock trampling. One lichen, *Texosporium sancti-jacobi*, is listed as a candidate (C2) species. Providing clumps of old trees and uneven-aged stands for their legacy of lichens can improve lichen conservation. Basic lichen surveys and studies of management effects are needed to supplement our poor knowledge base.

Bryophytes

Most bryophytes have wide Arctic-alpine and boreal distributions. Others are coastal and north Pacific or occur in arid environments as part of soil crusts. Four taxa are endemic to the assessment area. Eleven ecological groups of bryophytes were identified based on common use of substrates. Changes in water quality affect aquatic submerged and wet-rock species. Forest canopy openings often adversely affect mycorrhizal species associated with decaying wood and forest humus and duff. Commercial collection of bryophytes may affect some of the humus and duff species. Other species in bogs, fens, and other environments are poorly studied. Dry soil species are critical to soil protection. Many species, at least 400, may be regionally rare. An inventory would help determine status, especially bryophytes in arid habitats, peatlands, floodplains, geothermal areas, isolated canyons, on calcareous rocks, and mineralized deposits. Bryophyte conservation can include training for identification, adding bryophyte identification to field vegetation plot data, and inventorying bryophytes in protected areas.

Vascular Plants

Vascular plants in the assessment area number at least 8,000 species, which include at least 154 local or regional endemics. The diversity comes from complex biophysical environments along gradients of elevation, bedrock and soils, temperature, and moisture. Native plant communities have declined significantly in the assessment area, prompting concerns about future conservation of rare species and rare plant communities. Of particular concern are communities affected by grazing, exotic species introduction, and timber harvest. Examples include bunchgrass grasslands of the Palouse region and low elevation cedar/hemlock old forests. The sustained harvestability of some 205 plant taxa are of concern to American Indians. Conservation measures can include monitoring rare species and plant communities; off-site collection of pollen, seeds, and rare plants; and protecting of key areas of high species rarity, endemism, and diversity.

Invertebrates

No terrestrial invertebrate species is listed as threatened, endangered, or C1 candidate (although five aquatic invertebrates are threatened or endangered). Thirty-eight terrestrial invertebrates are C2 candidate species. The FS does not list any as sensitive species and the BLM lists 25. Some 95 terrestrial mollusks would benefit from conservation attention singly or as groups; many of these are confined to calcareous substrates. Invertebrates are critical components of many ecosystem functions including detritivory and nutrient cycling. We identified 104 rare and endemic species that bear further watching. Functional roles of invertebrates include: detritivory and nutrient cycling; maintaining soil structure, chemistry, and productivity;

wood decomposition; herbivory; pathogenic effects on other organisms; and control of disease-causing organisms. Invertebrates can make excellent bioindicators of soil and vegetation health.

Most arthropods are poorly known; many are unnamed. Arthropod predators may control other invertebrate populations including some defoliator pests. They require a mix of habitat types, down wood, and vegetation substrates. Invertebrate pollinators are critical to maintaining the flora. In grasslands and forests, species groups, particularly herbivores, are important links in food webs and affect vegetation succession. A few are agricultural or forestry pests. Fire and changes in soil chemistry directly affect invertebrates, especially in range and forest conditions altered from historic structures. Other concerns are mechanical and livestock compaction and soil mixing. Other activities potentially harmful to desirable invertebrates include overgrazing, some recreation, loss of sphagnum bogs, exotic plants or arthropods, and pesticide use. Providing a diversity of habitats, maintaining soil structure and soil chemistry, and preventing or eradicating exotic species could enhance conservation of invertebrate species.

Vertebrates

Amphibians require water or moist environments, are susceptible to exotic species, and are associated more with substrates such as down wood or talus than with vegetation types or stages. Amphibians transfer nutrients from aquatic to terrestrial environments, are prey for predators, and contribute major biomass in forest ecosystems. Studies are needed to determine the effects of water quality changes, canopy closure, pesticides, livestock grazing, eutrophication, and ultraviolet radiation on amphibians and on their dispersal and distribution. Reptile distribution is more closely associated with elevation, aspect, and substrate than with vegetation. Reptiles are susceptible to dams, off-road vehicle use, loss of wetlands, livestock grazing, and fire suppression. Better survey techniques for reptiles are needed. Birds are susceptible to management-induced changes in vegetation, especially historic declines in old, single-story, interior ponderosa pine forests and grasslands dominated by *Agropyron* bunchgrass. In particular, impacts to grasslands have caused declines in Columbian sharp-tailed grouse numbers. Neotropical migrants would benefit from conservation and restoration of riparian, old forest, shrub-steppe, grassland, and juniper habitats. Mammalian population or habitat declines include some bat species and predators. Some 42 vertebrates are listed as endangered, threatened, or C2 candidate. Few locations still contain all top predators.

Biogeography, Endemism, and Biodiversity

Broad-scale biogeography of species is poorly studied in the assessment area. We identified some species closely associated with some of the nine landform classes. Distributions of local endemics can result from contracted ranges due to habitat loss or extirpations, overall scarcity of suitable environments, or other factors. Apparent peripheral, disjunct, and scattered distributions of some species may be an artifact of the location and size of the area of interest. Species such as boreal owl appear as disjunct populations because of breaks in distributions of suitable environments or incomplete sampling. Smaller and more isolated disjunct populations are likely to be more susceptible to local declines or extinctions. Locally endemic species or subspecies are highly habitat-specific, such as Coeur d'Alene salamander. Most Ecological Reporting Units had at least some unique species, although many species overlapped several ERUs. Some species are closely associated with single biophysical factors, although many species are likely correlated with multiple factors.

We mapped centers of concentration for (1) species rarity and endemism and (2) high biodiversity. Centers of concentration were mapped separately for plants and for animals. Locations with several centers of concentration for these two types defined smaller "hot spots" for plants and animals combined (map 1.9). We identified 12 hot spots of species rarity and endemism and seven hot spots of high biodiversity. Additional hot spots may be identified at finer levels of geographic resolution

than we used in this project. Hot spots included southwestern Oregon, the Snake River, the Columbia River Gorge, and desert steppe in central and southern Washington.

Environmental condition maintenance within these hot spots can be one aspect of a broader biodiversity conservation strategy. Other aspects can address protecting type locations of rare fungi, lichens, bryophytes, and vascular plants; protecting unique plant communities; *ex situ* plant conservation measures; providing for plant and animal species associated with rare or declining vegetation communities (especially native grasslands, native shrublands, and old-growth forests); ensuring adequate habitat for plant and animal species of interest to American Indian tribes; and conserving locations still containing all top vertebrate carnivores.

Natural areas on Federal lands total 11.72 million hectares in 26 land allocation categories. The size of existing natural areas might be suitable for supporting at least small populations of at least 70 percent of vertebrate species. Natural areas of various kinds might be "realigned" or enhanced to better coincide with hot spots of species rarity and endemism and hot spots of high biodiversity. Criteria for selecting new natural areas might be based on consistent ecological themes.

Maintaining Ecological Integrity of Terrestrial Ecosystems

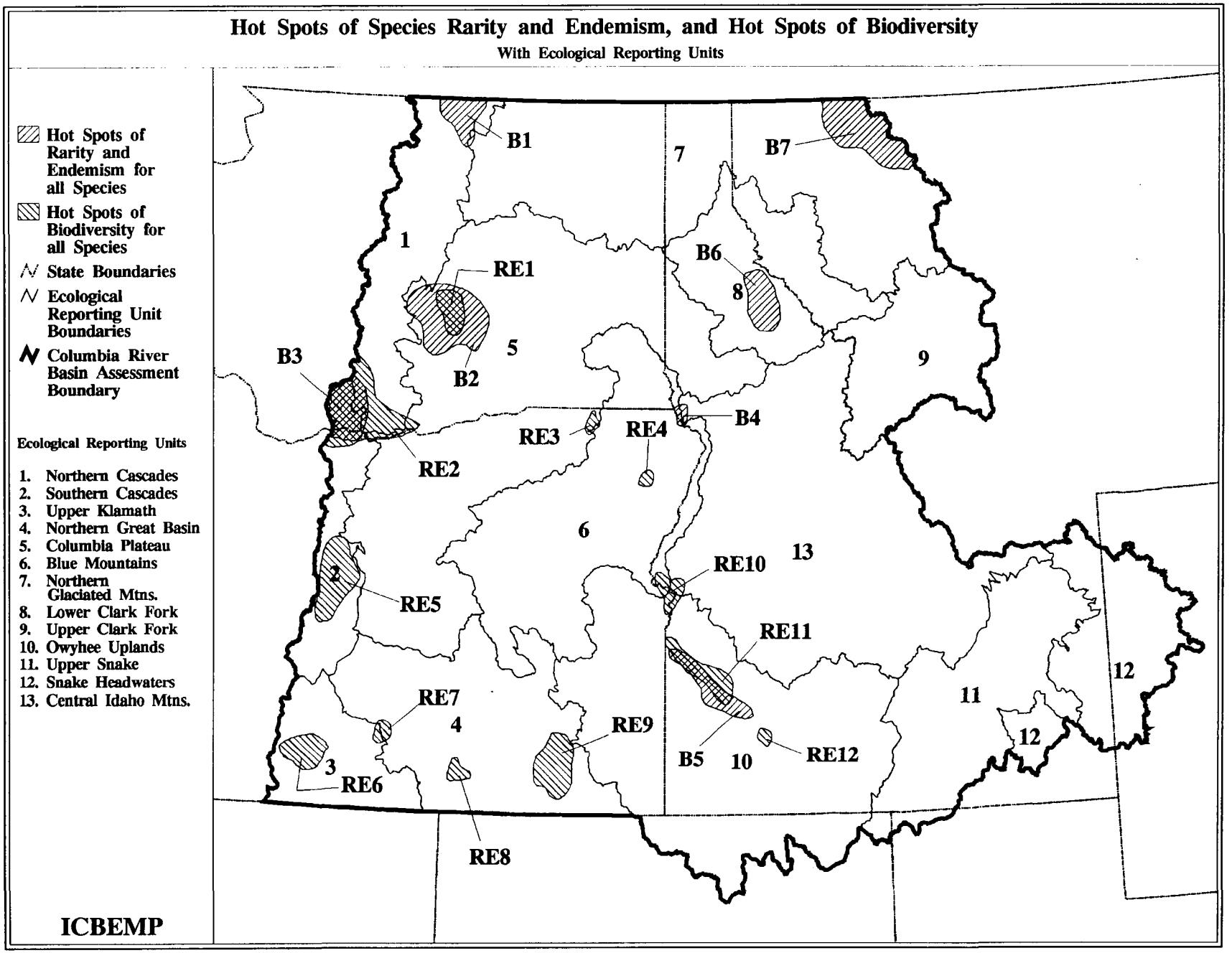
Our findings suggest some measures for helping to maintain terrestrial ecosystem integrity. (1) To conserve biodiversity, some realignment of natural areas may better represent ecosystems and provide for rare and endemic species. Also, conservation measures can be considered for at least 12 "hot spots" of species rarity, endemism, and richness. The full array of historic vegetation conditions in the Basin can be provided. (2) For maintaining long-term terrestrial ecosystem productivity, the ecological roles of soil micro-organisms could be better studied and incorporated into management. (Also helpful would be providing environments for unique assemblages of species and functional groups of species.) (3) For maintaining long-term evolutionary potential, populations of species with disjunct distributions could be provided for, as could populations of locally and regionally endemic species and locally endemic subspecies. Protection could be afforded for rare plant type localities. Both in-field and off-site rare plant conservation measures could be instituted.

Additional Work

Some policy questions and issues cannot be addressed at the broad regional scale. Additional work is necessary for (1) further describing historical trends and current conditions and threats for species at finer scales of resolution than this current study affords, and (2) collecting basic scientific knowledge on life history, ecology, and distribution of many species.

Much basic scientific information on species could be gathered through inventories of many fungi, lichens, bryophytes, and rare plants. Selected rare plant communities could be monitored. Basic inventories and taxonomy studies of invertebrates could be conducted, along with studies on basic ecology, biology, and ecological roles of many plants and most invertebrates. Early warning indicators (bioindicators) of potentially degrading ecosystem health could be identified and used cost-effectively. Potentially useful bioindicators include some soil crusts, micro-organisms, arthropod herbivores, fungi, lichens, and bryophytes.

About 86 percent of arthropods, 67 percent of fungi, and 51 percent of mollusk species estimated to occur in the assessment area have not been studied, surveyed, or, in some cases, even identified. Much inventory and basic systematics work remains to be done on these groups. Soil micro-organism groups and microbiotic (soil) crusts within the assessment area are poorly known and little studied (critical for maintaining soil productivity). They are critical for maintaining soil productivity.



Map 1.9—Hot spots of species rarity and endemism, and hot spots of biodiversity.

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EXECUTIVE SUMMARY-ECONOMIC ASSESSMENT OF THE BASIN

A fundamental tenet of land stewardship is for managers to direct and maintain ecosystems to fulfill the objectives of the owners. For the Forest Service and Bureau of Land Management, providing a broad array of ecosystem goods, functions, and conditions is appropriate. It is required by law. In order to implement ecosystem management, these agencies have a threefold economic challenge: to produce the bundle of ecosystem goods, functions, and conditions that society wants (economic efficiency), whose distribution of benefits is according to societal wishes (equity), without adversely affecting economic activity. We address each of these issues in turn. At the end, we briefly characterize the economic issues related to fish, minerals, range, recreation, and timber.

Economic Efficiency

Under current management, FS and BLM lands in the Basin provide society with a wide array of benefits. The current and future importance of the benefits (that could be measured and valued) is shown in table 1.7. This table shows that among outputs and conditions we evaluated, unroaded areas on FS- and BLM-administered lands are highly valued. Unroaded areas will continue to be valued through the year 2045, although their relative importance may diminish. The relative importance of other outputs will probably shift over time. Existence values aside, the three most highly ranked uses for FS- and BLM-administered lands in the Basin are currently timber, fishing, and hunting. Our projections indicate that by the year 2045 the three most highly valued uses will be motor viewing, day use, and trail use. This suggests that the FS and BLM will face a fundamental shift in their constituencies. It also suggests that the objectives of land management activities might be different in the future. Currently, there is lower relative importance placed on wildlife viewing, motor and nonmotor boating, range, off-road vehicle (ORV) use, and snowmobiling provided by FS- and BLM-administered lands. These activities are included in the "other" category in table 1.7.

Given their differences in natural resource endowments, road infrastructure, unroaded areas, proximity to population centers, and residents' age and income characteristics, each ERU is predicted to provide society with a different bundle of benefits. In the coming decades, most ERUs will probably experience a reordering of priorities, generally toward recreation.

The institutional framework and societal desires from public land stewardship continuously evolve. During the course of U.S. history, major land management themes have changed from privatization (1800-1891), to conservation and scientific management (1891-1945), to commodity production (1945-1960), to increasingly complex and contentious demands (1960-present). Today, the agencies are faced with attempting to balance these traditional issues with demands for ecosystem health and fire management. Society's objectives for public land stewardship will likely continue to change.

Table 1.7— The relative importance of some outputs from FS- and BLM-administered lands in the Basin, for the years 1995 and 2045.

Activity	1995 Value	2045 Value
	Percent	
Camping	3.45	4.40
Day Use	5.28	8.11
Fishing	9.88	6.64
Hunting	9.48	6.31
Motor viewing	1.88	9.46
Timber	11.49	5.38
Trail Use	3.28	6.85
Existence value of unroaded areas	46.86	41.43
Winter Sports	5.05	5.70
Other	3.35	5.72
Total	100.00	100.00

Broad indicators suggest we are sustaining forest acreage and inventory at the Basin level. Recreational impacts coupled with Christmas tree harvest, firewood gathering, and mushroom and berry picking have created a growing problem. Because these valuable resources are available to the public at little or no cost, there is little incentive for harvesters to conserve these resources. The increases in human population predicted for the Northwest suggest that demands on ecosystems and public resources will continue to increase. Establishing a fee system for recreation and special products could protect ecosystem conditions in recreational settings, maintain sustainable or harvestable levels of species, and provide new sources of revenue.

Equity

The benefits of the FS and BLM lands in the Basin are distributed widely. Consumers of beef or timber benefit, because these goods are traded in national markets. People who enjoy knowing unroaded areas exist may never visit the Basin, yet receive benefits. Millions of people, mostly residents of the Basin and the Northwest, recreate here; there is little difference in participation rates among people with different lifestyles.

About 220,000 jobs are associated with current levels of range, recreation, and timber harvest on FS and BLM lands. Range accounts for 1 percent of these jobs, recreation 87 percent, and timber 12 percent. In addition, there are jobs associated with mining special forest and range product harvest, but the number is unknown.

Federal revenue-sharing distributions to county governments are currently determined from timber sales and grazing permits. Yet some of these counties bear costs associated with recreation: infrastructure, road maintenance, and emergency services, for example. If recreation values were included, some counties could double or triple their revenues.

Economic Activity

The Basin

Agriculture and agricultural services remain economic strengths of the Basin. It has a large, diverse economy of 1.5 million jobs that is experiencing an above-average growth rate. Per capita income is growing faster than the U.S. rate, and the poverty rate is generally lower than the U.S. average. The past two decades have seen rapid population growth. What was a mature, resource-based economy has matured into a diverse economy oriented toward the technology-based, transportation, and service sectors.

We expect the general economic growth in the Basin to continue, sustained by in-migration in some areas. Growth is expected in services, finance, insurance, real estate, trade, and agricultural services. The fastest growth is expected in the service sector, which includes health, business, educational, and legal services. The manufacturing, farming, and government sectors are expected to decline over the next 50 years.

Traditional, regional economics views growth as a function of expansion in basic manufacturing industries. Contemporary challengers argue that other industries should be considered part of the economic base. Both approaches recognize that some locations have unique advantages or endowments that will attract certain types of industries. Traditionalists view these as resource endowments for extractive industries. In the contemporary schema, these include amenity or quality of life considerations that attract business, capital, and skilled labor. Our findings indicate that changes in management strategies by the FS and BLM have little effect on the economy of the Basin or its subregions from either of these two approaches. However, the effects of the agencies actions may be more pronounced at specific, local levels.

The nine regional economies in the Basin are diverse, and they are resilient to changes in FS and BLM commodity outputs. Overall, the forest products industry has had a neutral effect on recent economic growth. We found no relation between economic well-being at the county level (expressed as per capita income) and either the forest products processing facilities or the presence of timberlands—whether Federal, FS only, or private. Basin-wide, the cattle industry accounts for 29 percent of agricultural sales, but only seven percent is dependent on BLM and FS forage. Recreation accounts for 14.6 percent of the jobs in the Basin. Mining accounts for 0.5 percent, but we were unable to acquire data to determine what percent of mining jobs is attributable to FS and BLM resources.

The Boise Bureau of Economic Analysis (BEA) region is strong in agriculture, agricultural services, transportation, finance, insurance, and real estate. Twelve percent of the cattle are dependent on Federal forage. This is above the Basin average.

The Butte BEA region is the only regional economy in the Basin without a strong agricultural sector. Mining is very important there along with transportation and services.

The Idaho Falls BEA region is strong in agriculture, agricultural services, construction, and trade. Mining is important, though less so than in the Butte BEA region. Both employment attributable to recreation (30 percent), and the portion of cattle dependent on Federal forage (11 percent), are above the Basin average.

The Missoula BEA region is strong in agriculture, agricultural services, construction, and transportation. Employment attributable to recreation is 31 percent, considerably above the Basin average.

The Pendleton BEA region is strong in agriculture, agricultural services, and manufacturing. Both forest products and food processing are important components of its manufacturing sector. Economic diversity is fairly high, suggesting this economy is resilient to fluctuations in the forest products industry.

The Redmond-Bend BEA region is strong in agriculture and agricultural services. Both employment attributable to recreation (25 percent), and the portion of cattle dependent on Federal forage (9 percent), are above Basin averages. Forest products and food processing are both important components of its manufacturing sector. Like the Pendleton BEA region, economic diversity is fairly high, suggesting this economy is resilient to fluctuations in the forest products industry.

The Spokane, Tri-Cities, and Twin Falls BEA regions all are strong in agriculture and agricultural services. In addition, the Spokane BEA region is strong in trade, and the Twin Falls BEA region is strong in construction. None of these regional economies is likely to be affected by changes in FS and BLM commodity outputs.

Counties

Counties grouped according to a typology of income specialization or other characteristics exhibit different patterns of economic behavior. Those dominated by the service sector have consistently shown the highest rates of economic and population growth since 1970. They have also exhibited high resiliency, rebounding faster than other counties after the early 1980s recession. These include counties with trade-center towns, and growing recreation and tourism economies. Counties dominated by recreation or retirees have shown consistently high rates of population growth, total employment, and total personal income over the last 20 years. Between 1979 and 1989, counties dominated by manufacturing income showed the highest tendency to evolve into a different kind of economy. Many of these did so because of losses in the wood products or mining sectors.

Community Economies

Maintenance of stability in timber-dependent communities is often thought to be a FS responsibility, although the agency has no economic legal mandate. No facts document a link between sustained timber flow and community stability.

What makes timber communities less resilient than others is their tendency to be isolated and to lack economic diversity. These traits make their economies sensitive to changes in interest rates, labor productivity, consumer preferences, and national business cycles—all factors over which the FS and BLM have little influence.

In 1987, the FS identified 66 Basin communities as timber-dependent. Today, 29 exhibit characteristics indicating that their economies are sensitive to Federal timber sales. These are communities isolated from fast-growing populations and economies in the Basin. Federal policies toward such communities are more accurately viewed as political, not economic, reflecting political preferences about equity or distribution of wealth. Given that human populations in the Basin are expected to double over the next 50 years, the notion that any community may maintain stability is questionable. The more appropriate question is what attributes of communities and their economies best accommodate change.

Characterizations of Specific Resources

Fish

Through a multitude of actions of others—ocean fishing, government hydropower projects, irrigated agriculture, forestry, and grazing—the FS and BLM are managing some of the last remnants of good-quality habitat for declining fish stocks. The net result of these actions, plus habitat degradation, has been the virtual elimination of a valuable commercial fishery. It has also meant incalculable damages to the American Indians for whom salmon formed the economic, cultural, and spiritual basis of their lives. Spiritual values aside, currently the diminished Columbia Basin fishery is most valued for recreation. Much of this recreation takes place on public lands. The FS and BLM mandate to maintain habitats that support strong fish populations will probably increase as these conditions continue: human population growth and associated land-use changes, commercial fishing pressures, climatic influences on ocean habitat, and fish passage through hydropower facilities.

Minerals

There is a smaller percent of mining employment in the Basin than in the nation (0.45 percent versus 0.66 percent), but mining is very important in the six counties that account for 70 percent of the Basin's mineral production value. The Basin produces 30 percent of the Nation's silver, 12 percent of its phosphate, and 11 percent of its gold.

Metal prices, laws, and regulations will determine future mineral production rates within the Basin. The extent to which mining activity will affect public lands is difficult to know. The greatest probability for mineral development in the long term is along three geologic trend-lines which run through six ERUs. One is a northeasterly trend from southeastern Oregon into central Montana (the Owyhee, Central Idaho Mountains, and Upper Clark Fork ERUs), in which the most economically attractive targets include copper, cobalt, and large, low-grade deposits of gold and silver. In the western Northern Glaciated Mountain and North Cascades ERUs, mining for gold and silver will likely continue—underground in the short term, becoming open pit mines in the future. Considerable base metal resources lie in a northwesterly trend from southwestern Montana into northeastern Washington (Upper Clark Fork, Lower Clark Fork, and Northern Glaciated Mountains ERUs). Large-scale open-pit mining and phosphate ore processing are likely to continue in the Snake Headwaters and Upper Snake ERUs over the long term.

Range

The livestock industry's reliance on BLM and FS forage varies from 1 to 11 percent in the BEA regions, with a Basin-wide average of 7 percent. Cattle sales dependent on BLM and FS Animal Unit Months (AUMs) average 2 percent of total agricultural sales across the Basin. Many of the counties most highly reliant on Federal forage sell proportionately low numbers of cattle and calves, suggesting that the rangelands have low productivity. If current trends continue, forage use will decrease on BLM lands by 18 percent, and on FS lands by 19 percent, over the next two decades.

On average, holders of BLM or FS grazing permits run bigger, more profitable operations than those of nonpermittees. Permit acreage and AUMs are skewed toward the largest operations—a small number of individuals, corporations, and partnerships.

Recreation

FS and BLM lands in the Basin provide over 200 million recreation activity days per year, valued at $1.0 billion per year (in terms of willingness-to-pay). This is over 80 percent of the recreation value provided by all Federal lands in the Basin. At present, recreation on FS and BLM lands has a higher willingness-to-pay value than the market value of timber or range outputs in every ERU, except the Klamath Basin in which timber values will be surpassed by recreation by the year 2005. Fishing provides the greatest benefits of all activities ($300 million), followed by day use ($250 million), downhill and cross-country skiing ($230 million), hunting ($146 million), and camping ($75 million). By the year 2045, the larger and older human population will most value (in decreasing order) motor viewing, day use, trail use, fishing, and hunting.

The FS and BLM manage over 90 percent of the federally owned recreation acres in almost every ERU and Recreation Opportunity Spectrum (ROS) class in the Basin. Seventy-five percent of all activity days take place in roaded natural settings (road densities between 1.7 and 4.2 miles per square mile). Roads and access to riparian areas will be the most highly valued recreation activities for the next 50 years. If charged, recreation fees could be used to finance road maintenance, offsetting other potential decreases in road funds.

Purchases of food, equipment, lodging, transportation, licenses, and other items associated with recreation on public lands add up to significant expenditures and support some 220,000 jobs in the

Basin. The percentage of the job force supported by recreation is above the Basin average in the Idaho Falls, Missoula, and Redmond-Bend BEA regions.

A trade-off exists between access for some types of recreation and providing primitive/semi-primitive recreational settings for others. In the lower 48 states, 70 percent of the unroaded areas larger than 200,000 acres lie in the Basin. Fifty-six percent of trail use in the Basin takes place in the primitive/semi-primitive settings. Trail use is highly valued in both the Northern Cascades and Central Idaho Mountains ERUs, yet so are activities dependent on roads. An appropriate balance between roaded natural and primitive/semi-primitive settings is a question that needs further study.

Scenic integrity is another important element of high-value recreation activities such as motor viewing and day use. Managers might consider using silvicultural prescriptions that improve scenic integrity–through creating a more natural appearance and avoiding sharp edges or contrasts–particularly in ERUs such as the Northern Cascades and Central Idaho Mountains. These ERUs are expected to be highly valued for motor viewing and day use.

Special Forest and Range Products

Little is known about the special forest and range products industry in the Basin, because data on jobs and harvest are not regularly gathered. Relative to industry west of the Cascade mountains, the industry in the Basin is small but growing. It is focused around wild edible mushrooms and huckleberries. Rapid industry expansion is expected to continue. Under the present permitting system some of these species may be over-harvested.

Timber

By the year 2040, softwood timber harvest in the United States is projected to increase by 35 percent (0.6 percent per year), to 14.6 billion cubic feet. In the past five years, federal harvests have been shifting from the western to the southern states. Western states now account for 45 percent of the harvest. Timber harvest in the Basin currently accounts for 10 percent of total U.S. harvest; it has declined by 7 percent since 1986 and is expected to decline another 5 percent by the end of the decade. Public-land harvest is currently 46 percent of total harvest in the Basin.

In recent years, the number of timber jobs in Idaho and Montana has declined owing to technological improvements; no such trend exists for eastern Oregon and Washington. Based on current harvest projections, we expect modest employment declines to continue owing to related declines in timber harvest. More than 80 percent of the timber harvest in the Basin occurs in four economic areas—Spokane, Missoula, Redmond-Bend, and Pendleton; this includes both private and public timber.

Water

Current water use in the Basin (34.3 billion gallons per day) is almost entirely (93 percent) for irrigated agriculture with only minor amounts used for domestic, commercial, and industrial purposes (5 percent), and livestock (2 percent). Southern Idaho accounts for 62 percent of the water withdrawals. Projections based on per capita water use for commercial, domestic, and industrial water purposes suggests potential conflict over water use between municipalities and irrigators. Eight out of nine economic areas would have to reduce the amount of land in irrigated agriculture to meet municipal needs.

Water use and water policies while not controlled by the FS and BLM do affect land management in the Basin. For example, the listing of chinook and sockeye salmon in the Snake River has caused reconsideration of land management practices. In addition, changes in water allocation is one of the options available for ensuring the viability of fish populations. Complicating the water issue is the impact of increasing demands for water based recreational activities many of which take place on federal lands.

EXECUTIVE SUMMARY- SOCIAL ASSESSMENT OF THE BASIN



Many social, political, economic, and cultural factors and trends influence natural resource management in the Basin. In turn, natural resource management on Federal lands has indelibly shaped the social character of the people and the stability and resiliency of communities within the Basin. The social assessment documents many types of human-environment interactions to provide a better understanding of the social, cultural, and institutional context for addressing major ecosystem management policy questions.

The focus in this assessment is on eight types of interactions between people and the environment: settlement patterns; population and demographics; relevant attitudes, beliefs, and values of people who care about the Basin's physical, biological, economic, and social components; health and resiliency of small, rural communities; value of natural resource-based amenities; unique status of American Indians and their relations with the environment; role of the public in management of lands administered by the Forest Service and BLM; and the many institutions involved with natural resource management.

History of Human Settlement

The Columbia Basin has been occupied by people for at least 12,000 years. People in the original Columbia Plateau culture possessed lifeways and knowledge of the land gained over thousands of years. Specific places for fishing, hunting, and gathering became important to tribal groups for their supply of food within a yearly rhythm of seasonal rounds. The widespread use of fire by American Indians over long periods helped shape the mosaic of vegetation and associated animal communities in the interior West.

Natural resource and transportation development played critical roles in subsequent Euro-American settlement of the Basin. Mining, timber production, ranching, farming, and commercial fish harvest were important in the late 1800s; all but commercial fish harvesting are still viable industries. Communities became established in locations conducive to supporting the industries of the early era. In addition, development of communities throughout the Basin followed extension of the railroad network. In the early 1900s, road construction further opened up the area.

Society's needs and values determined choices about types of crops, dam building for hydroelectric power, road construction, natural resource and development. Throughout history, societies have had evolving needs for natural resources and evolving attitudes about the acceptability of those uses. Societal decisions about people's appropriate role in the ecosystem will continue to have far-reaching effects, both on human uses and values and the resulting effects on other ecosystem components.

Basin Population

The 1990 population in the Basin was just under three million people. The project area is sparsely populated, with a density of about 20 people per square mile, compared to the national average of 70. The counties in the Basin account for about 8 percent of the land area in the United States, but only 1.2 percent of the population. Nearly half of the population is located in 12 of the 100 counties, although just six of these (Ada and Canyon in Idaho, and Benton, Yakima, Franklin, and Spokane in Washington) are large enough to be called metropolitan counties.

The age distribution of Basin residents is similar to that of the Nation, but the Basin has a larger proportion of people under 18 years of age and a smaller proportion in the prime wage-earning years of 25 to 49. There is a larger proportion of Whites (92 percent) and American Indians (2.4 percent) than in the Nation as a whole (80 percent and 0.8 percent respectively), and a smaller proportion of Blacks (0.6 percent, compared to 12 percent nationally) and Hispanics (6.7 percent, compared to 9 percent nationally).

The Basin's population patterns over the last 45 years paralleled dramatic national changes. Between 1950 and 1970, there was a significant out-migration from rural to urban settings; over one-third of the counties in the Basin showed population losses. During the 1970s, however, most counties in the Basin reported population increases. The 1980s demonstrated a return to traditional urban migration and population patterns.

In the early 1990s, population growth again occurred throughout the Basin, with 96 percent of the counties increasing in population. The recreation counties (recreation and tourism play a large role in the economy) were particularly important centers of growth, accounting for 24 percent of the Basin's population increase.

Assumptions about migration rates affect estimates of future population growth patterns. A low estimate, already exceeded in many areas, would result in a population of about 3.5 million by year 2040; a higher estimate of 6.5 million would double the Basin's current population. Recent swings in population settlement patterns make predicting the most likely scenario difficult. Although overall population density would remain well below the national average under either scenario, there is reasonable potential for greatly increased growth. This would affect Basin resources and factor into their management.

Attitudes, Beliefs, and Values

Survey data from previous surveys and those conducted for the Interior Columbia Basin Ecosystem Management Project were used to assess people's attitudes, beliefs, and values relevant to natural resource management in the Basin. According to recent national surveys, a majority of the American public is concerned about environmental quality and believes environmental issues are a high social priority. Public support, however, could be lower than it was several years ago. Support for endangered species laws and regulations is also strong, but may have decreased slightly over the past few years. The public expressed increasing concern with seeking a balance between species protection and costs to society; this concern is especially strong among rural project-area residents. Support for salmon recovery and a willingness to accept resulting socioeconomic effects seemed stronger than support for endangered species in general. Most people perceive the major barriers to salmon recovery to be dams and over-fishing, rather than lack of suitable habitat.

Although people support the goal of healthy forests and rangelands, some are skeptical about ecosystem management and attempts to mimic natural processes. Disturbance events such as fire, insects, and disease have negative connotations for many people. Although many people understand these events occur naturally in ecosystems, many may also consider the results to constitute resource

waste. Many people claim they have yet to hear a good definition of ecosystem management. A better understanding of the concept should not be assumed to lead to greater acceptance. Many who support ecosystem management doubt that agencies have the ability or desire to implement it adequately. Some people clearly believe that ecosystem management is an excuse for agencies to continue cutting timber under the guise of forest health. Other people are simply opposed to the idea of ecosystem management for many reasons, including perceived effects on private lands; cost of restoration efforts; and perceived economic effects on individuals, communities, and broader economies.

Survey research typically found differences in opinions between residents of small rural towns and residents of larger urban areas or national publics in general. National samples tend to be stronger on environmental protection and less sympathetic to local economic effects than are local residents. This is perhaps because the national group shares more of the benefits than the costs. Small towns residents in the Pacific Northwest are less likely to favor strengthening the Federal role in resource protection. However, the opinions of these two population segments are similar on many issues, such as favoring an increased public role in public land management.

One value that has implications for ecosystem management is sense of place, which refers to how people define ecosystems and specific locations in the landscape based on their meanings and images. Place names relay traditional knowledge of land and resources by referring to plants and animals that characterize a location, actions of people at a location, spiritual role of the location, or some other important attribute of the site.

Recreation visitors develop attachments to places based on their past experiences, which are the meanings that often pass from one generation to another. People who earn their living from public land resources and opportunities typically develop close relationships to places on the land. Community residents and other social groups tend to develop collective definitions of places that are socially important.

The concept of place has not been widely or uniformly used by federal land management agencies, yet the task of defining places has proven to be a positive process for involving community residents and initiating discussion about common visions for public land management. For the purpose of public land management, place assessment best occurs at a community level, which avoids defining places with meaning only to a few individuals or places that are so broad as to have little meaning in a management context. Understanding place meanings can help ecosystem managers design actions to mitigate effects on places. It can also help resolve conflicts over uses of Federal lands.

Rural Communities

The Bureau of Census recognizes 476 communities within the Basin, including 29 cities larger than 10,000 in population and 49 Census Designated Places (locations that are unincorporated but have an identity to the local population). Of the other 398 small rural communities, 68 percent are communities of 1,500 or less, which is the smallest size class. These communities range from 22 to 1,500 in size and have an average population of 520.

Within the Basin, community health is defined by the capacity to adapt to change. This ability, termed community resiliency, is a function of economic structure, physical infrastructure, civic leadership, community cohesiveness, and amenities. The data suggested that there is no one common formula to achieving community resiliency; many strategies have proven successful. Natural resource dependent communities that have been confronted with significant challenges are among the most resilient, because they have successfully learned how to facilitate change. Other communities, however, are challenged to maintain their viability.

Population size is the single best predictor of a community's current condition and resiliency. Larger towns, which tend to have stronger economic bases, are viewed more positively by

participants in self-assessment workshops. Although larger towns also tend to have a greater degree of economic diversity than smaller towns, a greater population does not always mean a more diverse economic structure. Although people's perceptions of their community's economy are usually accurate, people tend to underestimate the diversity of their economy and overestimate the importance of traditional industries.

The community is an important level of social analysis, because communities have a large variety of sociocultural groupings that could be affected differently by ecosystem management programs and activities. Occupational groups that have identities strongly associated with natural resources are sometimes called "communities of interest." Changes in public land conditions and outputs could significantly affect the quality of people's lives regardless of their community's resiliency.

The concept of community resiliency needs further research and validation, and linkages with natural resources and other characteristics require additional exploration. Research is needed to identify and measure such concepts as resiliency and dependency and to develop systems to monitor the various interactions of communities with natural resources and public lands. This research should not focus on dependency *per se*, but on the many interactions between human communities and other ecosystem components.

Role of Public Land Amenities

Environmentally based amenities managed by the Federal Government have many social and economic roles in the Basin. The amenities contribute to the quality of life of Basin residents, attract new migrants, and provide recreational settings for residents and nonresidents. The Basin's many roadless areas provide these and many other benefits. Despite the importance of amenities, such as recreation opportunities and scenery, systems to map and inventory these values are not well integrated into current agency planning systems at ecoregion scales.

Between 1991 and 1993, an average of 200 million recreation activity days per year occurred on FS- or BLM-managed lands in the Basin. Roaded natural settings received about 75 percent of all activity days. Some activities such as trail use occurred mainly in primitive and semi-primitive areas. About 50 percent of all camping occurred in roaded natural settings. The rest was equally divided between primitive/semi-primitive and rural/urban settings. Just over six million people were estimated to have participated in wildlife-oriented activities within the four main Basin states. Wildlife viewing, photographing, and related wildlife activities were more popular than hunting and fishing in all four states.

The Basin contains 70 percent of the unroaded areas that are 200,000 acres or greater in the lower 48 states. Access to wildland-based recreation opportunities is important to the rural-oriented lifestyle of area residents and contributes to the region's identity. Landscape appearance and scenery are important environmentally based amenities, not just as settings for recreation, but as components of the Basin's image both to residents and non-residents.

The supply of scenery in the Basin was measured in terms of landscape themes and degree of scenic integrity. The five themes used to describe Basin landscapes were: naturally-evolving forest and shrub/grasslands (which cover 7 percent of the acreage in the Basin), natural-appearing forestlands (37 percent of the Basin), natural-appearing shrub/grasslands (30 percent of the Basin), agricultural lands (20 percent of the Basin), and developed areas (6 percent of the Basin).

Scenic integrity is a measure of "visual intactness." It was developed by combining data on vegetative structure, landform, and road density through a computerized program called geographic information systems (GIS). Scenic integrity was described using five categories ranging from low to very high. Less than 1 percent of the acreage administered by the Forest Service or BLM was rated as low in scenic integrity, 11 percent rated as moderately low, 38 percent as moderately high, 31 percent as high, and 14 percent as very high.

The social assessment was hampered by a lack of uniform, good quality Basin-wide data layers on important place meanings such as scenery and recreation opportunities. Although computer technology has advanced in the last few years, integration of social data lags considerably. Greater use and integration of social values into GIS technology now appears possible.

American Indians

The Indian peoples of the northern intermontane region are part of a large, loose social web strengthened by their shared experience of the Columbia Basin and surrounding ecosystems. Although the various Indian societies in the region differ in many ways, they hold a common belief about their relationship with the land and water. Their traditional subsistence economy is broad-based and includes fishing, fowling, hunting, and gathering of terrestrial and aquatic resources over very large geographic areas encompassing a diverse range of important places. Consequently, Indian peoples have accrued an encyclopedic knowledge of their environment through the millennia. Their uses and values of the land are both utilitarian and symbolic, merged in an inseparable manner.

Through various treaties, laws, and court cases, American Indians have different status, and the Federal Government relates to tribes on a government-to-government basis. Treaties and agreements established a trust relationship between Indians and the Federal Government. In these, the Federal Government became a manager or trustee over unceded remaining Indian lands and public lands. American Indians retained rights on these lands. Pre-existing rights not specifically granted to the United States through treaties or agreements, or not expressly terminated by Congress, continue to this day. The Federal Government is responsible for assisting tribes while still recognizing their sovereign rights.

Access to federally administered land is important for American Indian tribes. They need access in order to uphold their rights to resource use that are reserved under treaties. These resource uses include, but are not limited to, activities such as gathering culturally significant plant species, engaging in hunting practices, and using ceremonial sites.

The Federal Government's trust responsibilities, based on treaties and subsequent interpretations, are far reaching. They have not been satisfactorily articulated in terms that are understandable and agreeable to all involved entities. Similarly, consultation processes that direct Forest Service and BLM offices to formally interact with tribes on a regular basis have not been established. The National Environmental Policy Act and other project- or program-specific consultation requirements do not meet tribal needs. They seek meaningful consultation or participation in decisions that affect resources important to their cultures.

Role of the Public

Public participation in public land planning, implementation, and monitoring has been conducted by the Forest Service and BLM on an individual project basis for the most part. In a survey conducted for the Interior Columbia Basin Ecosystem Management Project, the public favored expansion of this role, either by acting as a full and equal partner or by serving on advisory boards. The public also expressed concern about the efficiency of public participation. Public participation was considered successful when roles of managers, scientists, and publics were clear; guidelines on public participation techniques would be helpful in developing direction and consistency.

Many public and private collaborative groups formed in the Basin over the past few years to jointly address natural resource issues. These groups typically had a balanced range of stakeholders regarding a given piece of land, natural resource, or decision. These groups provided many benefits, including opportunities for mutual learning, increased ownership in decisions, and improved

agency ability to implement plans. The groups also provided models of collaboration for use in ecosystem management strategies.

The Northwest Forest Plan created Province Advisory Committees, which was a new approach to public participation. Each of the 12 provinces, created as management units for the plan, has an advisory committee composed of Federal employees and members of the public. The plan also established Adaptive Management Areas that called for new forms of ongoing collaboration in planning, management, and monitoring public lands. A similar effort began in 1995, when the BLM and Forest Service formed Resource Advisory Councils (RACs), each covering a distinct geographic area in eastern Oregon and Washington. The RACs are designed to make recommendations to the Forest Service and BLM on ecosystem management, watershed planning, and other local or regional natural resource issues. The list of objectives for RACs includes collaborating in resource management across jurisdictions, promoting partnerships and working groups to develop regional solutions to management issues, assisting with educational efforts, sharing science and other information, and encouraging and supporting local groups to help implement ecosystem management.

Research is needed to identify measures of success, the public's response to sophisticated technology such as GIS, and the desirability of various distinct approaches at different geographic scales. Such approaches would invariably require involvement of affected stakeholder groups, because their perceptions of success are equally as important as any objective's measure. A research program to understand trends in people's attitudes, beliefs, and values regarding ecosystem management would be valuable for future planning and implementation efforts. The program would be most helpful if conducted at local, regional, and national scales.

Institutional Capacity

Society's approaches to solving collective problems involve various government agencies, as well as formalized agreements. Ecosystem management has a particular need for institutions to work effectively together, managing resources and opportunities across jurisdictional boundaries.

At the Federal level, the executive, legislative, and judicial branches have recently had an active interest in natural resource management. The BLM and Forest Service exist within a system of federal agencies that manage ecosystem components. In some cases, the agencies have missions with a narrower focus. As part of a larger Federal Government system, the BLM and Forest Service often participate in international coordination efforts to protect and maintain environmental quality. The Congress has mandated specific actions for the BLM and Forest Service over the past decade. In some cases, Congressional direction is legislated. In others, specific projects are funded through appropriations bills and attached riders.

The judicial branch is involved in environmental issues. Using litigation to address grievances is a practice that has increased markedly over the past two decades. The courts and administrative appeals process have become significant agents of change within the agencies. Survey research suggests the public would rather not rely on legislation or court cases. It prefers to work with land managers to achieve mutually desirable conditions. The public often favors increasing the role of local or state government.

Cross-jurisdictional approaches to ecosystem management may result in closer working relationships between the BLM, the Forest Service, and state and local governments. Together, the groups can identify and accomplish mutually agreeable goals. State agencies, like agencies in the Federal Government, have divided legal jurisdictions over natural resource issues. Each state within the Basin has its own unique system of agency jurisdiction and policies that relate to natural resource management. Some state agencies oversee activities on

public lands or share co-management responsibilities with Federal agencies. Although state agencies want to help develop Federal policy, they have experienced expanding responsibilities and declining budgets. Priority differences between state and Federal agencies are expected owing to distinct mandates and constituencies of each.

County governments are basic political organizational units that provide services to county residents. They work in conjunction with state, municipal, and other special governmental offices to support the public's needs. County governments become *de facto* land management agencies addressing many ecosystem issues through zoning ordinances, property taxation collections, and comprehensive planning responsibilities.

The relationship between county governments and the Forest Service and BLM assumed a new dimension in the Basin during the ICBEMP. The Association of Oregon Counties, the Washington Association of Counties, the Montana Association of Counties, and the Idaho Association of Counties created a new institution, the Eastside Ecosystem Coalition of Counties, to observe activities of the ICBEMP and to communicate the interests of county governments.

Land and property rights, which have a central role in ecosystem management, are highly controversial social issues that are being increasingly defined in the courts. One aspect of this debate is the idea of "takings." The idea is based on the U.S. Constitution's Fifth Amendment which states that private property shall not be taken for public use without just compensation. Advocates for private property insist that government regulations, especially those initiated for environmental protection, constitute "taking" because they reduce the opportunity for property to be freely used at the discretion of the individual. Another central issue is consolidation of private ownerships and the increased public reliance on Federal lands for access to valued opportunities.

The ability of agencies to implement ecosystem management could be challenged by the multiplicity of agencies involved, any conflicting mandates and goals, their various constituencies and legal authorities, significant cross jurisdictional boundary management questions, and short implementation time frames. Studies of previous cross-jurisdictional management efforts have shown that tolerance for change is critical. This suggests using an approach that emphasizes incremental changes and places authority for managing change with those most directly affected. Open information exchange is another key factor to accepting change. The institutions' success depends largely on learning from past practices.

There are numerous institutional challenges to implementing ecosystem management. Those identified in the social assessment include poor communication; difficulty understanding ecosystem management; laws, such as the Federal Advisory Committee Act, that may pose a challenge to some forms of desirable public participation; and aspects of BLM and Forest Service policies and procedures such as budgeting and contracting.

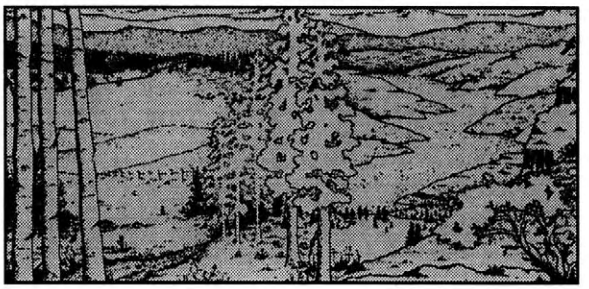
Human use of the Basin's natural resources is a major determinant of ecosystem conditions. Over time, human uses have changed dramatically, resulting in equally dramatic effects on the land, water, air, and other species. Human values regarding ecosystems have changed as well, as have the economic needs of an increasingly complex society.

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EXECUTIVE SUMMARY- INFORMATION SYSTEM DEVELOPMENT AND DOCUMENTATION



Land use planning that is regional in scope requires tools more advanced than those typically used for landscape and resource analysis. Traditionally, maps, graphs, charts, and diagrams have been used to analyze and visualize the natural environment. Today, Geographic Information Systems (GIS) provide the tools and techniques that allow regional projects to be accomplished in a highly efficient, integrated, and accurate manner.

A GIS is especially well-suited to dealing with spatial and temporal problems (problems of dimension, space, and time). Without advanced computer technology, software, and trained and experienced individuals, the volume of data collected in support of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) would have been a great burden. GIS allowed the Science Integration Team (SIT) to dynamically model and analyze living systems throughout the Basin in ways that were impractical only a decade ago.

The ICBEMP is the largest interagency database development effort undertaken by the agencies involved, covering more than 58 million hectares (over 144 million acres). The project information and technology plan was based in part on the plan developed for the Forest Ecosystem Management Assessment Team (FEMAT), but the ICBEMP team had more time and considerably more data. Work for the ICBEMP was accomplished in a number of locations. A dispersed approach to data collection and analysis was necessary owing to the cost and inefficiency of relocating all equipment and personnel to one location.

A Spatial Analysis Team was established to manage data and support the analytical needs of the ICBEMP. This team was composed of U.S. Department of the Interior Bureau of Land Management, U.S. Department of Agriculture Forest Service, and contract personnel who were located in Walla Walla, Spokane, and Wenatchee, Washington; Portland, Oregon; Missoula, Montana; and Boise and Coeur d'Alene, Idaho. The interagency group was charged with the collecting available GIS data, capturing new data, and supporting analysis for the SIT and Environmental Impact Statement (EIS) Team. The Spatial Analysis Team was also responsible for the documentation and distribution of data to project personnel, federal agencies, tribal governments, the general public, and other interested parties.

Data and Analysis

Over 170 different GIS data layers or themes were compiled or created in support of the ICBEMP Assessment and the development of the Eastside and UCRB EISs. The data layers were derived from source maps, photos, or transfer media ranging from 1:12,000 to 1:4,000,000 in scale. Some GIS layers mapped features continuously across the entire Project (Scientific Assessment and EIS area) while others covered discrete areas only (that is, subsample areas). Major data providers included individual administrative units of the FS, BLM, U.S. Fish and Wildlife Service, Environmental Protection Agency, U.S. Geological Survey,

U.S. Bureau of Mines, Bonneville Power Administration, universities, state agencies, and non-governmental organizations.

Data analysis occurred in GIS and in the database environment. GIS analysis used two data architectures: vector (lines, polygons, and points) and raster (matrices or grids). Some of the data were created in vector form (such as information captured from a map, like ownership boundaries), while other data were created in raster form (including elevation models, vegetation models, and data based on satellite imagery). Vector data were sometimes converted to raster data for the analysis process.

Information that was gathered specifically for this project (that is, it did not exist digitally before and was requested in a digital form) were either scanned or digitized once a manuscript of the data was created. These digital data sets were then attributed and brought into the GIS.

Data that were entered into the corporate data structure (master data) were plotted and inspected, and in cases of error or uncertainty, sent back to the originator for validation. Information about the data (metadata) that was compiled included information on scale and accuracy. These metadata were available to the teams and were included with any data distributed to other parties.

While analyzing management options, a variety of systems and methods were used to evaluate and analyze the existing and derived data. GIS played a key role in tying the Columbia River Basin Successional Model vegetative outputs to Management Regions, Ecological Reporting Units, and subwatersheds. Conventional databases were necessary to synthesize, summarize, and report information. Some of the databases can be spatially referenced to an existing ICBEMP GIS data layer.

Documentation, Management, and Sharing of Data

In a project such as the ICBEMP, where many cooperators shared data obtained from many sources, data documentation is a necessity. The data documentation, often referred to as metadata, is in the process of becoming standardized within the Federal Government. In 1994, Executive Order 12906 gave the Federal Geographic Data Committee (FGDC) direction to establish the National Spatial Data Infrastructure including the "technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data." Part of that order calls for standardized data documentation. Each agency must use the standard developed by the FGDC (FGDC Content Standard for Digital Geospatial Metadata) to document new data it collects or produces.

At the time initial planning began for the ICBEMP, the FGDC metadata standard was in early draft form. The project adopted the metadata standard previously developed by the Northwest Forest Plan effort. The resulting metadata are generally compatible but less extensive than what is described in the 1994 FGDC standard.

For management of metadata, SPUDD (Spatial Unified Data Dictionary), an Oracle database application, was used. It was developed by FS and BLM personnel for use in the Northwest Forest Plan effort and was enhanced during this project. It has the capability to store information about proposed data and document existing data sets.

It was recognized at the outset of the ICBEMP that there would be data tracking problems. This was due to the large number of people involved at various offices and to the scope of analysis that was being planned. There was a desire to make data immediately available while maintaining control so that the implications of data changes could be managed. The SPUDD was available to track

metadata for themes as they became ready for use in the ICBEMP, but the SPUDD was not able to track the changes to the data after they were entered. For this reason the Automated Tracking Manager (ATM) was designed to track GIS data and associated metadata. ATM could also recreate GIS processes. Other commercially available products were reviewed, but they were inadequate for project needs.

The ATM provided a useful tool to determine how the GIS data sets related to each other. While most GIS work was not done within the ATM, it was used as a library of processes performed. The ATM is expected to be used for continuous management of the ICBEMP GIS data and as a reference tool well into the future.

The ICBEMP began to release spatial data and maps to the public and government agencies in November 1994. Unlike previous projects, the data and maps were made available while the project data were being analyzed. A brief policy paper was prepared to provide interested individuals with the data release objectives, the processes for completing requests for data and maps, and cost information.

Information Management Recommendations

A key element for ecosystem management is the need for consistent, current, and accurate information concerning the ecological and biophysical environments across the landscape. This information is necessary at several levels of resolution. Research is needed to develop better data structures that link scales (both temporal and spatial). The collection and management of these data need to be effectively coordinated and shared between federal, state, and local agencies in order to implement ecosystem management. Federal, state, and local governments working with the public can help ensure success through their shared commitment and vision for a resource information system.

An ongoing commitment to ecosystem management and modeling will mean that federal agencies will need to reassess their individual resource inventory programs. They also need to strive for a set of interagency standards tied to ecosystem management. Currently, data are collected in many formats between and within agencies. This makes integrating data very difficult. Data need to be collected for all ownerships across ecosystems in a standardized fashion for ecological and biophysical information. Minimum data standards for vegetation, aquatic, fisheries, and terrestrial components of the landscape need to be established. Additional information in excess of the minimum required could be collected by individual agencies for their own needs. Data collected at the project level, once standardized, could be aggregated for mid-scale and broad-scale analyses.

The GIS data and associated databases collected and created for use in the ICBEMP Assessment need to be managed, maintained, and shared. A central information clearinghouse could be established to support the update and implementation of FS and BLM plans. This clearinghouse could manage, distribute, and provide user support for both spatial and nonspatial data and models from the ICBEMP. Agencies could profit from the information investment of this project and develop processes for long-term resource information management.

There are several GIS data layers that need to be standardized and collected continuously across the Basin for future analyses. Theme content standardization and attributes would help build a more functional interagency data set. The following themes should be included: administrative boundaries, surface ownership administration, current land use allocations for all agencies, natural areas, wilderness, unroaded areas, and current management area categories for all agencies. Many of these themes may be used for project level work where no finer resolution data exist. In addition, many of the newly captured data sets from the ICBEMP could be maintained and improved for future analyses. These include, but are not limited

to: 6th-field hydrologic units (subwatersheds), broad-scale vegetation (1 kilometer), river reach stream inventory and databases, and the fish-related databases.

A number of GIS data sets desired by ICBEMP were not readily available nor could they be captured into GIS in a timely manner. These include: land type associations, consistently classified vegetation from satellite imagery (mid-scale vegetation), enhanced 1:100,000 stream network (until continuous 1:24,000 base data is available), and base data at 1:24,000 [digital elevation models, cultural features, streams (should be enhanced), and roads (enhanced to contain logging roads and others not on USGS base maps)]. Collected basin wide and in a standardized way, these data sets would be useful in future planning efforts.

A technology transfer program would provide field offices, other agencies, and the general public with access to and comprehension of the data, models, and information that were developed for the ICBEMP. Technology transfer is crucial for providing user support and training to the field offices over the next several years. Maintenance and periodic updates of the GIS data, databases, and models collected and developed for this project will benefit subsequent regional analyses.

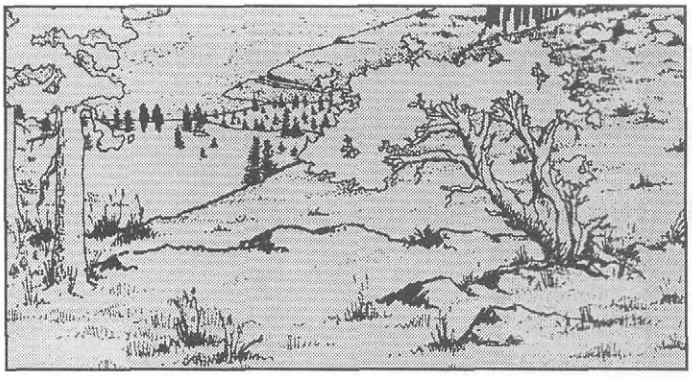
Conclusion

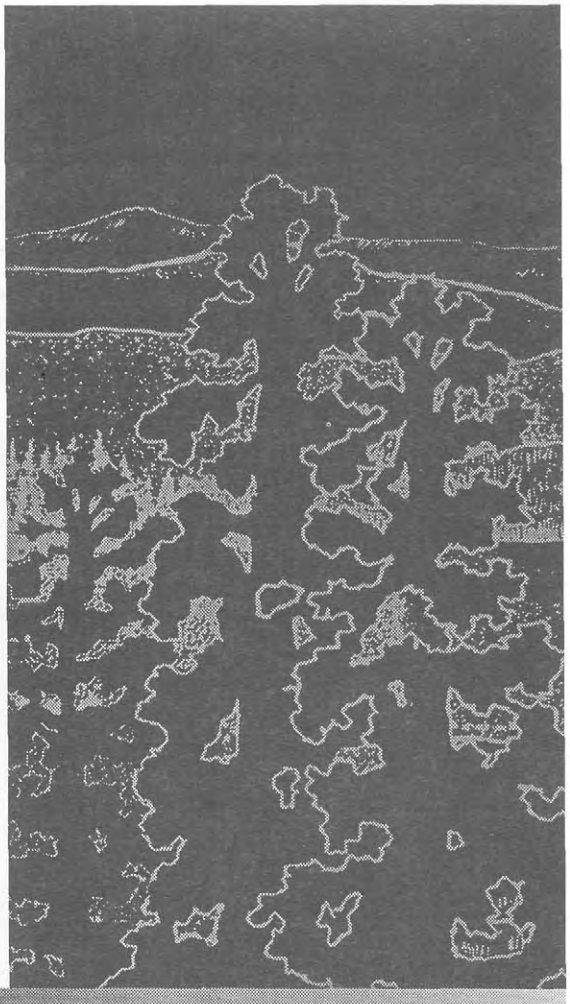
Good progress has been made in building cooperation between agencies in order to implement ecosystem management. Our experience shows that information management is possible and critical in an interagency environment. It is hoped that the documentation of information resource management methods employed by the ICBEMP and the resulting recommendations will increase the effectiveness for future broad-scale efforts. This project highlights the importance of a long-term information resource management strategy for the implementation of ecosystem management.

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CHAPTER 2

Biophysical Environments of the Basin

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TABLE OF CONTENTS



Introduction 107

Ecological Principles 108

Description of Ecological Systems 108

Hierarchy Theory 110

Pattern Analysis 110

Ecosystem Characterization 111

Description of Primary Biophysical Environments 111

Geologic Settings 114

General Description of the Geologic Environments of the Basin 115

Approach Used in Geologic Setting Description 116

Uses and Limitations of Geologic Information 116

Geoclimatic Settings 118

Ecoregions 118

Subsections 120

Subsection Groups 123

Potential Vegetation Settings 127

Methods Used in Broad-Scale Potential Vegetation Classification and Mapping 127

Riparian Potential Vegetation Settings 130

Results of Broad-Scale Potential Vegetation Classification and Mapping 130

Drainage Basin Settings 136

Delineation 136

Subsampling 137

Subbasin and Subwatershed Selection 137

Classification 138

Stream Type Settings 144

Ecological Process Interpretations 149
Soil Erosion, Mass Failure, and Sedimentation 151
Soil Erosion 151
Mass Failure 152
Sedimentation 157
Hydrologic Function 157
Peak Flows 157
Runoff Characteristics 163
Stream Channel Sensitivity and Resiliency Ratings 164
Vegetation Response to Climate Change 165
Modeling Approach 165
Modeling Results 171
Development of Ecological Reporting Units 172
Description of Basic Ecosystem Components 176
Geology Features 176
Geologic Processes 176
Pleistocene Epoch Glacial and Flood Processes 181
Minerals and Mining Impacts 184
Climate Features 185
Weather Data 188
Trends in Regional Climate Patterns 189
Disturbance Climate Events 190
Air Quality Climate 198
Soil Features 201
Province Descriptions 201
General Effects of Management Activities 203
Hydrology Features 207
ERU Characterization Procedures 207
Effects of Management Activities on Hydrologic Systems 226
Summary Characterization of Climate, Geology, Soils, and Hydrology by ERU 231
Climate Overview 231
Ecological Reporting Unit Descriptions 245
ERU 1: Northern Cascades 245

ERU 2: Southern Cascades 246
ERU 3: Upper Klamath 247
ERU 4: Northern Great Basin 248
ERU 5: Columbia Plateau 248
ERU 6: Blue Mountains 250
ERU 7: Northern Glaciated Mountains 251
ERU 8: Lower Clark Fork 253
ERU 9: Upper Clark Fork 254
ERU 10: Owyhee Uplands 255
ERU 11: Upper Snake 256
ERU 12: Snake Headquarters 257
ERU 13: Central Idaho Mountains 258

Hydrologic Integrity Assessment 259

Assessment of Hydrologic Disturbance 259

Assessment of Hydrologic Resiliency 260

Assessment of Hydrologic and Riparian Integrity 264

Forest Cluster Hydrologic Integrity Narrative Descriptions 269

Range Cluster Hydrologic Integrity Narrative Descriptions 274

Acknowledgments 277

References 293

Glossary 309

Appendix 2-A 315

LIST OF TABLES

Table 2.1 Hierarchical relations between assessment scales and various types of ecosystem delineation. 113

Table 2.2 Typical map scales and polygon sizes of terrestrial biophysical environment ecological units. 122

Table 2.3 Principal map unit design criteria used in the construction of terrestrial biophysical environment ecological units. 122

Table 2.4 Forest biome temperature-moisture gradient potential vegetation classification for section M333C of the Basin. 129

Table 2.5 List of site parameter/GIS rules used in the "vegetation-site" model for broad-scale potential vegetation environment mapping. 129

Table 2.6 Vegetation site rules used in the construction of a broad-scale potential vegetation environment map for section M333C of the Basin. 133

Table 2.7	Listing of the direct and indirect biophysical environment variables used in the subregional scale watershed classification of the Basin	140
Table 2.8a	Description of the primary direct biophysical environment variables considered in subregional-scale watershed classification of the Basin.	142
Table 2.8b	Description of the primary indirect biophysical environment variables considered in subregional watershed classification of the Basin.	143
Table 2.9	Description of the stream type groups used in the hydrologic characterization of the Basin.	146
Table 2.10	List of stream type groups identified within the Basin and their associated management interpretations.	150
Table 2.11	Geoclimatic characteristics of ecological reporting units.	177
Table 2.12	Relativitized percent composition of different hydrologic flow type regimes by ERU, as determined by unregulated subbasin samples.	208
Table 2.13a	Primary lithologic composition of subwatersheds by ecological reporting unit.	209
Table 2.13b	Explanation for lithology code used in table 2.13a.	211
Table 2.14	Primary geoclimatic subsection group composition of subwatersheds by ecological reporting unit.	212
Table 2.15	Primary regional scale potential vegetation type composition of subwatersheds by ecological reporting unit.	213
Table 2.16	Mean values for selected morphometric and climatic attributes of subwatersheds by ecological reporting unit.	215
Table 2.17	Estimated stream type group composition of subwatersheds by ecological reporting unit.	216
Table 2.18	Observed valley bottom type composition of sampled subwatersheds by ecological reporting unit.	221
Table 2.19	Observed stream type composition of sampled subwatersheds by ecological reporting unit.	223
Table 2.20	Average similarity ratings of subwatersheds based on hydrologic hazard and stream channel sensitivity criteria by ecological reporting unit.	227
Table 2.21	Data set descriptions for climate data used in the Basin assessment.	236
Table 2.22a	Climate Summary for each Ecological Reporting Unit (ERU) with number of weather stations.	237
Table 2.22b	Seasonal trends in daily temperature range (delT), average temperature (Tavg) and precipitation (PPT) for each Ecological Reporting Unit (ERU).	243
Table 2.23	Hydrologic integrity, disturbance, and resiliency rating summary statistics for six forest environment clusters of the Basin.	267
Table 2.24	Hydrologic integrity, disturbance, and resiliency rating summary statistics for six rangeland environment clusters of the Basin.	268

LIST OF FIGURES

Figure 2.1 Agents of pattern formation. 112

Figure 2.2 An ecosystem characterization example of subalpine fir forests in the northern Rocky Mountains. 113

Figure 2.3 Longitudinal, cross-sectional, and plan views of major stream types. 145

Figure 2.4 Box plot of hydrologic stream recovery potential following disturbance, based on average subbasin ratings by ERU. 227

Figure 2.5 The hydrologic cycle. 228

LIST OF MAPS

Map 2.1 Landscape ecology characterization area. 109

Map 2.2 Lithologic group map of the Pacific Northwest. 117

Map 2.3 Geoclimatic subsection groups. 120

Map 2.4 Geoclimatic sections. 119

Map 2.5 Coarse-level potential vegetation environment map. 131

Map 2.6 Regional-level potential vegetation environment map. 132

Map 2.7 The subbasins and subwatersheds used in vegetation and stream pattern trend subsampling. 139

Map 2.8 Hydrologic subregions. 141

Map 2.9 Relative non-vegetated surface soil erosion hazards of subbasins. 153

Map 2.10 Relative vegetated surface soil erosion hazards of subbasins. 154

Map 2.11 Relative earth flow hazards of subbasins. 155

Map 2.12 Relative debris avalanche hazards of subbasins. 156

Map 2.13 Relative sediment delivery potentials of subbasins. 158

Map 2.14 Relative non-vegetated sediment delivery hazards of subbasins. 159

Map 2.15 Relative vegetated sediment delivery hazards of subbasins. 160

Map 2.16 Relative road erosion hazards of subbasins. 161

Map 2.17 Relative road sediment delivery hazards of subbasins. 162

Map 2.18 Relative sensitivity of streams to increased sediment and flow as summarized by subbasins. 166

Map 2.19 Relative stream bank sensitivity as summarized by subbasins. 167

Map 2.20 Relative sensitivity of streams to riparian vegetation alteration as summarized by subbasins. 168

Map 2.21 Relative stream recovery potentials as summarized by subbasins. 169

Map 2.22 Master watershed sensitivity index of subbasins. 170

Map 2.23 Predicted distribution of *Thuja plicata/Clintonia uniflora* plant communities under current climate conditions. 173

Map 2.24 Predicted distribution of *Thuja plicata/Clintonia uniflora* plant communities under a doubled CO_2 climate change scenario. 174

Map 2.25 Regional map showing aspects of the late Pleistocene paleogeography of the Pacific Northwest. 182
Map 2.26 Map showing mineral deposit favorable areas ranked by anticipated levels of economic activity. 186
Map 2.27 Average annual precipitation (western United States). 187
Map 2.28 Total number of lightning strikes (1986-1990) 191
Map 2.29 Lightning-caused fire locations (1990). 192
Map 2.30 Total months with PDSI <-3.0 (1895-1994). 195
Map 2.31 Percentage of floods classified as pure snowmelt. 197
Map 2.32 Ecological reporting units. 232
Map 2.33 Basin's climate by three broad regions. 233
Map 2.34 Relative hydrologic disturbance ratings of forest environments within subbasins. 261
Map 2.35 Relative hydrologic disturbance ratings of rangeland environments within subbasins. 262
Map 2.36 Relative riparian disturbance ratings of rangeland environments within subbasins. 263
Map 2.37 Relative hydrologic recovery potential ratings of forest environments within subbasins. 265
Map 2.38 Relative hydrologic recovery potential ratings of rangeland environments within subbasins. 266
Map 2.39 Relative hydrologic integrity ratings of forest environments within subbasins. 270
Map 2.40 Relative hydrologic integrity ratings of rangeland environments within subbasins. 271
Map 2.41 Relative riparian integrity ratings of rangeland environments within subbasins. 272
Map 2.42 Forest clusters. 273
Map 2.43 Range clusters. 275

BIOPHYSICAL ENVIRONMENTS OF THE BASIN



Introduction

This chapter describes important biophysical environments of the Interior Columbia Basin and those portions of the Klamath River Basin and Great Basin in Oregon (Basin). Specifically included is information about methods used in describing the environments, and descriptions of the environments' ecological processes, associated management interpretations, and general characteristics. Information is presented at multiple spatial scales for various types of biophysical environments, including geologic, geoclimatic, potential vegetation, soils, and hydrologic systems. The various levels and types of biophysical environments described in this chapter are important to the ecological assessment of the Basin for the following reasons:

- They facilitate the delineation and description of terrestrial and aquatic ecosystems that behave in a similar manner given their potential ecosystem composition, structure, and function.
- They delineate areas with similar production potentials for management.
- They provide a basis for interpretations concerning hazards and limitations to management.
- They influence (to a large degree) the natural disturbance processes that create finer-scale ecosystem patterns (for example, existing vegetation and species distributions).
- They provide a needed context for the use and development of predictive models concerning future ecosystem pattern and process relations.

The chapter is organized by six major topics, as identified and briefly described below:

Ecological Principles: This section presents a general overview of key principles that provides the foundation for a landscape ecology-based approach to assessment. The overview includes a discussion of the importance of hierarchy theory, pattern recognition, and ecological characterization to integrated ecological assessments. Biophysical environment mapping is also discussed.

Primary Biophysical Environments of the Basin: In this section is a discussion on the methods used in the mapping, as well as descriptions of selected biophysical environments within the Basin. First presented is a general description of biophysical environments, including their basic properties and uses in ecological characterization and assessment. Next described are approaches used in identifying and characterizing the geologic, geoclimatic, potential vegetation, and hydrologic settings at multiple spatial scales within the Basin.

Ecological Process Interpretations: Presented in this section are the logic and methods used in characterizing various ecological processes that are strongly influenced by the properties of biophysical environments. Analysis results are described, where appropriate, and various ecological process interpretive maps are included that display relative differences between subbasins across the Basin.

Hazard, sensitivity, and resiliency ratings are described as appropriate to the ecological processes of soil erosion, mass failure, sedimentation, peak flows, channel maintenance, and climate change.

Development of Ecological Reporting Units: This section describes the logic and methods used in the identification of integrated Ecological Reporting Units (ERUs) for the Basin. A total of 13 ERUs were delineated for the Basin based on their terrestrial and aquatic biophysical environment, as well as social/economic criteria. These delineations were used extensively by the different Science Integration Team (SIT) staff areas in the reporting of assessment results at the regional level.

Basic Ecosystem Components by Ecological Reporting Units: This section describes the geologic, edaphic, and hydrologic features of each Ecological Reporting Unit (ERU) within the Basin. These summaries provide a regional overview of the variability of important ecosystem components across the Basin. For each component, there is information concerning: existing pattern/process relations, general opportunities and limitations to management, and the effects of certain management practices on the health and resiliency of an ecosystem. Also presented is an integrated summary characterization of climate, geology, soils, and hydrology.

The characterization area needed to provide spatial context for many biophysical environments in this report was larger than the Interior Columbia Basin Ecosystem Management Project (ICBEMP) assessment area. Accordingly, the Science Integration Team (SIT) Landscape Ecology Staff identified a larger characterization area for describing the Basin's biophysical environments. The boundary of this larger characterization area followed the geoclimatic sections (Bailey 1994, McNab and Avers 1994) of the ICBEMP assessment area (map 2.1).

Hydrologic Integrity Assessment: This section describes the methods used in addressing the hydrologic integrity of the Basin. This assessment, along with other staff contributions, was used in the development of the Science Integration Team's document titled *An Integrated Scientific Assessment for Ecosystem Management in the Interior Columbia Basin and Portions of the Klamath and Great Basins* (Quigley and others 1996), referenced as the *Integrated Assessment.* Results of this hydrologic integrity assessment are presented by the six rangeland and six forest environment themes used in the SIT's *Integrated Assessment.* Also described are the primary management impacts to hydrologic function and the resiliency of subbasins within the Basin following disturbance, as well as the process used in integrating this information in the assessment of hydrologic integrity by subbasin. Narrative summaries of analysis results are included to provide a regional overview of the Basin's existing hydrologic integrity conditions.

Ecological Principles

This section presents a general overview of key ecological principles that provide the foundation for a landscape ecology-based approach to ecological assessment as described by Jensen and others (1996). The ecological principles discussed in this section were incorporated into various ecosystem characterization and analysis efforts by the Landscape Ecology Staff. They are provided to assist the readers understanding of both the conceptual relationship of the Basin's biophysical environments and their importance to ecological pattern and process prediction.

Description of Ecological Systems

Ecological systems are groups of interacting, interdependent parts (for example, species and resources) linked to each other by the exchange of energy, matter, and information. Ecological systems are considered complex because they are characterized by strong interactions between components, feedback loops, significant time and space lags, discontinuities, thresholds, and limits (Costanza and others 1993). Pattern recognition techniques, which are often used to describe ecological systems, have been used for many years by the medical and social sciences in dealing with complex systems. Because ecological systems can be

Map 2.1—Landscape ecology characterization area.

described at many different scales (Levin 1992), the spatial and temporal relations of specific ecological systems or any of their components need to be clearly defined. The scientific products generally used in conservation and land management planning are descriptions, predictions, diagnoses, and prescriptions. Describing ecological systems of interest is a routine scientific endeavor that leads to the generation of classifications and maps.

Predictions concerning future states of ecological systems under various management strategies require determination of the relations that exist between patterns and either hypothesized causal factors or agents of pattern formation. Once a correlation or a cause-effect relation between pattern and process is determined, predictions are made using:

- Summarization of data and information performed during the classification process and/or the generation of maps.
- Statistical or simulation modeling.
- A combination of these two approaches.

For ecosystem predictions to be appropriately translated into conservation or land management actions, these correlations should be based on rigorous analyses.

Hierarchy Theory

The concepts of scale and pattern are interwoven (Hutchinson 1957, Levin 1992). Complex ecosystem patterns, landscapes, and the multitude of processes that form them exist within a scaled hierarchical framework (Allen and others 1984, Allen and Starr 1982, O'Neill and others 1986). Scale dependency is important because the relationship between ecological processes, and the patterns they create, changes with spatial scale (Turner 1990). In recent years, considerable attention has been directed to describing the formal hierarchical organization of ecological systems. As applied to landscape ecology, hierarchy theory provides the framework needed to describe an ecosystem's components and their scaled relations.

Four tenets of hierarchy theory are required for an understanding of landscape patterns and their dynamics (Allen and others 1984, O'Neill and others 1996):

- The whole/part duality of systems states that every component of a system, ecological or otherwise, is a whole and a part at the same time. For example, a forest (a whole) is made up of trees (the parts). However, at larger spatial scales, the regional landscape is the whole and the forest becomes a part. The notion of whole/part duality is very important to the characterization of ecological systems.
- Patterns, processes, and their interactions can be defined at multiple spatial and temporal scales. These scales need to be clearly identified.
- There is no single scale of ecological organization that is correct for all purposes. This is an important consideration because scientists often provide information/interpretation on ecological systems at a single or limited number of scales.
- The definition of an ecological hierarchy (component patterns and processes) is dictated by the objectives of a study or planning endeavor.

Pattern Analysis

Implementation of hierarchy theory in the description of ecological systems is achieved through explicit characterization of the scaled relations that exist between the patterns of interest (for example, species and habitats) and the ecological factors that determine such patterns (that is, the agents of pattern formation) (Urban and others 1987). This type of ecosystem characterization is commonly called pattern analysis (Bourgeron and Jensen 1994) and can be illustrated using fish distributions as the ecological pattern of interest. Fish species may be visualized as exhibiting different patterns of organization (for example, individuals to metapopulations) that follow different spatial and temporal scales (fig. 2.1a). The formal definition of the hierarchical

arrangement of fish distribution patterns is important because it requires explicit statements concerning the spatial and temporal bounds of each pattern and their nesting order. Such an objective-specific exercise provides the basis for identifying pattern formation agents (Bourgeron and Jensen 1994, Urban and others 1987).

The agents of pattern formation can be organized into different hierarchies of biotic processes (fig. 2.1b), disturbance processes (fig. 2.1c), and environmental constraints (or biophysical environments) (fig. 2.1d). In this example, biotic processes important to understanding fish distribution patterns may include: behavior or physiologic adjustment at the channel unit or stream reach level, dispersal or genetic exchange at the watershed level, and speciation or extinction at the river basin level (or broader scales) (fig. 2.1b). The specific spatial and temporal relations that exist between fish distribution patterns and biotic processes are efficiently described through this type of characterization. In a similar manner, the relation between fish distribution patterns and disturbances (fig. 2.1c) and environmental constraints (fig. 2.1d) can be described if each variable is clearly specified and its spatial and temporal bounds clearly identified. At the watershed level, for example, population or guild distributions may be viewed as responding to mass wasting or flooding disturbance processes, which in turn are a function of local climate, geology, and landform environmental constraints (fig. 2.1d).

Ecosystem Characterization

Ecosystem characterization is: (1) the appropriate relation of patterns and processes at all scales of interest, and (2) the description and mapping of the entities determined through relating these patterns and processes. To match patterns and processes, ecological hierarchies such as the four tenets described in the preceding section are superimposed. Figure 2.2 illustrates this point with a terrestrial ecosystem example of subalpine fir forests in the northern Rocky Mountains. This example shows the relationship of each pattern to specific biotic processes, disturbances, and environmental constraints. For example, at the level of an individual tree in the canopy, the corresponding biotic process is tree replacement (for example, from lodgepole pine to subalpine fir), which is driven by tree fall (disturbance), which is influenced by slope and aspect (environmental constraints). At a finer scale, the pattern is the seedling, the biotic process is germination, and the environmental constraint is the snowbank on which the seed lands. Above the individual tree level, the stand becomes the whole of which the individual tree is a part. The biotic process at the stand level is succession, which integrates individual tree replacement at larger spatial and temporal scales. Stand level succession from lodgepole to subalpine fir may take over 200 years. Disturbances at this scale may include windthrow, insects or pathogens, and stand-consuming fires. Environmental constraints include slope, aspect, and landform that are commonly displayed by land type biophysical environment maps (table 2.1). The proper match of patterns to their agents of formation is important to ecosystem characterization because incorrect coupling limits the effectiveness of predicting future states of the ecological system, which in turn inhibits development of realistic land management plans.

Description of Primary Biophysical Environments

Biophysical environment maps are used to describe terrestrial or aquatic ecosystems that behave in a similar manner given their potential ecosystem composition, structure, and function (Jensen and Bourgeron 1994). Such maps are also commonly used in the delineation of environmental constraints for ecological pattern analysis. Biophysical environment maps delineate areas with similar management response potential and resource production capabilities and are constructed based on landscape components that do not display high temporal variability at a given scale of mapping (for example, regional climate, geology, or landforms).

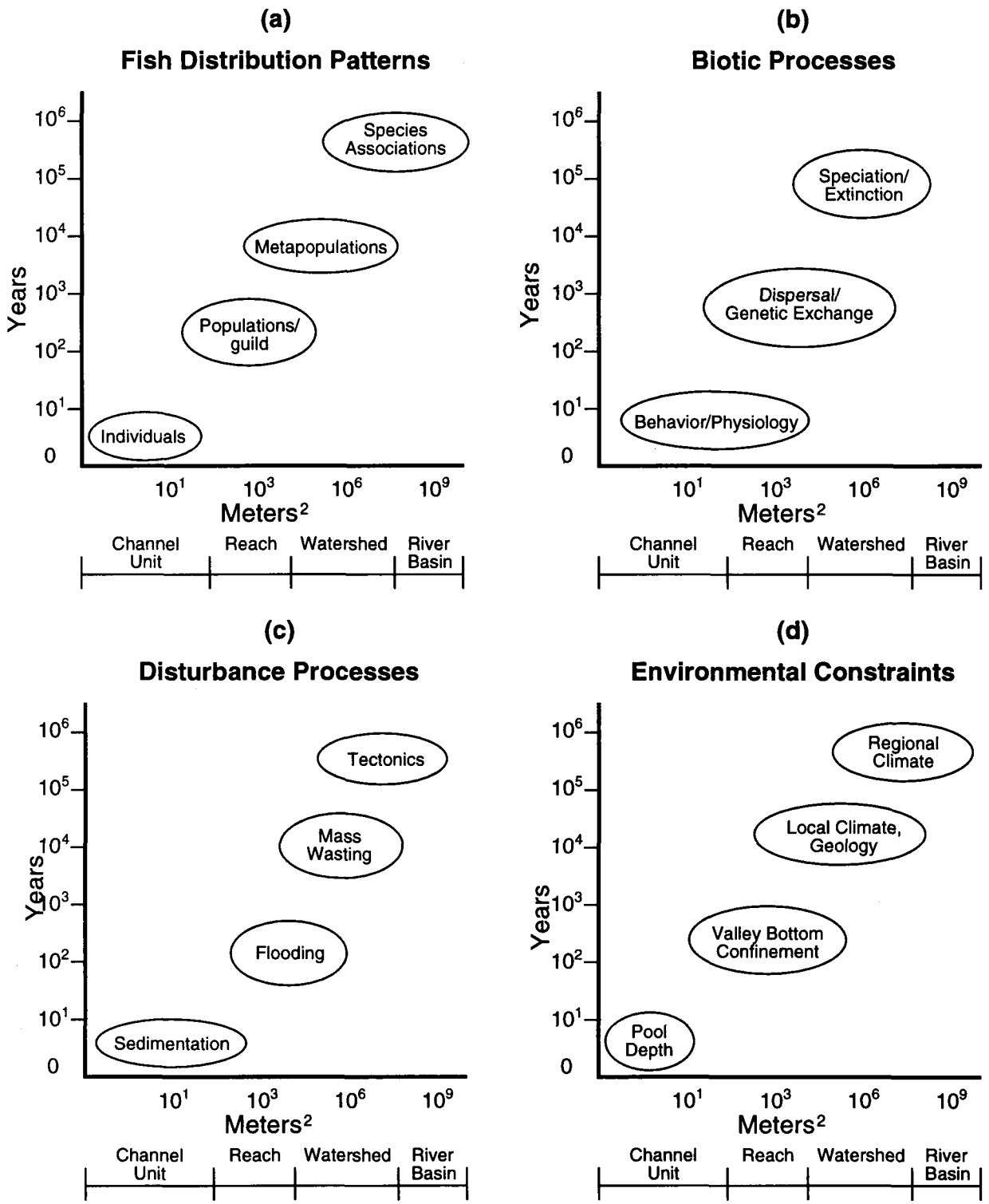


Figure 2.1—Agents of pattern formation.

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Table 2.1—Hierarchical relations between assessment scales and various types of ecosystem delineation.

	Biophysical Environments		Existing Conditions	
Assessment Scale	**Terrestrial Units[1]**	**Aquatic Units[2]**	**Vegetation Units[3]**	**Social Assessment Units**
Global	Domain	Zoogeographic Region	Class	Continent
Continental	Division	Zoogeographic Subregion	Subclass	Nation
Regional	Province	River Basin	Group	State
Subregion	Section Subsection	Subbasin	Formation	County
Landscape	Landtype Association	Watershed/Subwatershed	Series	Community
Land Unit	Landtype Phase	Valley Section/Stream Reach	Association	Neighborhood
Site	Ecological Site	Channel Unit	Species	Individual

[1]ECO Map 1993
[2]USDA Forest Service 1994a
[3]Driscoll and others 1984

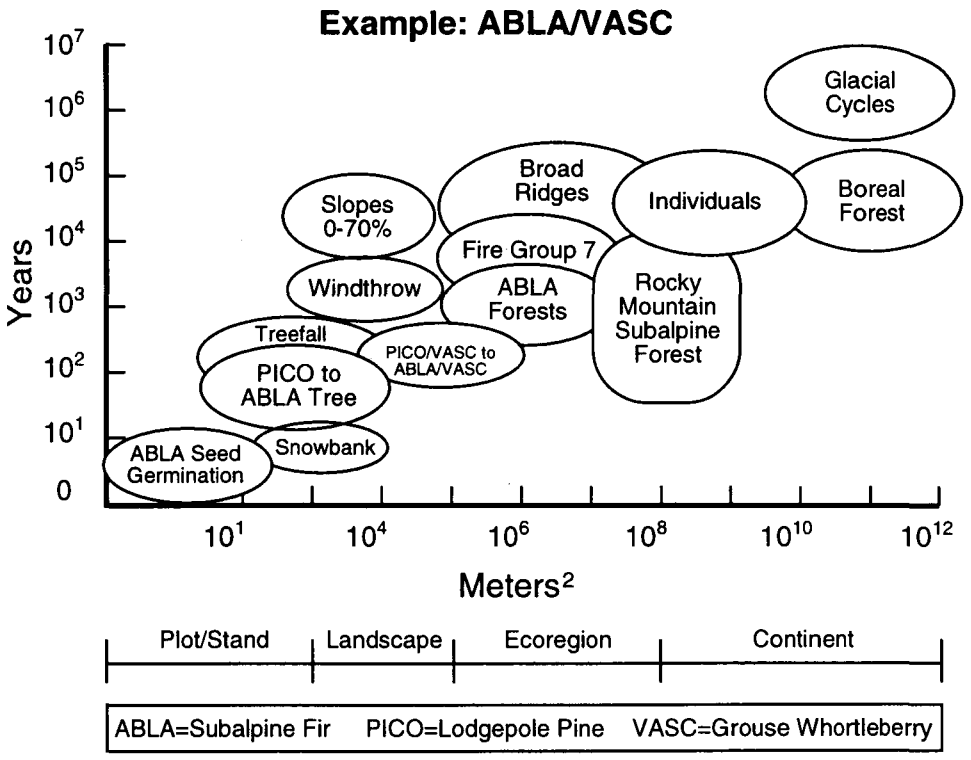


Figure 2.2—An ecosystem characterization example of subalpine fir forests in the Northern Rocky Mountains.

Ecological units (Bailey and others 1994a; Cleland and others, in press; McNab and Avers 1994), land units (Zonneveld 1989), ecoregions (Omernick 1987), biogeoclimatic ecosystems (Meidinger and Pojar 1991), and land systems (Christian and Stewart 1968) are examples of biophysical environment mapping systems that delineate ecologically homogeneous environments at different spatial scales based primarily on climatic, geomorphic, and biotic criteria. Hierarchical watershed/geoclimatic maps are additional examples of biophysical environment maps that are increasingly being used in aquatic system assessment efforts (Jensen and others 1996, Maxwell and others 1995).

The ecosystem components used in developing biophysical environment maps (for example, climate, landforms, geology, or soils) do not change following most management activities; consequently, such maps provide a useful template for interpretation of data such as existing vegetation that commonly display change following management treatments. These types of data describe the "existing condition" of the landscape and are commonly associated with appropriate biophysical environment settings in determining the condition or "health" of an area. The effects of management practices on the landscape are most efficiently described by contrasting the "existing condition" of an area with other managed or unmanaged areas of similar biophysical environment settings. This process minimizes the natural variability among sites, facilitating more direct descriptions of the relations between observed landscape conditions and management treatments.

Biophysical environment maps may be delineated at different spatial scales (table 2.1) dependent on assessment needs and the types of ecological patterns and processes to be predicted. Regional, subregional, and landscape scales of biophysical environment maps were developed by the Landscape Ecology Staff for use in the assessment of the Basin. These maps included:

- Geologic Environments
- Geoclimatic Ecological Units
- Potential Vegetation Settings
- Hydrologic Environments
- Integrated Ecological Reporting Units

Ecological pattern and process relations, successional pathway dynamics, and management potential/hazard ratings were developed for these biophysical environment maps to assist various SIT and Environmental Impact Statement (EIS) team efforts. Descriptions of these biophysical environments and suggestions concerning their use and limitations in ecological assessment activities are provided in the following discussion.

Geologic Settings

Despite the fact that the geologic components of a biophysical environment do not change as a result of management activity, geologic process rates may change dramatically as a result of management. Geologic components and processes profoundly influence other ecosystem components and processes, including current and potential vegetation patterns and successional processes, as well as terrestrial and aquatic habitat and productivity, and human settlement patterns. Changes in geologic process rates due to human activity may also profoundly affect ecosystems through increased erosion, sedimentation, and toxic element release. Human activity can also improve ecological conditions through management activities that preserve or mimic natural processes. From a human perspective, some important geologic processes are catastrophic; these include volcanic eruptions and their associated effects, earthquakes, earth movements such as landslides and rockfalls, and large floods. The influence of, and interactions between, geologic processes and other ecosystem processes are described later in this chapter. The geologic environments that constrain such processes are described below.

General Description of the Geologic Environments of the Basin

The geologic components of any ecosystem can be subdivided into bedrock and surficial geologic units. Bedrock geologic units are those that are solid and underlie any unconsolidated surficial materials. These two types of units affect and interact with other ecosystem processes at many spatial and temporal scales. For example, erosion rates for most bedrock types with associated "natural" vegetative cover are generally low. Physical erosion rates for unconsolidated surficial deposits (such as alluvium, loess, or glacial till) are commonly higher than those found on bedrock units. Chemical weathering rates determine the release of rock components, such as nutrients and toxic elements, into the ecosystem. Disturbance of vegetative cover, road building, mining, agriculture, urbanization, dam building, and other human activities may profoundly increase the physical and chemical weathering rates of geologic materials. In a similar manner, such disturbances may also affect water retention or other characteristics of the rocks and soils of an area in such a way that they no longer support predisturbance vegetation cover types. Increased fluxes of sediment, toxic elements, and nutrients, or decreased water flows caused by human activities may irrevocably alter ecosystem processes and must be considered in land management planning. An understanding of both the geologic environments and geologic processes of a planning area are essential components of any ecological assessment effort.

The lithologic characteristics of rocks within the Basin are diverse, which in many cases defies simple classification of rock types by ERU. Bedrock geologic units within the Basin range in age from Precambrian rocks older than 2.7 billion years, to volcanic rocks formed during the Mt. St. Helens eruption of 1980. Rocks include:

- Those that crystallized deep within the earth's crust from liquids or by metamorphism, and which were subsequently exposed at the earth's surface by erosion.
- Rocks that formed as oceanic crust and have since been transported onto continents by plate tectonics.
- Flood basalts that cooled from giant lakes of lava.
- Volcanic rock formed by the present-day Cascade volcanos.
- Sandstones, shales, and conglomerates that formed through erosion and deposition of older rocks.
- Carbonate rocks formed from animal remains.
- Chemically deposited sedimentary rocks.

Additionally, unique physical or chemical properties of lithologies such as serpentinite, some tuffs, and carbonate rocks provide unique habitat for selected species that contributes to the landscape and species diversity of the Basin.

Different geologic processes have affected the rocks of the Basin in numerous ways during the course of geologic history. These processes (for example, erosion, deposition, consolidation, uplift, metamorphism, volcanism, and geochemical changes) have all occurred at different times throughout the history of the Basin, resulting in the different physiography, erosion characteristics, nutrient availability, and other landscape parameters present today. It is impossible, for example, to classify granite into a single erosion group or characteristic. Although much of the granitic rock of the Idaho batholith is crumbly and erodes relatively easily, other granitic units (for example, rocks in the Bighorn Crags or the Sawtooth Mountain Range) display wide ranges in natural erosion rates.

Surficial geologic units may develop directly through physical and chemical weathering of bedrock geologic units, or they may be transported from elsewhere as glacial till and alluvium, or as wind-blown dust, sand, or volcanic ash. Discussion of the surficial geologic units of the Basin and their related soil properties is presented later in this chapter.

Approach Used in Geologic Setting Description

Geologic, hydrologic, and mineral resource data were compiled, interpreted, and synthesized from published and unpublished sources and databases. The earth science themes for the Basin assessment were delineated and developed through collaboration with scientists from all SIT staff disciplines.

Individual digitized state geologic maps were used to create a lithologic group map of the Pacific Northwest, including all of Washington, Oregon, Idaho, and parts of Montana, Wyoming, Utah, Nevada, and California (map 2.2) (Johnson and Raines in press). These individual state coverages were then used to develop the derivative maps required for this study. Derivative map products included:

- Areas favorable for sand, gravel, and phosphate resources (Bookstrom and others, in press a).
- Areas favorable for cave-dwelling bats (for example, lithologies such as carbonate develop caverns, recent basalt flows contain lava tubes, and mine portals provide man-made caves) (Frost and others 1996).
- Geochemical nutrients (carbonate, potassium, iron, aluminum, magnesium, and phosphorous).
- Heavy metal distribution maps (Raines and Smith, in press).

This lithologic group map and the derivative geochemical and lithologic maps were used in developing maps for soil erosion potential and sediment supply, watershed classification, geoclimatic subsections, and potential vegetation. These maps were also used to evaluate terrestrial species habitat and "hot spots" of species richness and endemism, as well as aquatic characteristic correlation matrices and aquatic integrity indices.

Mineral resource databases of the U.S. Geological Survey (USGS) and U.S. Bureau of Mines (USBM) were queried to provide information on metallic mineral deposits and their current production status and to project possible economic development over the Basin within the next 10 years. The longer term metallic mineral resource potential of the Basin was displayed in maps of permissive or favorable rankings for the occurrence of 29 distinct mineral deposit types (Box and others, in press). The economic feasibility of development of as yet undiscovered mineral deposits in permissive areas was also described (U.S. Bureau of Mines 1995). In addition to their economic applications, such types of mineral resource information provided an assessment of likely future disturbance areas resulting from mining-related activities (Zientek and others, in press a). Mineral resource (Box and others, in press) and existing deposit information (Bookstrom and others, in press b) were used in the assessment of aquatic system integrity; past, current, and future economic activity and conditions; and biophysical environments.

Data from the National Geochemical database (Hoffman and Buttleman 1994) were used to evaluate metal loadings in streams draining areas with exposed mineral resources (Raines and Smith in press). Geochemical data from stream sediment samples were found to correlate well with geochemical characteristics delineated on the lithologic group map (Johnson and Raines, in press). Digitized versions of published hazard maps, including earthquake and volcanic hazards (Hoblitt and others 1987), as well as geothermal well and spring coverages were also produced. Stream flow, water quality, and aquifer data sets from the USGS Water Resources Division were utilized in the Economics, Broadscale Assessment of Aquatic Species and Habitats, and Landscape Dynamics assessments. Descriptions of the map themes supplied and reports generated for the project by the USGS are discussed in Chapter 8, Information System Development and Documentation.

Uses and Limitations of Geologic Information

The geologic, hydrologic, mineral resource, and process data compiled and interpreted in this assessment provide important information for addressing many issues related to ecosystem

Map 2.2—Lithologic group map of the Pacific Northwest.

pattern and process relations. The utility of geologic information in this, or any other ecosystem assessment and monitoring program, is limited only by:

- Scale of analysis.
- Completeness and appropriateness of the geologic or hydrologic database to the questions being asked.
- Understanding of the processes or patterns being investigated.

For regional-scale analysis such as the ICBEMP, generalized geologic and related derivative maps at 1:500,000 scale are appropriate for nutrient distribution description, mineral resource and mineral impact assessment, regional stream character description, and vegetation pattern analysis, among others. For watershed- or landscape-level analysis, bedrock and surficial geologic maps at scales as large as 1:24,000 or larger are commonly required to address erosion, vegetation pattern, species habitat, aquatic integrity, and other important issues.

Geologic, geochemical, geophysical, and hydrologic data have many uses in ecosystem assessment and monitoring. Earth science data (especially when combined with climatic, biologic, landscape ecology, or other data sets) provide important information for addressing many of the issues commonly identified in multi-scale ecological assessments.

Geoclimatic Settings

Hierarchical, geoclimatic-based ecological unit maps (Cleland and others, in press) were developed for regional, subregional, and landscape scale assessment efforts. Terrestrial environments described by these maps include provinces, sections (Bailey and others 1994a, McNab and Avers 1994), subsections (Nesser and others in press), and subsection groups. Provinces, sections, and subsections were used to identify progressively finer delineations of unique ecoregions with similar climate, landform, and surficial geologic material composition.

A subsection group map of the Basin (map 2.3) was constructed from individual subsection delineations (Nesser and others, in press) to display repeatable ecological units with similar climate, landforms, and surficial materials features. These mapping units were primarily used to develop watershed classifications, to map probable stream type group distributions, and to describe general hydrologic environments by ecological reporting unit (ERU). Ecoregions, subsections, and subsection groups were the primary geoclimatic maps used in most of the landscape ecology assessment work. The following discussion summarizes the construction, associated information, and general use of these various maps in the assessment process.

Ecoregions

Ecoregions represent large regional ecosystems that are uniquely identified (labeled) in geoclimatic environment mapping. Several maps and descriptions of the ecoregions of the United States have been prepared over the last several decades (Bailey 1978, 1982, 1988; Bailey and others 1994a; Driscoll and others 1984; Omernik 1987). Such maps are commonly constructed based on features such as climate, landforms, geologic materials, potential natural vegetation, land use, and soils.

In 1994, a map of the ecoregions and subregions of the United States was published at a scale of 1:7,500,000 (Bailey and others 1994a). This map delineated terrestrial biophysical environment ecological units at the following four levels of specificity: domains, divisions, provinces, and sections. Domains are normally defined using broad climatic zones. Divisions are defined using regional climatic factors. Provinces are defined using potential vegetation communities, landforms, and altitudinal zonations. Sections are further defined based on physiography (geology and topography). A companion publication (McNab and Avers 1994) to this map of the

Map 2.3—Geoclimatic subsection groups.

Nation's ecoregions and subregions was also published to provide map unit descriptions for the sections displayed on the map. Terrestrial (geoclimatic-based) biophysical environments of the Basin are displayed at the section level in map 2.4. A total of 7 provinces and 23 sections occur within the landscape ecology characterization area displayed in map 2.4.

Although some of the earlier Land System Inventories (LSI) and more recent ecoregion mapping were done at several scales, a standardized framework for their construction did not exist until recently. In 1994, a National Hierarchical Framework of Ecological Units (Cleland and others, in press) was established that defined different levels of terrestrial biophysical environment mapping appropriate to multi-scale ecological assessment efforts (table 2.1). To provide a basic overview of this mapping system, the mapping scales associated with this hierarchy are displayed in table 2.2 and the principal criteria used in map unit design are described in table 2.3.

Subsections

For the assessment of the Basin, a subsection level map of over 203 million acres was produced that identified 283 unique geoclimatic environments (Nesser and others, in press). This map was prepared at a scale of 1:500,000 because this was the only scale where associated base maps, topographic maps, and geologic maps were available for the seven states covered by the map. This map scale was also considered to be the highest resolution that could be mapped in the amount of time available that was consistent with recommendations outlined in the National Hierarchy of Ecological Units (Cleland and others, in press).

Ecosystem components considered in the delineation of subsection mapping units are the differentiating criteria used in map construction. Other components used to describe each subsection (but not in map unit delineation) are referred to as accessory characteristics. Three primary differentia (differentiating criteria) were used in constructing the subsection map for this project: geologic material, landform, and climate. These ecosystem components were considered to be the important driving variables (at the 1:500,000 scale) of many finer-scale patterns and processes within the Basin. A complete description of the differentiating criteria and accessory characteristics associated with the geoclimatic subsections of the Basin is provided by Nesser and others (in press). The following is a general summary of that information:

In development of the geoclimatic subsection map of the Basin, geologic materials were first separated by major groups of bedrock types (for example, intrusive igneous, carbonate sedimentary, and metasedimentary) and surficial materials (for example, alluvium, glacial till, and residuum). These classes of geologic materials could not be more specific than the state geology maps used in subsection map construction. Broad landform types (for example, glaciated mountains, plateaus, and plains) were the second important differentia used in map construction. General climate zones, which were inferred from general vegetation patterns, were also considered in map design (for example, grassland, shrublands, and forest). In some cases, these vegetation classes were further subdivided based on knowledge of local vegetation ecology.

Information concerning numerous other ecosystem features (accessory characteristics) was used in the description of each subsection. Examples of this information include soils, mean annual precipitation, mean annual air temperature, surface water characteristics, slope range, elevation range, and disturbance regimes. Summarization of this information was included in map unit description reports for each subsection (Nesser and others, in press).

The USGS 1:500,000 Albers Conic Equal-Area Projection Maps for the states of Montana, Idaho, Washington, Oregon, California, Nevada, Utah, and Wyoming were used as subsection base maps. Geologic materials were determined from 1:500,000 State geology maps with some minor refinements based on local knowledge. General landforms were determined using 1:500,000 State topographic maps and local knowledge.

Map 2.4—Geoclimatic sections.

Table 2.2—Typical map scales and polygon sizes of terrestrial biophysical environment ecological units.

Ecological Unit	Map Scale Range	General Polygon Size
Domain	1:30,000,000 or smaller	1,000,000s of square miles
Division	1:30,000,000 to 1:7,500,000	100,000s of square miles
Province	1:15,000,000 to 1:5,000,000	10,000s of square miles
Section	1:7,500,000 to 1:3,500,000	1,000s of square miles
Subsection	1:3,500,000 to 1:250,000	10s to low 1,000 of acres
Landtype Association	1:250,000 to 1:60,000	high 100s to 1,000s acres
Landtype	1:60,000 to 1:24,000	10s to 100s of acres
Landtype Phase	1:24,000 or larger	Less than 100 acres

Table 2.3—Principal map unit design criteria used in the construction of terrestrial biophysical environment ecological units.

Ecological Unit	Principal Map Unit Design Criteria
Domain	• Broad climatic zones or groups (such as dry, humid, and tropical).
Division	• Regional climatic types (Koppen 1931, Trewartha 1968). • Vegetational affinities (such as prairie or forest). • Soil order.
Province	• Dominant potential natural vegetation (Kuchler 1964). • Highlands or mountains with complex vertical climate-vegetation-soil zonation.
Section	• Geomorphic province, geologic age, stratigraphy, lithology. • Regional climatic data. • Phases of soil orders, suborders or great groups. • Potential natural vegetation. • Potential natural communities (PNC) (FSH 2090).
Subsection	• Geomorphic process, surficial geology, lithology. • Phases of soil orders, suborders, or great groups. • Subregional climatic data. • PNC (formation or series).
Landtype Association	• Geomorphic process, geologic formation, surficial geology, and elevation. • Phases of soil subgroups, families, or series. • Local climate. • PNC (series, subseries, plant associations).
Landtype	• Landform and topography (elevation, aspect, slope gradient and position). • Phases of soil subgroups, families, or series. • Rock type, geomorphic process. • PNC (plant associations).
Landtype Phase	• Phases of soil families or series. • Landform and slope position. • PNC (plant associations or phases).

Broad climatic zones were inferred from potential natural vegetation mapping units of Kuchler (1964) and other regional and local sources of information.

Characterization of average annual precipitation for map units was achieved using the PRISM model. PRISM (Precipitation-elevation Regressions on Independent Slopes Model) is an analytical model that distributes point measurements to a regular grid on regional to continental scales. PRISM uses a Digital Elevation Model (DEM) to estimate precipitation at each DEM cell using a regression of precipitation versus orographic elevation. Precipitation maps based on PRISM were provided by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). Statewide climatic data and local knowledge were also used in subsection map development.

Soils were described for each subsection using local survey data and experience where possible. Other sources of soils information included Major Land Resource Areas and State Soil Geographic DataBases from the NRCS. DEM data and hydrography coverages were also used in the characterization of subsection map units.

Subsection maps were constructed during workshops comprised primarily of soil scientists and geologists knowledgeable about local areas. Preliminary subsection maps of parts of the Basin (Arnold 1994, Holdorf 1994) were compiled and edited by project coordinators. These maps were then reviewed and modified by soil scientists, geologists, and ecologists from the USDA Forest Service (FS), NRCS, U.S. Department of Interior (USDI) Bureau of Land Management (BLM), and USGS. A list of all the people who assisted with construction of the subsection maps for the Basin is available in Nesser and others (in press).

Brief initial descriptions of subsections were provided by Arnold (1994) and Holdorf (1994); however, most map unit descriptions were written by the same people who finalized map unit delineation. Subsection maps were redrafted, edited, digitized, and attributed by the Montana State Library and the Pacific Northwest Regional Office of the FS in Portland, Oregon. Plots of this map were constructed at 1:500,000, 1:1,500,000, and 1:2,000,000 scales for different assessment effort needs.

Subsection Groups

The 283 subsections of the Basin were combined into 39 subsection groups for subsequent terrestrial and aquatic system analysis. Groupings of subsections were made by province based primarily on similarities of landform and surficial geologic characteristics. Bedrock geology, average annual precipitation, and slope characteristics were also considered in subsection group identification. The following is a generalized description of the 39 subsection groups identified within the Basin by province (map 2.3). Only the most extensive types of rocks, landforms, geomorphic processes, and vegetation types within each subsection group are listed in these descriptions. At this level of generalization, smaller amounts of many other types of settings usually occur with a subsection group.

Great Plains-Palouse Dry Steppe Province (Number 331)

Subsection group 33101 consists of breaklands of Columbia River basalt that have been modified by stream downcutting. The general vegetative types include coniferous forest and grassland. Soils are generally coarse- to medium-textured. The subsection included in this unit is 331Af.

Subsection group 33102 consists of foothills and plateaus of basalt with a mantle of loess that have been modified by fluvial processes. The general vegetative type is grassland. Soils are generally fine-textured. The subsections included in this group are 331Aa-d and g.

Subsection group 33103 consists of plateaus of basalt with a mantle of loess that occur in areas of high precipitation and have been modified by fluvial processes. The general vegetative type is grassland. Soils are generally fine-textured. The subsection included in this unit is 331Aa.

Intermountain Semi-Desert Province (Number 342)

Subsection group 34201 consists of breaklands and steep foothills of mostly igneous extrusive rocks with lesser amounts of intrusives and sedimentary rocks. These materials have been modified by uplifting and downcutting. The general vegetative type is grassland with some coniferous forests at higher elevations. Soils are generally coarse- to medium-textured. The subsections included in this group are 342Bc and 342Ie.

Subsection group 34202 consists of plateaus and high plains of basalts and tuffs that have been modified by fluvial and aeolian processes. The general vegetative types include shrubland and grassland. Soils are generally coarse- to medium-textured. The subsections included in this group are 342Cc-e and 342Da-f.

Subsection group 34203 consists of plateaus and high plains of fluvial and lacustrine sediments and ash deposits that have been created by aeolian, fluvial, and lacustrine processes. The general vegetative types include grassland and shrubland. Soils are generally fine-textured. The subsections included in this group are 342Bd, 342Ca and b, 342Hc, and 342Ib and d.

Subsection group 34204 consists of intermontane basins and valleys composed mainly of alluvium, ash, and lacustrine materials over basalt. The general vegetative types include shrubland and grassland. Soils are generally medium- to fine-textured. Subsections included in this group are 342Bh, 342Hd, and 342Ia.

Subsection group 34205 consists of plateaus and foothills composed mainly of tuffs and basalts that have been modified by fluvial and aeolian processes. The general vegetative types include shrubland and grassland. Soils are generally coarse- to medium-textured. Subsections included in this group are 342Bb and j, 342Ch and I, 342Ha and b, and 342If and g.

Subsection group 34206 consists of mountains composed mainly of tuffs and basalts that have been modified by fluvial processes. The general vegetative types include shrubland and grassland. Soils are generally coarse- to medium-textured. The subsections included in this group are 342Ba, g, and I; and 342Cg.

Subsection group 34207 consists of foothills composed mainly of loess over basalt that have been modified by fluvial and aeolian processes. The general vegetative type is grassland. Soils are generally fine-textured. The subsection included in this unit is 342Ic.

Cascade Mixed Forest-Coniferous Forest-Alpine Meadow Province (Number M242)

Subsection group M24201 consists of glaciated mountains and foothills of igneous and sedimentary rocks that have been modified by glacial and fluvial processes. The general vegetative type is coniferous forest. Soils are generally medium- to fine-textured. The subsections included in this group are M242Ca, b, e, g, m, o-q, and s-u.

Subsection group M24202 consists of plains of ash and pumice over volcanic rocks, mostly basalt, that have been modified by alluvial and volcanic processes. The general vegetative type is coniferous forest. Soils are generally fine-textured. The subsection included in this unit is M242Cd.

Subsection group M24203 consists of mountains covered by ash or pumice and frequently underlain by igneous extrusive rocks. These materials have been modified by fluvial, mass wasting, and aeolian processes. The general vegetative type is coniferous forest. Soils are generally coarse-textured. The subsection in this group is M242Cf.

Subsection group M24204 consists of intermontane basins covered by ash, pumice, and alluvium. These materials have been modified by fluvial processes. The general vegetative type is coniferous forest. Soils are generally fine-textured. The subsection in this group is M242Cv.

Subsection group M24205 consists of mountains and foothills covered by ash and pumice and frequently underlain by igneous extrusive rocks. These materials have been modified by fluvial,

mass wasting, and aeolian processes. The general vegetative type is coniferous forest. Soils are generally fine-textured. The subsections included in this group are M242Cc and n.

Sierran Steppe-Mixed Forest-Coniferous Forest-Alpine Meadow Province (Number M261)

Subsection group M26101 consists of foothills of extrusive igneous rocks and some alluvium that have been modified by fluvial processes. The general vegetative types include shrubland and grassland with lesser amounts of forest. Soils are generally coarse- to medium-textured. Subsections included in this group are M261Da and e.

Subsection group M26102 consists of intermontane basins, foothills, and plateaus of igneous extrusive rocks overlain by ash, pumice, and alluvium that have been modified by fluvial and volcanic processes. The general vegetative types include coniferous forest, grassland, and shrubland. Soils are generally coarse- to medium-textured. Subsections included in this group are M261Db and M261Ga and d.

Subsection group M26103 consists of glaciated mountains and foothills of volcanic rocks that have been modified by glacial, fluvial, and mass wasting processes. The general vegetative type is coniferous forest. Soils are generally coarse- to medium-textured. Subsections included in this group are M261Dc and d.

Subsection group M26104 consists of mountains of extrusive igneous rocks that have been modified by fluvial processes. The general vegetative type is coniferous forest. Soils are generally coarse- to medium-textured. Subsections included in this group are M261Dg and M261Gb.

Subsection group M26105 consists of mountains of extrusive igneous rocks that have been modified by fluvial processes. The general vegetative type is coniferous forest. Soils are generally fine-textured. Subsections included in this group are M261Df and h, and M261Gc.

Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province (Number M331)

Subsection group M33101 consists of foothills and plateaus of volcanic and metamorphic rocks that have been modified by colluvial, fluvial, glacial, and periglacial processes. The general vegetative types include forest, grassland, and shrubland. Soils are generally medium- to fine-textured. Subsections included in this group are M331Ab, f, I, and n.

Subsection group M33102 consists of intermontane basins and valleys of valley fill, alluvium, and lacustrine materials overlying volcanic and sedimentary rocks. The general vegetative types include coniferous forest, grassland, and shrubland. Soils are generally medium- to fine-textured. Subsections included in this group are M331Aa, k, and l; and M331Da, e, h, j, v, and w.

Subsection group M33103 consists of glaciated mountains of volcanic and sedimentary rocks that have been modified by colluvial, fluvial, residual glacial, and periglacial processes. The general vegetative types include coniferous forest, shrubland, and some alpine tundra. Soils are generally coarse-textured. Subsections included in this group are M331Dk, m, and t; and M331Ja-e.

Subsection group M33104 consists of glaciated mountains of volcanic and sedimentary rocks that have been modified by colluvial, fluvial, residual, and glacial processes. The general vegetative types are coniferous forest with some shrubland. Soils are generally fine-textured. Subsections included in this group are M331Dd, o, and p.

Subsection group M33105 consists of mountains of volcanic rocks that have been modified by colluvial, fluvial, and periglacial processes. The general vegetative types include coniferous forest, grassland, and shrubland. Soils are generally coarse- to medium-textured. Subsections included in this group are M331Ac, d, g, h, and j.

Subsection group M33106 consists of mountains of sedimentary and volcanic rocks that have been

modified by colluvial, fluvial, residual, glacial, and periglacial processes. The general vegetative types include coniferous forest, grassland, and shrubland. Soils are generally fine-textured. Subsections included in this group are M331Ae, m, o, p and M331Db, c, f, g, I, and u.

Middle Rocky Mountain Steppe-Coniferous Forest-Alpine Meadow Province (Number M332)

Subsection group M33201 consists of breaklands and foothills of granitic rocks that have been modified by fluvial, colluvial, and mass wasting processes. The general vegetative types include coniferous forest, grassland, and shrubland. Soils are generally coarse- to medium-textured. Subsections included in this group are M332Aa, o, q, cc, gg, pp, and xx.

Subsection group M33202 consists of foothills of granitic and volcanic rocks with some metamorphics and sedimentary rocks that have been modified by glacial, fluvial, and residual processes. The general vegetative types include coniferous forest, grassland, and shrubland. Soils are generally medium- to fine-textured. Subsections included in this group are M332Au, ll, and qq; M332Da and o; M332Fa; and M332Gb, o, r, and u.

Subsection group M33203 consists of intermontane basins and valleys of sediments that have been modified by fluvial and glacial processes. The general vegetative types include coniferous forest, grassland, and shrubland. Soils are generally coarse- to medium-textured. Subsections included in this group are M332Aj, bb, ff, kk, and oo; M332Bm; M332Dk, l, and t; M332Er, u, v, w, and cc; and M332Gt.

Subsection group M33204 consists of intermontane basins and valleys of alluvium, lacustrine, and loess deposits that have been modified by fluvial, mass wasting, glacial, and aeolian processes. General vegetative types include coniferous forest, grassland, and shrubland. Soils are generally fine-textured. Subsections included in this group are M332Ad; M332Bb, e, and I; M332Eg and q; and M332Gl.

Subsection group M33205 consists of glaciated mountains of granitics and gneiss with lesser amounts of volcanic and sedimentary rocks that have been modified by glacial, periglacial, fluvial, colluvial, and mass wasting processes. General vegetative types include coniferous forest, grassland, and shrubland. Soils are generally coarse- to medium-textured. Subsections included in this group are M332Ae, f, k, m, r, t, v, ii, mm, and nn; M332Ba and d; M332De, j; M332Eb, h, x, y, and ff; M332Fi and t; and M332Gd.

Subsection group M33206 consists of glaciated mountains of granitic and sedimentary rocks that have been modified by glacial, periglacial, colluvial, and fluvial processes. General vegetative types include coniferous forest, grassland, and shrubland. Soils are generally fine-textured. Subsections included in this group are M332Ab; M332Bh; M332Ca-d; M332Ed, I, p, and z; and M332Gk.

Subsection group M33207 is heterogeneous consisting of mountains of igneous and metamorphic rocks with lesser amounts of sedimentary rocks. These materials have been modified by fluvial, colluvial, mass wasting, frost churning and glacial processes. The general vegetative types include coniferous forest, grassland, and shrubland. Soils are generally coarse- to medium-textured. Subsections included in this group are M332Ah, I, l, n, s, w, x, y, z, aa, ee, hh, jj, yy, and zz; M332Bc, j, and l; M332Df and s; M332Ec, e, f, m, n, s, and aa; M332Fc, d, e, g, and h; and M332Gf, q, s, and v.

Subsection group M33208 is very heterogeneous and consists of mountains of igneous, sedimentary, and metamorphic rocks. These materials have been modified mainly by fluvial and colluvial processes with lesser amounts of glaciation, frost churning, and mass wasting. The general vegetative types include coniferous forest, grassland, and shrubland. Soils are generally fine-textured. Subsections included in this group are M332Ag; M332Bf, g, k, and n; M332Db-d, g-I, m, n, q, and r; M332Ea, k, l, t, and dd; M332Fb; and M332Ga, and g-j.

Subsection group M33209 consists of plateaus of basalt and granite that have been modified by fluvial and colluvial processes. The general vegetative types include forest and grassland. Soils are generally medium- to fine-textured. Subsections included in this group are M332Ap, and rr; and M332Gm, n, and p.

Northern Rocky Mountain Forest-Steppe-Coniferous Forest-Alpine Meadow Province (Number M333)

Subsection group M33301 consists of foothills of granitics and gneisses that have been modified by fluvial and colluvial processes. The general vegetative types include coniferous forest and grassland. Soils are generally fine-textured. Subsections included in this group are M333Am and M333De.

Subsection group M33302 consists of intermontane basins, valleys, and till plains of lacustrine, glacial outwash, alluvium, and till. The general vegetative types include forest and grassland with a smaller amount of shrubland. Soils are generally medium- to fine-textured. Subsections included in this group are M333Ac, d, r, and s; and M333Bc.

Subsection group M33303 consists of glaciated mountains of granitic and metasedimentary rocks that have been modified by glacial and fluvial processes. The general vegetative type is coniferous forest. Soils are generally medium- to fine-textured. Subsections included in this group are M333Aa, b, e, and h-k; M333Ba, b, and e; and M333Ca, b, d, and g.

Subsection group M33304 consists of mountains and breaklands of granitic and metasedimentary rocks. These materials have been modified mainly by fluvial and colluvial processes with some frost churning and alpine glaciation at higher elevations. The general vegetative type is coniferous forest. Soils are generally medium- to fine-textured. Subsections included in this group are M333Af, g, o, and q; M333Bf; and M333Da-d, and f-j.

Potential Vegetation Settings

This section summarizes the approach used to model the distribution of broad-scale potential vegetation (PV) settings over the assessment area. Although the specific definitions may change, PV is always understood to be an expression of the biophysical environment of an area regardless of the study scale or existing vegetation status (Eilenberg 1988, Kuchler 1988). The methods used in PV classification and mapping, as well as descriptions of the PV environments identified within the Basin, are outlined in Reid and others (1996). The following is a summary of that report.

Potential vegetation maps are used in conjunction with other maps of abiotic features, such as landforms, to define biophysical environments at different spatial scales (Zonneveld 1989). Such maps provide the context for understanding relations between disturbance regimes and other ecological processes and the existing landscape patterns of an area, such as the existing vegetation. Potential vegetation maps are also commonly used as input into models of landscape pattern change under various scenarios such as different management strategies or global climate change. In this assessment, PV maps were used for different portions of the Terrestrial, Aquatic, and Landscape Ecology staff assessments see Chapters 5, 4, and 3 respectively. For example, PV maps were used as input to the Columbia River Basin SUccession Model (CRBSUM) for modeling change in vegetation patterns under a doubling of carbon dioxide (CO_2) scenario. PV maps were also used in the construction of hydrologic subregion maps.

Methods Used in Broad-Scale Potential Vegetation Classification and Mapping

The dependent variable of the vegetation site model used in broad-scale PV mapping was a vegetation type. Over large areas such as the Basin, there was a need to use a standardized and regionalized classification system (Bourgeron 1988 and 1989). In this modeling exercise, The Nature Conservancy's (TNC) Western Regional Vegetation Classification (WRVC) (Bourgeron and Engelking 1994) was

adopted. This classification included the existing natural and semi-natural vegetation in the western United States. (See Reid and others 1996 for further discussion of the WRVC and its development and use).

Potential vegetation classifications were generated at three classification scales: section, regional, and coarse. Initial classifications were developed by dividing vegetation types into three broad physiognomic classes: forest, shrubland, and herbaceous types. Potential vegetation types and their relationship to temperature-moisture gradients were then defined for each physiognomic class: (1) for each geoclimatic section (section level) and (2) across the entire assessment area (regional level). A coarse-level PV classification was generated by defining 20 PV types in relation to Basin-wide temperature-moisture gradients, regardless of the physiognomic type.

The process of determining the potential vegetation classifications and their temperature-moisture gradient relations included the generation of a list of PV plant associations over the Basin and the arrangement of the potential plant associations into section-level classifications.

The general approach used was to consider as PV all plant associations that represented the end point of successional sequences. A master list of such plant associations by physiognomic class was generated from the WRVC for the Basin (Reid and others 1996). This master list was revised as necessary before, during, and after all the workshops used in PV map construction. A total of 807 plant associations were associated with the classifications used in PV mapping (Reid and others 1996).

Section-level PV classifications were built for each of the three broad physiognomic classes of vegetation (forest, shrubland, and herbaceous types) from the master list of PV plant associations. This task was accomplished in various workshops by staff from the FS, U.S. Fish and Wildlife Service (USFWS), BLM, NRCS, and TNC, as well as other professionals with broad regional knowledge of these PV plant associations.

Moisture and temperature gradients were divided into four coarse segments resulting in 4 by 4 matrices (four temperature settings by four moisture settings). Workshop participants were asked to list the PV plant associations within each temperature-moisture setting (for example, cold or wet setting) for each physiognomic class. There were 16 PV types for each physiognomic class, for a total of 64 possible PV classes within each geoclimatic section of the Basin. An example of this classification system is provided in table 2.4.

Temperature and moisture gradients were scaled by physiognomic class within each geoclimatic section. For example, within a given section, the cold or wet cell for forests was not necessarily equivalent to the cold or wet cell for the shrublands. Moreover, a given temperature-moisture cell [for example, cold (or wet) for forests] was not necessarily equivalent among geoclimatic sections (for example, between a high mountain section and a low desert section).

Section-level classifications were aggregated into a regional classification using regional temperature-moisture 4 by 4 matrices for each physiognomic class. This process created three regional PV classifications, one for each physiognomic class for a total of 48 regional PV types (Reid and others 1996). A coarse-level temperature-moisture matrix of 20 cells was also created. In constructing this matrix, the 48 regional PV types were aggregated into the cells of the coarse-level matrix regardless of their physiognomic class. Descriptions of the vegetation types in both the regional and coarse-level PV classes are provided by Reid and others (1996).

The independent variables (related to the vegetation type dependent variable described above) for the vegetation model were selected on the basis of their ability to be derived from the DEM data for each 1-km^2 pixel of the grid covering the entire Basin. Elevation, slope, and aspect (table 2.5) were chosen since they are closely related to the direct ecological factors that define potential vegetation environments (for example, solar radiation). The assignment of the biophysical settings to section-level PV classes (model calibration) was done on a geoclimatic subsection basis by professionals with local field experience (Reid and others 1996).

Table 2.4—Forest biome temperature-moisture gradient potential vegetation classifications for section M333C of the Basin (Reid and others 1996).

Moisture:	Wet (1)	Moist (2)	Dry (3)	Very Dry (4)
Temperature:				
Cold (1)	ABLA/CACA4	ABLA/MEFE	ABLA/LUGLH LALY/ABLA	ABLA/VASC ABLA-PIAL/VASC PIAL-ABLA
Cool (2)	PICEA/EQAR ABLA/OPHO THPL/ATFI	ABLA/LIB03 THPL/GYDR TSME/CLUN2 ABLA/CLUN2 PICEA/GATR3 PICEA/CLUN2	ABLA/VACE PSME/LIBO3 ABGR/XETE ABLA/XETE ABLA/VAGL	PICEA/VACE PSME/VACE
Warm (3)	THPL/OPHO ABGR/SETR PICEA/COGE16	THPL/CLUN2 THPL/ASCA2 ABGR/LIBO3 ABGR/CLUN2	PSME/CARU PSME/PMA5 ABGR/PHMA5 PHME/VAGL	PSME/SYAL
Hot (4)	POTR5/COSE16 PORT15/COSE1 PICEA/LYAM3 PSME/COSE16	POTR5/OSOC		

Table 2.5—List of site parameter/GIS rules used in the "vegetation-site" model for broad-scale potential vegetation environment mapping.

Elevation (meters)	Aspect	Slope
0 -304	Northeast	Flat
305 -609	Southwest	5 - 29%
610 -914	Flat	30 - 59%
915 -1,219		Greater than 60%
1,220 -1,523		
1,524 -1,828		
1,829 -2,133		
2,134 -2,438		
2,439 -2,743		
2,744 -3,047		
3,048 -3,352		
3,353 -3,657		
3,658 -3,962		
3,963 -4,267		

Section-level PV mapping was accomplished within each geoclimatic subsection by reading the slope, aspect, and elevation values for each pixel and using them to index the name of the section-level PV type in the pixel. Inaccuracy in the DEM was corrected during a series of workshop sessions conducted for quality control of the three scales of maps produced.

Predictive models of coarse-level PV type distributions were constructed based on current and projected future climate data. The coarse-level PV map generated for the Basin (map 2.5) was used to provide the source of PV data under current climatic conditions. The resulting models were used to produce maps of predicted PV environments under current climate conditions and a doubled CO_2 climate change scenario.

Generalized linear models were used to quantify PV response to climatic conditions in this study. Nine climate attributes were selected as predictor variables in the analysis. A map of the distribution of 20 PV types under current climatic conditions previously generated for the assessment (Reid and others 1996) provided the source of PV data used. To construct the models, the current climatic conditions generated over the Basin at a 2-by-2-kilometer scale for a normal climate year (Thornton and Running 1996) were associated with the pixels of the base PV map. For a more complete description of the modeling approach and climatic attributes used in this characterization refer to Thornton and others (in press).

Riparian Potential Vegetation Settings

Riparian plant associations within the Basin were identified based on the Regional Hierarchical Classification of Western United States Vegetation (Bourgeron and Engelking 1994) and a series of workshops involving local experts. These plant associations were then aggregated into Riparian Plant Association Groups based on climatic zone, vegetation structure, and moisture status/indicator species criteria. Riparian Plant Association Group composition was assigned by workshop participants to dominant valley bottom settings within each of the 48 regional-level PV environments described above. This assignment facilitated spatial identification of probable riparian PV environments at a 1-km^2 grid throughout the Basin. Descriptions and methods used in the classification and mapping of riparian plant association groups are provided by Manning and others (in press).

Results of Broad-Scale Potential Vegetation Classification and Mapping

A map was produced for each geoclimatic section using the section-level PV classifications and their assigned elevation, aspect, and slope settings by subsections (Reid and others 1996). These maps were reviewed by TNC, and State Heritage ecologists, as well as FS and BLM professionals. Overlapping and missing data areas in these maps were corrected, and changes in vegetation-site classifications were made as necessary and subjected to further review.

Calibration of vegetation-site models was performed separately for each PV type by elevation class within each geoclimatic subsection. Once vegetation-site models were revised, resulting attribute matrices were generated section by section to describe the possible ecological range of each section-level PV class. Table 2.6 provides an example of an attribute matrix for the Northern Rockies section (see Reid and others 1996 for a description of all sections). A final map of all section-level potential vegetation environments was produced at a 1:2,000,000 scale (Reid and others 1996).

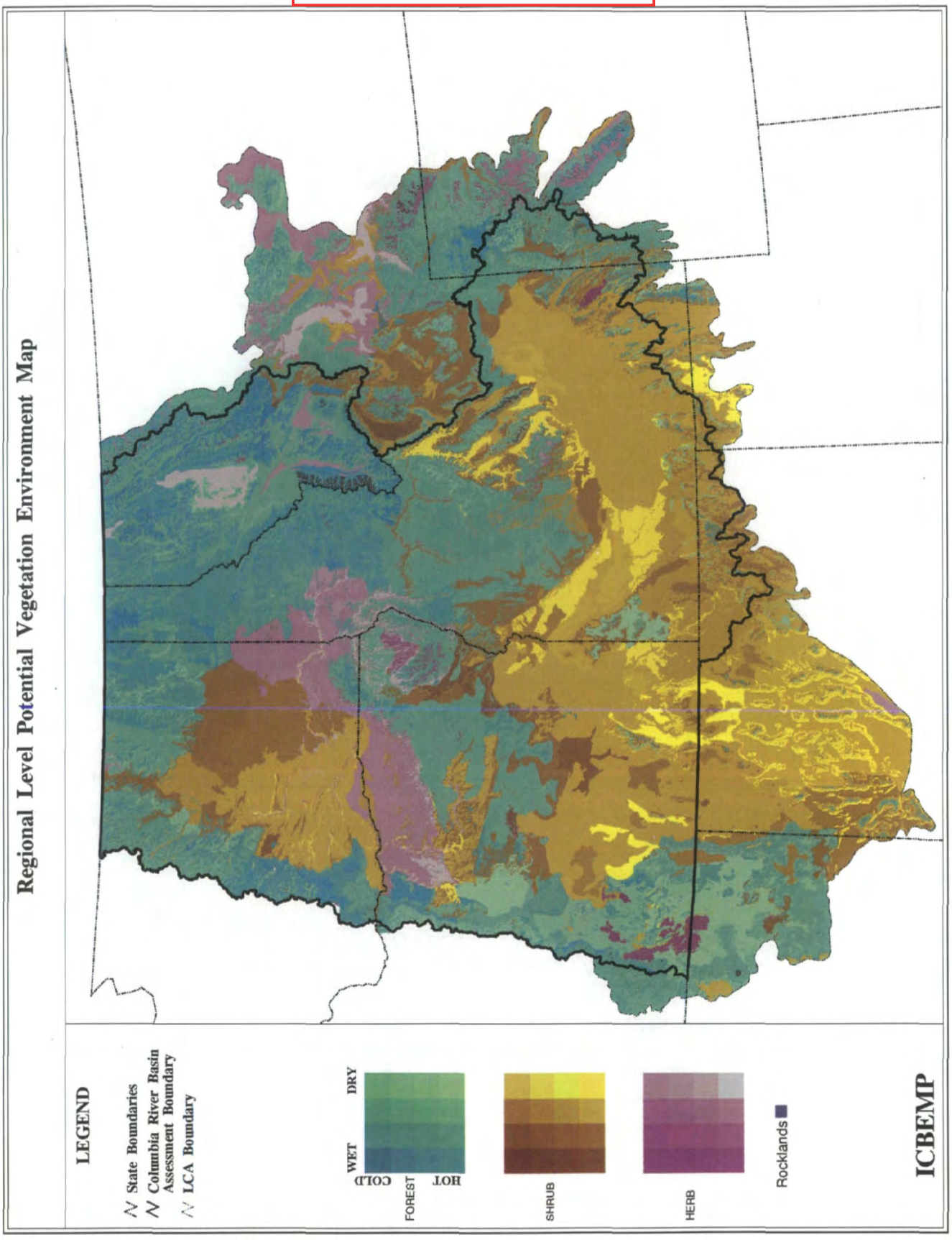
Coarse- and regional-level potential vegetation environment maps (maps 2.5 and 2.6) were produced from section-level maps by establishing relations between section-level classes and regional classes and then establishing relations between regional classes and coarse-level classes (Reid and others 1996). All maps produced by this process were reviewed, and as with the section-level PV map, overlapping and missing data areas and obvious errors in the maps were corrected.

Map 2.5—Coarse-level potential vegetation environment map.

Continue

Previous

This file was created by scanning the printed publication.
Mis-scans identified by the software have been corrected;
however, some errors may remain.



Map 2.6—Regional-level potential vegetation environment map.

Table 2.6—Vegetation site rules used in the construction of a broad-scale potential vegetation environment map for section M333C of the Basin (Reid and others 1996).

Gradients			Vegetation-Site Rules		
Temperature[1] 1-4	Moisture[2] 1-4	Plant Associations	Elevation (meters)	Aspect	Slope
		Forests			
1	1	ABLA/CACA4	---------- Not mapped[3] ----------		
1	2	ABLA/MEFE	1,220-2,590	All	All
1	3	LALY-ABLA	1,829-2,285	Flat,Northeast	All
1	3	ABLA/LUGLH			
1	4	ABLA/VASC	1,982-2,285	All	All
1	4	ABLA-PIAL/VASC			
1	4	PIAL-AHLA			
2	1	PICEA/EQAR			
2	1	ABLA/OPHO	---------- Not mapped ----------		
2	1	THPLA/ATFI			
2	2	ABLA/LIBO3	610-2,133	All	All
2	2	THPL/GYDR			
2	2	TSME/CLUN2			
2	2	ABLA/CLUN2			
2	2	PICEA/CLUN2			
2	3	ABLA/VACE	1,220-2,133	Southwest	GT5
2	3	PSME/LIBO3			
2	3	ABGR/XETE			
2	3	AHLA/XETE			
2	3	ABLA/VAGL			
2	4	PSME/VACR	762-1,219	All	LT40
2	4	PICEA/VACE			
3	1	THPL/OPHO			
3	1	ABGR/SETR			
3	1	PICEA/COSE16	---------- Not mapped ----------		
3	2	THPL/CLUN2	1,067-1,523	All	LT60
3	2	THPL/ASCA2			
3	2	ABGR/LIBO3			
3	2	ABGR/CLUN2			
3	3	PSME/CARO	1,067-1,676	Southwest	5-59
3	3	PSME/PHMAS			
3	3	ABGR/HPMAS			
3	3	PSME/VAGL			
3	4	PSME/SYAL	---------- Not mapped ----------		
4	1	POTR5/COSE16	---------- Not mapped ----------		
4	1	POTR15/COSE16			
4	1	PICEA/LYAM3			
4	1	PSME/COSE16			
4	2	POTR/OSOC	---------- Not mapped ----------		

Table 2.6 (continued).

Gradients			Vegetation-Site Rules		
Temperature[1] 1-4	Moisture[2] 1-4	Plant Associations	Elevation (meters)	Aspect	Slope
		Shrublands			
1	1	SAPL/CASC12	---------- Not mapped ----------		
1	1	SACA4/CARO6			
1	1	KAMI/CASC12			
1	2	PHEM/ANLA3	---------- Not mapped ----------		
2	1	SAGE2/CAAO	---------- Not mapped ----------		
2	1	SAGE2/CACA4			
2	1	BEGL/CARO6			
2	2	SAWO/DECE	---------- Not mapped ----------		
2	2	ALIN2			
2	2	ALVIS			
2	2	SABE2			
3	1	SALU2/CARO6	---------- Not mapped ----------		
3	1	SALU2/CACA4			
3	1	SADR			
3	2	SALUL	---------- Not mapped ----------		
3	2	COSE16			
3	2	SAEX			
3	3	PEFL15/FESC	---------- Not mapped ----------		
3	3	PEFL15/DECE			
		Herbaceous Lands			
1	1	CACA4	---------- Not mapped ----------		
1	1				
1	1				
1	1				
1	2	Alpine Rangeland	2,286-2,743	All	LT60
2	1	ELQU2	---------- Not mapped ----------		
2	1	ELPA3			
2	1	CARO6			
2	1	CABU6			
2	1	CAAQ			
2	1	CALA11			
2	2	DECE-CAREX	---------- Not mapped ----------		
2	2	DECE			
2	3	FEID-ELTR7	----------Not mapped ----------		
3	1	PHAU7	---------- Not mapped ----------		
3	1	EQFL			
3	1	GLBO			
3	1	CAAP3			

Table 2.6 (continued).

Gradients					
Temperature[1] 1-4	Moisture[2] 1-4	Plant Associations	Vegetation-Site Rules Elevation (meters)	Aspect	Slope
3	2	POPA2	---------- Not mapped ----------		
3	2	JUBA			
3	2	CANE2			
3	3	FEID-DECE	---------- Not mapped ----------		
3	3	FEID-STRI2			
3	4	FESC-FEID	---------- Not mapped ----------		
4	1	TYLA	---------- Not mapped ----------		
4	1	SCAC			
4	4	FESC-PSSP6	---------- Not mapped ----------		
4	4	FEID-PSSP6			
		Rocks	2,286-2,590	Northeast/ Southwest	GT60

[1]Temperature: 1=Cold; 2=Cool; 3=Warm; 4=Hot

[2] Moisture: 1=Wet; 2=Moist; 3=Dry; 4=Very Dry

[3] Not mapped -- Plant associations did not occur in mappable areal extents.

Broad-scale potential vegetation environment maps were analyzed to inspect general patterns between vegetation and elevation at different spatial scales. Area statistics for these maps [in square kilometers (km^2)] were provided by Reid and others (1996) for frequency and relative percentage of:

- Main elevational classes by geoclimatic section.
- Section-level PV classes by geoclimatic section.
- Regional-level PV classes across the Basin.
- Coarse-level PV classes across the Basin.

To evaluate the performance of vegetation site model and the quality of the model-generated potential vegetation maps, quantitative comparisons were made between the model-generated maps and field data collected on plots within the Northern Rockies section. This section was chosen as a test area because of the large number of previously sampled plots and the known level of confidence in the PV assignments by field investigators. The three main limitations to the use of plots for map evaluation discussed in Reid and others (1996). A total of 2,545 plots with reliable PV plant association assignment were used in this evaluation.

Map performance was based on the percentage of plots in which the predicted map class and the observed class were identical. On the average, correspondence between predicted PV and plot data for all PV types was 29 percent at the section level, 32 percent at the regional level, and 31 percent at the coarse level (Reid and others 1996). The comparisons were broadened to include the chance of making an error of one class (Reid and others 1996). For forest classes, the degree of correspondence was on the average 45 percent at the section level, 46 percent at the regional level, and 43 percent at the coarse level (Reid and others

1996). These numbers were encouraging because, as a consequence of the limitations discussed by Reid and others (1996), the quantified degree of correspondence between the maps and the plot database were expected to be much lower than between model-generated maps and current methods of accuracy assessment.

The models used to predict potential vegetation environments were correct (on average) close to half of the time when an error of one class was allowed. These results are similar to those described by other scientists in Switzerland (Brzeziecki and others 1993) and in California (Walker and others 1995). Such models are interesting because they could be modified easily to conform to new information, and they could be used to identify relations between vegetation and driving (direct) variables through the use of simple process models.

Predicted changes in PV distribution under a double CO_2 scenario were also assessed in this study by comparing predicted future PV with predicted current PV maps. Examination of these maps allowed identification of areas in which change is predicted to occur in a particular direction, as well as areas in which little change might be expected. Results of this analysis indicated that, in general, following climate change of the type projected, mesic vegetation types are predicted to expand in area across the Basin.

Climate attributes were entered into a model for each PV class using a forward step-wise procedure in the analysis of PV distribution change. The equation resulting from model development for each PV class was used to predict probability of occurrence ranging from 0 to 1. Individual model performance evaluation was then conducted on validation data sets. Accuracy was 65 to 87 percent of pixels correctly predicted. The 20 equations developed in this study were then used to predict the PV class for each pixel over the entire Basin under both current climatic conditions and predicted climatic conditions under a scenario of doubled CO_2. To generate maps of PV climate change, the highest probability of occurrence of a PV class for each pixel was selected.

Extensive overlap in climate attribute values occurred among PV classes. In addition, the base PV map used as a data source in analysis had a different spatial scale (1- by-1 km) than the climate attributes (2-by-2 km). Consequently, when comparing the model-predicted current conditions PV map with the base PV map, only 35 percent of pixels were correctly predicted. When the three highest probabilities of occurrence were used to determine whether the correct PV class was predicted, accuracy was 72 percent.

Drainage Basin Settings

Delineation

Continuous delineations of watersheds across the assessment area were developed to facilitate integration of terrestrial and aquatic ecosystem information. The procedures used in watershed delineation were described in detail by Brewer and Callahan (in press). A total of approximately 7,500 base unit subwatersheds (6th-field HUCs) were identified within the Basin, and about 12,000 subwatersheds were identified within the landscape characterization area. Delineation of these hydrologic units was consistent with national direction and existing interagency efforts within and near the assessment area. Watersheds by their very nature are a nested hierarchy; a small watershed is contained within a larger watershed which, in turn, is contained within a still larger one. The delineation and numeric identification of watersheds used in the assessment of the Basin follows a similar logic. The numeric coding system used was based on the one prepared by the USGS in cooperation with the Water Resources Council. This system consists of fields of paired digits referred to as Hydrologic Unit Codes (HUC). The first four fields (8 digits) are assigned and published by the USGS and are commonly referred to as 4th-field HUCs. The ICBEMP watershed delineation further subdivides 4th-field hydrologic units into smaller, nested

5th-field and 6th-field hydrologic units. It is the 6th-field hydrologic unit (referred to as 6th-field HUC or subwatershed) that was used as the basic characterization unit for the ICBEMP assessment effort.

Subsampling

Land and hydrologic unit sampling framework—To provide insight into management induced cause-and-effect relations between terrestrial and aquatic ecosystems, it is preferable that ecological characterizations classify environments as terrestrial (biological and physical) and hydrologic at scales appropriate to observing the patterns, processes, and interactions of interest. For example, if an analysis is to evaluate effects of roads on the distribution of bull trout life histories in an area, the analysis area ought to consist of hydrologic units that are large enough to represent a nearly full complement of trout life histories. If this was not the case, it would be difficult to separate effects of stream network size from the effects of hydrology, climate, geology, vegetation, and landform. The ECOMAP hierarchy (Cleland and others, in press) provided the framework used in the identification of terrestrial ecological units in this assessment, and the USGS hydrologic unit hierarchy (Seaber and others 1987) provided an initial framework for hydrologic unit identification. Both terrestrial and hydrologic criteria were used to stratify watersheds for sampling and characterization in this assessment.

The USGS hydrologic unit hierarchy provides a nested four-level delineation of watersheds of similar size and scale for the entire United States. The fourth level in this hierarchy (4th-field HUCs) was used to initially stratify watersheds of the assessment area for sampling. In addition, results from the Eastside Forest Ecosystem Health Assessment (Lehmkuhl and others 1994) indicated that smaller hydrologic units of 8,000 or more hectares (20,000 acres) were suitable for characterizing (on a sampling basis) patterns and trends in structural attributes (both composition and configuration) of vegetation within 4th-field HUCs. Complete hydrologic unit coverages of this scale for the entire Basin were lacking in the existing USGS hierarchy. Consequently, two additional nested levels (5th- and 6th-field HUCs) were delineated for this assessment.

Subbasin and Subwatershed Selection

Subbasins were selected from a formal stratification of all subbasins by their province-level ecological unit membership and similarity of area in 305 meter (1,000 ft.) elevation zones. Subbasin areas in each elevation zone were derived in a geographical information system (GIS) using a 90-meter DEM at a scale of 1 kilometer with raster coverages. Similarity analyses employed the percent similarity algorithm (Pielou 1984) shown below:

$$ps=200\ \frac{\sum \min (x_i y_i)}{\sum x_i+\sum y_i}$$

where:

x_i = is the measure of attribute i in subbasin x,
y_i = is the measure of attribute i in subbasin y,

Generated pixel data were treated like any ecological data set consisting of sample units (subbasins) with species abundances (pixel counts within each province-elevation class). The intent of this analysis was to classify groups of similar subbasins. A smaller set of subbasins was then randomly drawn from within each group, from which subwatersheds were then randomly selected. Each group contained similar subbasins where the attributes of similarity were the province-elevation classes. Since provinces are by definition relatively homogeneous ecological land units at that scale (Cleland and others, in press), this approach was considered to be a reasonable method of stratification. A recursive analysis was used in the identification of subsample watersheds.

The following is a brief description of the steps used in each analysis cycle of that process:

1. The cluster analysis procedure TWINSPAN (TWo-way INdicator SPecies ANalysis) was used to divide the data into 4 to 6 groups (Hill 1979).
2. Two similarity index tables were developed using the percent similarity index (Pielou 1984). The first table was a subbasin comparison. Percent similarity uses abundance data to weight the importance of each attribute. For example, two subbasins with similar attributes that have similar abundance values would have higher values than two subbasins also having similar attributes but divergent abundance values. The second table was a cluster by cluster comparison using TWINSPAN output. These values represented averages of all the within-group or between group similarity values from the first table. Assessment of cluster homogeneity with respect to the presence or absence of attributes was possible using this table.
3. The similarity analysis described above was used and the membership of each cluster refined. The process for each cluster defined above was repeated, applying steps 1 and 3 for each cluster, and stopping when further division produced clusters too small to be useful or when further subdivision was not ecologically meaningful.

Sixteen subbasin strata were identified by this stratification process. These strata contained 4 to 18 subbasins, of which 2 to 4 were randomly selected without replacement from each stratum for sampling. The sampling intensity used in the Eastside Forest Ecosystem Health Assessment (Everett and others, 1994) across each stratum was in proportion to stratum size. Subbasins previously selected for the Eastside Forest Ecosystem Health Assessment (Everett and others 1994, Lehmkuhl and others 1994) were included in the sample because these data were readily available, and subwatersheds within these subbasins were randomly selected. In all, 43 subbasins were sampled for vegetation and stream pattern changes with current and historic aerial photos (map 2.7).

Subwatersheds were randomly selected for vegetation mapping until at least 15 percent of the area of each selected subbasin was represented. Availability of recent historical and current aerial photography was researched for each selected subwatershed. Aerial photo coverages of selected subwatersheds were unavailable or incomplete for a few subbasins containing mostly private lands or rangelands. These subbasins were randomly replaced with others having sufficient photo coverage as they were encountered in the selection process. Ultimately, 337 subwatersheds were selected for sampling of aerial photo vegetation and stream patterns (map 2.7).

A primary concern in using subwatersheds of different sizes in vegetation pattern analyses is the correlation between landscape pattern attributes and landscape area (O'Neill and others 1988, Turner 1989). Recent studies have shown that sample estimates of landscape attributes change asymptotically rather than linearly with landscape area (Lehmkuhl and Raphael 1993). Accordingly, subwatersheds averaging at least 4,000 hectares (10,000 acres) in size were selected for sampling to avoid bias associated with smaller sampling units. When subwatersheds smaller than 4,000 hectares were encountered in the sample, they were joined with an adjacent subwatershed to make larger hydrologic units for sampling.

Classification

Hydrologic regions and subregions were identified within the Basin through grouping of similar 4th- and 6th-field HUCs (respectively) based on geoclimatic, morphometric, and hydrologic function criteria. Primary objectives for development of these watershed classification groupings included:

- Prediction of finer-scale aquatic patterns (for example, valley bottoms, stream types, and channel units).
- Identification of watershed settings with similar management potentials and response to disturbance.

Map 2.7—The subbasins and subwatersheds used in vegetation and stream pattern trend subsampling.

Methods and results of the watershed classification procedures used in this assessment are described in Jensen and others (in press). The following is a brief summarization of information contained in that report.

A draft map of hydrologic regions within the Basin was constructed for this project based on the composition of geoclimatic subsection groups and regional scale potential vegetation environments within each 4th-field HUC. These composition values were used in an agglomerative hierarchical clustering analysis (Ward 1963), which indicated that 14 groupings of 4th-field HUCs provided optimum classification of the subbasins within the Basin based on the biophysical environment variables studied.

Classification groupings identified through cluster analysis were associated to a data file for each 4th-field HUC (see Appendix 2A), which was used to produce an initial map of 14 hydrologic subregions within the Basin. This map was subsequently refined (in conjunction with other materials) in the development of an ecological reporting unit (ERU) map that identified 13 environments (hydrologic regions) across the Basin. ERUs were developed in this project to facilitate common reporting of analysis information between different staffs. Hydrologic information is summarized by ERUs later in this chapter.

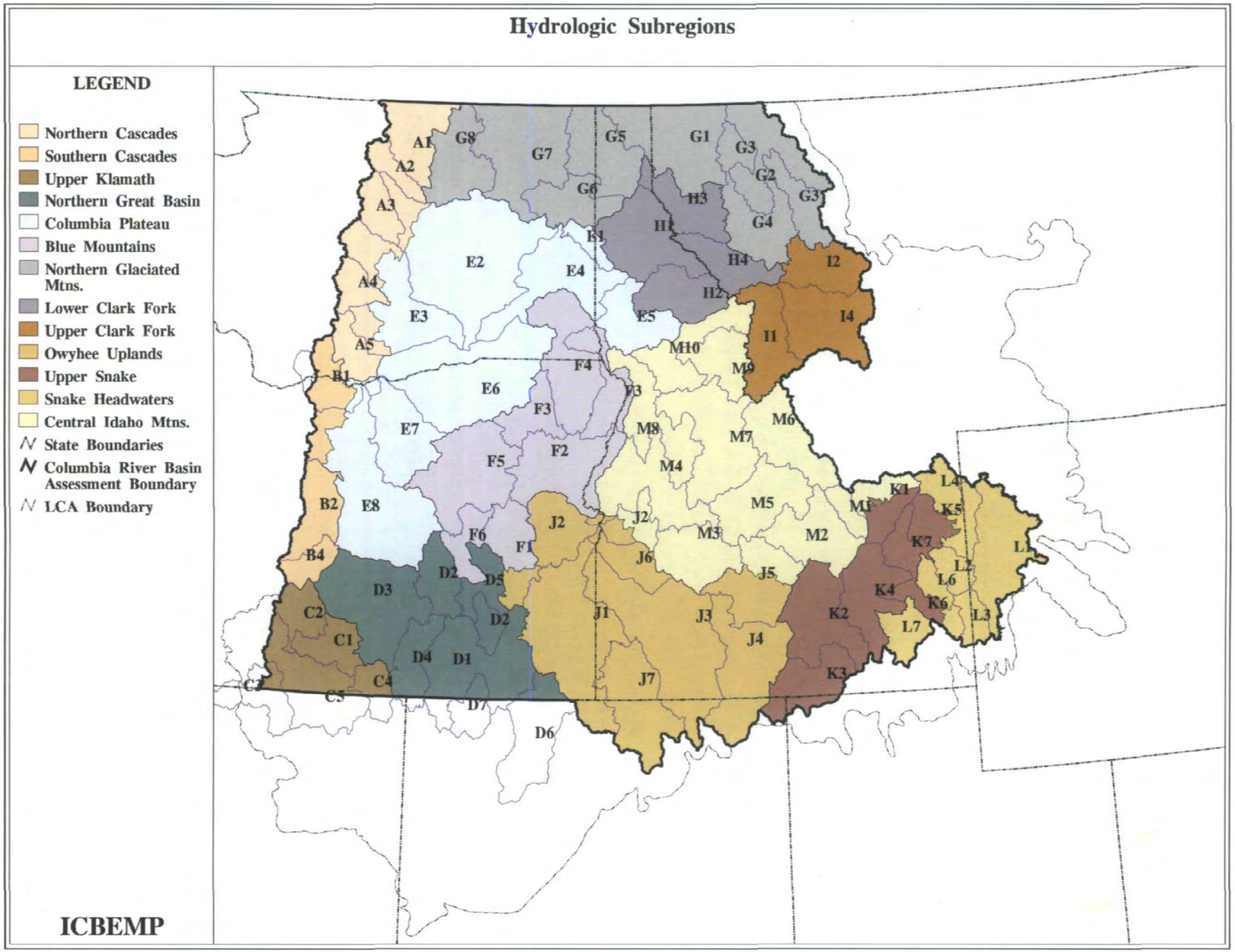
A subwatershed-based (6th-field HUC) map of 84 hydrologic subregions within the Basin (map 2.8) was developed following hierarchical principles of ecological unit mapping as described by the ECOMAP working group of the FS (Cleland and others, in press). The primary objective for identification of hydrologic subregions (at a 1:500,000 scale) was to predict areas with similar finer scale aquatic pattern composition (that is, valley bottoms and stream types), and hence similar management potential and response to disturbance (Jensen and others 1996). Realization of this objective required:

- Aerial photo estimation of valley bottom and stream type composition within subsample watersheds.
- Identification of direct and indirect biophysical environment variables that were the best predictors of valley bottom and stream type compositions within subsampled watersheds (tables 2.7, 2.8a and 2.8b).
- Development of hydrologic subregion maps based on the primary biophysical environment variables identified.

Canonical correspondence analyses indicated that a core set of 15 direct variables (for example, average watershed slope, drainage density, and 10-year peak flow) and 19 indirect variables (that is,

Table 2.7—Listing of the direct and indirect biophysical environment variables used in the subregional scale watershed classification of the Basin.

Direct Variables	Indirect Variables
Slope	M242-01
24-hour	SHD
DDensity	M332-02
JULYTAVG	Litho-23
WNSRAD	342-02
MINZ	Litho-17
AUGTAVG	Litho-25
TDEW	FCW
STE	M242-02
WNTMAX	M331-06
Flood10	Litho-19
PRECIP	FCD
Relief	HHW
MAXZ	342-05
SUPRCP	FHW
	FHD
	M242-04
	342-04
	M333-03



Map 2.8—Hydrologic subregions.

Table 2.8a—Description of the primary direct biophysical environment variables considered in subregional-scale watershed classification of the Basin. (Note: All variables were calculated to reflect average values for a 6th-field subwatershed.)

Variable Code	Description
Slope	Percent slope, calculated from a 90-meter digital elevation model.
DDensity	Drainage density (total stream length/watershed area).
MINZ	Minimum elevation (m).
MAXZ	Maximum elevation.
Relief	Relief ratio (MAXZ-MINZ/Watershed Area).
STE	Sediment transport efficiency (D Density x Slope).
Flood10	Estimated pore point, 10-year peak flow level [cubic feet per second (cfs)].
24-hour	2-year maximum 24-hour storm intensity (cm).
PRECIP	20-year average annual precipitation (cm).
SUPRCP	Average daily precipitation for summer months (June, July, August).
JULYTAVG	Average daily air temperature (Celsius) for July.
AUGTAVG	Average daily air temperature for August.
WNTMAX	Average daily maximum air temperature for winter months.
WNSRAD	Average daily solar radiation loading (Langleys) for winter months (December, January, February).
TDEW	Average annual daily dew point temperature.

9 subsection groups, 4 lithology groups, and 6 regional potential vegetation settings) accounted for approximately 30 percent of the species-sample and 76 percent of the species-environment variability that existed within the 337 subwatersheds sampled in this assessment (tables 2.8a and 2.8b). The 19 indirect biophysical environment variables identified in this analysis were used to produce an ecological unit classification of 7,462 6th-field subwatersheds within the Basin by a hierarchical agglomerative clustering technique (that is, hydrologic subregions were identified).

Discriminant analysis indicated that 13 direct biophysical environment variables could correctly assign 80 percent of the 6th-field subwatersheds to their indirect biophysical environment classification, thus demonstrating the strong relation that exists between indirect biophysical environment classifications (ecological units) and the direct biophysical environment variables that determine finer-scale aquatic patterns. This relation was further supported by the fact that hierarchical clustering of 6th-field subwatersheds by 13 direct biophysical variables produced exactly the same results as those obtained with 19 indirect biophysical variables. Analysis of variance indicated that subregional watershed classifications were also effective in explaining observed differences in stream type groups and management hazard ratings across all 6th-field subwatersheds. Results of this analysis indicated that ecological units (that is, indirect biophysical environments) could be effectively used to produce watershed classifications that integrate the effects of direct biophysical variables on finer-scale aquatic patterns and their associated opportunities and limitations for management. Map unit descriptions of the hydrologic subregions identified in this analysis will be provided in future publications.

Table 2.8b—Description of the primary indirect biophysical environment variables considered in subregional watershed classification of the Basin. (Composition of these variables within each 6th-code subwatershed was calculated for analysis.)

Biophysical Group	Variable Code	Description
Lithology Groupings	Litho-5	Calcareous meta-volcanics.
	Litho-8	Conglomerates.
	Litho-17	Lake sediments and playas.
	Litho-19	Loess.
	Litho-23	Mafic pyroclastics.
	Litho-25	Mafic volcanic flows.
	Litho-26	Metamorphosed conglomerates.
	Litho-32	Mixed eugeosynclinal materials.
	Litho-36	Sandstone.
	Litho-40	Ultramafic materials.
Subsection Groupings	342-02	Basalt plateaus with coarse-textured soils.
	342-03	Lacustrine plateaus with fine-textured soils.
	342-04	Alluvium intermontane basins with medium-textured soils.
	342-05	Volcanic tuff foothills with medium-textured soils.
	M242-01	Glaciated, igneous and sedimentary mountains with medium-textured soils.
	M242-02	Ash mantled, basalt plains with fine-textured soils.
	M242-04	Alluvium intermontane basins with fine-textured soils.
	M331-06	Sedimentary/volcanic mountains with fine-textured soils.
	M332-02	Granitic foothills with medium-textured soils.
	M333-03	Glaciated mountains with medium-textured soils.
Potential Vegetation Settings	FCD	Forestlands - cold, dry
	FCW	Forestlands - cold, wet
	FHD	Forestlands - hot, dry
	FHW	Forestlands - hot, wet
	HHW	Herbaceous lands - hot, wet
	SCW	Shrublands - cold, wet
	SHD	Shrublands - hot, dry

Stream Type Settings

The morphology of a natural stream channel is a function of current climate and the landform, lithology, and vegetation through which the stream flows. These biophysical patterns determine the streamflow regime, types of valley fill materials, channel substrate, and slopes of valley bottoms and stream channels. The morphology of a stream reach, in turn, determines the type and distribution of finer-scale, in-channel, habitat features such as pools, riffles, and glides; the interaction of the channel with its bed and floodplain; the dissipation of flood energy; and the ability of a stream to transport its sediment load.

Several methods exist for classifying stream channels. Many of these classification methods share similar parameters such as: valley width, valley slope, channel slope, channel planform, channel width and depth, and substrate materials (Maxwell and others 1995, Montgomery and Buffington 1993, Rosgen 1994). In this analysis, Rosgen stream types (Rosgen 1985, 1994) were used to classify streams interpreted from current and historic aerial photo coverage of subsampled watersheds and to estimate the distribution of grouped stream types across the Basin. The Rosgen stream type classification method was used because of its practicality (Minshall 1994) and its prior extensive use by BLM and FS personnel. This classification system also provides interpretations for stream types that are very useful in watershed analysis (Rosgen 1994).

The Rosgen stream type classification system is hierarchical. For example, level I of this system primarily uses stream planform pattern, stream longitudinal profile, and valley and landform characteristics that can be derived from aerial photography and topographic maps to classify streams as A, B, C, D, E, F, G, or DA types (Rosgen 1994). The morphology of level I stream types is illustrated in figure 2.3. Level II of this classification system requires additional field knowledge of parameters such as stream substrate size, bankfull width and depth, and entrenchment ratios. These additional parameters permit more refined interpretations of stream channel stability, sediment regime, and recovery potential. Channel substrate material is a particularly important parameter, and can generally be inferred from soils and geologic maps (Rosgen 1994) or customized watershed classifications (Jensen and others in press).

In this analysis, stream types were defined using modifications of Rosgen's (1994) classification methods. Three modifications were used to accommodate different data sources and types of analyses:

- Stream types A, B, and C: Channel habitat data from fisheries inventories across the Basin were aggregated into these three stream types, using valley slope and valley width criteria. Available fisheries inventory did not permit refinement of the Rosgen (1994) classification to reflect stream braiding or entrenchment of the channel within its valley (that is, stream types D, DA, E, F and G could not be identified). Preliminary tests of channel unit data indicated fair to good agreement between classified A, B, and C types and field estimates of similar stream types made by FS biologists. These A, B, and C stream types corresponded roughly to the source, transport, and response reach designations as defined by Montgomery and Buffington (1993). In terms of slope and valley criteria, source reaches would be classified as an A stream type; transport reaches would be classified as B, G, and D stream types; and response reaches would be classified as C, E, DA, and F stream types. Relative to these source, transport, and response designations, the level I Rosgen classification system provided more interpretations for management. For example, although B, G, and D stream types can all exist on a 2 to 4 percent slope, they respond very differently to changes in streamflows and sediment loads.
- Level I stream types A through G: Synoptic aerial photo coverage (1:20,000 to 1:12,000 scale) of 357 subsampled 6th-field subwatersheds were interpreted to estimate the distribution of stream types within each subwatershed. In

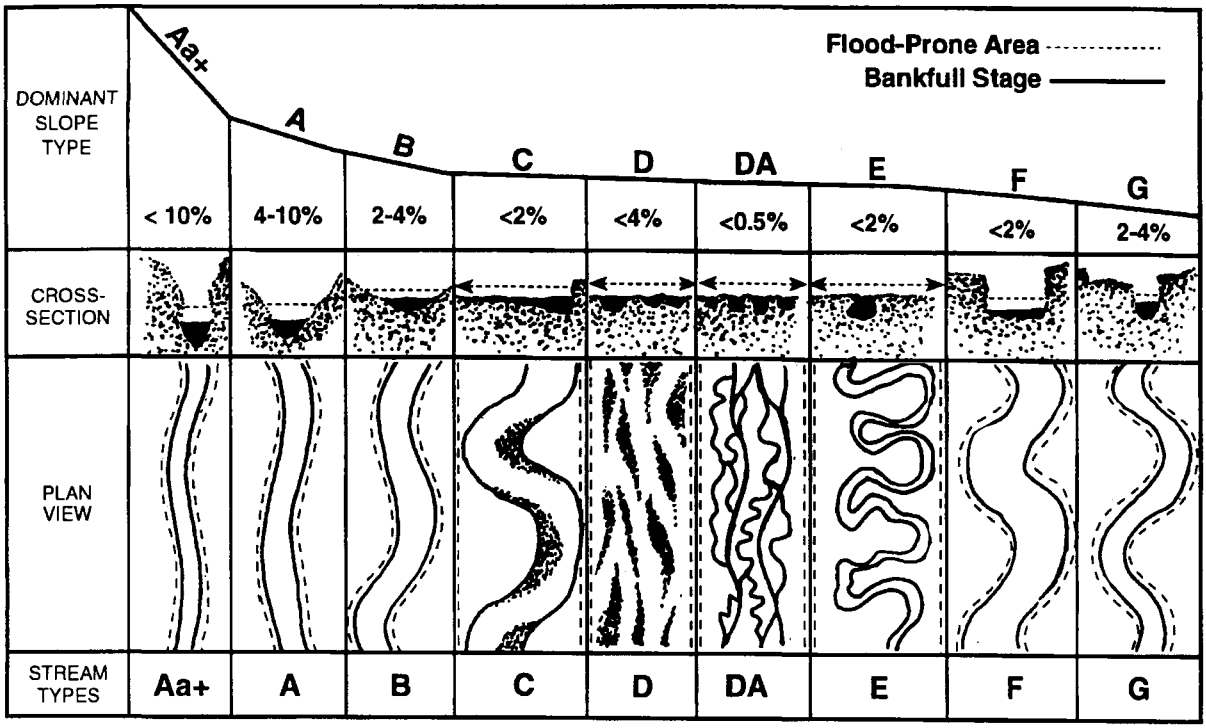


Figure 2.3—Longitudinal, cross-sectional, and plan views of major stream types (after Rosgen 1994).

addition, these photo interpretations recorded the presence of channelized streams, wetlands, beaver dams, and lakes (Brewer and others, in press b). Photo-interpretation results were checked for errors in application of classification rules (for example, the identification of an E stream type which was defined as a very low-gradient, highly sinuous channel on valley slopes of greater than 10 percent, and vice versa) throughout the photo-interpretation process. The photo-interpreted stream types characterized in this effort have not been field verified. Data from this sampling effort were used primarily in the development of sub-regional scale watershed classifications.

- Stream type groups 0-17: Level II of Rosgen's (1994) stream classification identified 42 stream types [that is, 8 alpha-types of Aa through G; and 6 subdivisions denoted numerically (1-6) that describe dominant channel materials, varying from bedrock to silt]. For this analysis, these 42 stream types were aggregated into 18 groups, based on similarities in morphology and channel materials, and hence, similarities in sensitivity to changes in streamflow and sediment. Table 2.9 outlines the relations among stream type groups, individual stream types, characteristic landform and geology, bedforms, energy and gradient characteristics, characteristic mode of stream adjustment, and in-channel and riparian habitat characteristics.

The probable distribution of stream type groups was estimated continuously across the Basin through various subject matter expert workshops and subsequent GIS modeling. The GIS map

Table 2.9—Description of the stream type groups used in the hydrologic characterization of the Basin.

Stream Type Group Code	Individual Stream Types	Characteristic Landform, Geology	Bedform	Energy/Sediment Characteristics	Characteristic Mode of Adjustment	In-channel and Riparian Habitat Characteristics
00	A1, A2	Structurally controlled, such as faults and bedding planes; talus, glacial moraines, lag deposits.	Step/pool & cascades; pools irregularly spaced at about 2-3 widths.	High energy, dissipated by frictional resistance from bedrock and boulders. Low sediment supply; low bedload; low sediment storage.	Morphology minimally affected by changes in flow or sediment, but LWD important to increase pools and sediment storage.	Steep (e.g., 10% + can act as barriers to fish migration. Discharges up to approx. 50 yr. R.I. inundate only narrow zone adjacent to stream.
01	A3	Glacial moraines & tills; alluvial fans; lag deposits; slide debris; tributaries incised in terraces.	Step/pool & cascades.	High energy, dissipated against bed and banks. High sediment supply; high bedload supply and transport.	Stores large volume of sediment in pools and behind LWD. Episodic inputs of sediment. Steep forms (>10%) associated *with debris avalanches and mass* wasting processes.	Same as above.
02	A4, A5	Debris fans; outwash fans; residual soils from weathered granitic and sedimentary rocks; glaciofluvial, deltaic, lacustrine, eolian deposits.	Step/pool & cascades.	High energy; high sediment supply; high sand bedload. Potentially high sediment storage behind LWD.	Bank erosion, channel rejuvenation common.	Same as above.
03	A6	Glacio-lacustrine; deltaic deposits; fine alluvium.	Step/pool & cascades.	High energy; high suspended washload; low bedload; low sediment storage.	Frequent collapsing of banks and bank erosion due to negative pore water pressure and liquefaction.	Same as above.
04	B1, B2, B3	Typically incised within narrow colluvial or structurally controlled valleys; coarse alluvium, colluvial materials, lag deposits from glaciation; *residuum from resistent lithologies.*	Step/pool; pools often erratically spaced, but at approx. 4-5 widths. Rapids predominate.	Moderate energy; low sediment supply; good sediment transport.	Very stable; aggradation and degradation processes are rare.	LWD important for creating pools for fisheries habitat. Discharges up to approx. 50 yr. RI inundate moderately wide *zone along stream.*
05	B4, B5, B6	Narrow valleys, often on rolling colluvial slopes, sometimes bounded by gently sloping pediments; associated with grussic granites, residual soils, aeolian deposits.	Step/pool; dominated by rapids and scour pools.	Moderate energy; low amounts of channel derived sediment; good sediment transport capacity; infrequent sediment deposition. Finer grained channels characterized by washload rather than bedload.	Finer-grained channels require good bank vegetation to maintain width/depth ratio.	Channels in good condition maintain pools; rapids maintain aeration. Discharges up to approx. 50-yr. RI inundate moderately wide zone along stream.
06	C1, C2	Bedrock within broad valleys; coarse deposition from past extreme flows.	Riffle/pool with pool spacing approx. 6-7 bankfull widths.	Moderate energy; high roughness due to coarse bed and meanders.	Adjusts laterally within adjacent floodprone areas; modern stream flows rarely entrain dominant bed materials.	Good connection with floodplain processes.
07	C3	Unconsolidated lag deposits or coarse colluvium within broad valleys.	Riffle/pool with pool spacing approx. 6-7 bankfull widths.	Moderate energy; moderate sediment supply.	Adjusts laterally, rates depends on type and extent of riparian vegetation.	Well-developed floodplain. Area frequently inundated by moderate floods maintains good *connection with riparian* vegetation process.

Table 2.9 (continued).

Stream Type Group Code	Individual Stream Types	Characteristic Landform, Geology	Bedform	Energy/Sediment Characteristics	Characteristic Mode of Adjustment	In-channel and Riparian Habitat Characteristics
08	C4, C5, C6	Broad alluvial valleys, often bounded by Holocene terraces, Valley fill is coarse alluvium to fine depositional materials (for example deltaic, lacustrine, ash, silts, clays).	Riffle/pool. Pool spacing approx. 5-7 bankfull widths.	Moderate energy; high sediment supply from channel. Sediment often redeposited within channel.	Adjusts both laterally and vertically in response to increased flows or loss of riparian vegetation. Bank erosion common, with accompanying lateral adjustments, and increases in width/depth ratio. Excessive sediment deposition can shift channel to braided form. Rates of adjustment depend on type and extent of riparian vegetation.	When in good condition represents "classic" meandering alluvial channel, with good connection to riparian vegetation and floodplain processes. Substrate is gravel to silts; pools can silt up if disturbed.
09	D3, D4 D5, D6	Broad alluvial valleys; associated with distributary channels, deltaic features, alluvial fans on steep terrain. Valley fill material varies from coarse to fine alluvium or lacustrine materials.	Closely spaced rapids and scour pools formed through converging &, diverging flows.	High energy, high sediment supply; very active deposition and erosion of channel bars.	Bank erosion and lateral adjustments occur frequently with runoff events. Aggradation via excessive deposition of longitudinal and transverse bars is common. Once established braided patterns tend to dominate modern river; unless upstream sediment supply is removed.	Pattern of rapids and scour pools is very unstable; runoff can disrupt spawning beds.
10	All DA	Broad, low gradient, tectonically active basins undergoing vertical accretion. Often associated with extensive wetlands in cohesive sediments.			Very stable; river builds silt-rich levies that often have herbaceous or forest vegetation. Channels respond to disturbance as individual channels. Adjustments are infrequent, but usually occur laterally, via channel avulsion or abandonment.	Numerous side channels, meanders, and accessible overwintering areas associated with wetlands and ponds. Good connection with riparian vegetation and floodplain processes.
11	E3, E4, E5, E6	Found at all elevations in broad alluvial valleys, although especially common in high mountain meadows.	Riffle/pool.	High energy at high streamflows. Low sediment supply (if riparian vegetation is present); very high sediment transport capacity.	Very stable in absence of disturbance; highly sinuous planform maintains bed elevation without downcutting. Increased flows or disturbance to banks can trigger adjustments via increases in width depth ratio, channel straightening, and increased channel gradient.	Shaded, undercut banks, generally fast flow. Good connection with riparian vegetation and floodplain processes.

Table 2.9 (continued).

Stream Type Group Code	Individual Stream Types	Characteristic Landform, Geology	Bedform	Energy/Sediment Characteristics	Characteristic Mode of Adjustment	In-channel and Riparian Habitat Characteristics
12	F1, F2	Deeply entrenched in bedrock or boulders within broad valleys or plains. Channel is often geologically old.	Riffle/pool.	Moderate energy; low sediment from bed and banks; low sediment deposition.	Very stable; often acts as upstream grade control.	Pools generally not as deep due to low sinuosity and trapezoidal channel form. Poor connection with floodplain due to entrenchment of channel.
13	F3	Entrenched in coarse depositional alluvium; often found in terrace-bounded alluvial valleys, deltas, and coastal plains.	Riffle/pool.	Moderate energy; dissipated against bed and entrenched banks. High bedload of coarse cobble/ gravel bedload. Some deposition of channel bars.	Active bank erosion adds to channel sediment supply. Channel bars are common and create hydraulic stress on banks.	Same as above.
14	F4					
15	F5, F6	Entrenched in sandy, lacustrine deposits; often found in terrace-bounded alluvial valleys, deltas and coastal plains.	Riffle/pool.	Moderate energy; dissipated against unstable, entrenched banks and bed. Very high channel-derived sediment; low bedload. Generally low sediment transport capacity.	Very unstable vertically and laterally. Bank erosion occurs via fluvial entrainment, mass wasting, bank saturation, and collapse. Sediment deposition is common; eventually creating a floodplain within the bankfull channel. Remainder sediment transported downstream. Banks composed of cohesive, fine-grained soils can be quite stable if deep-rooted riparian vegetation is maintained.	Same as above, except substrate is sand and silt. Disturbance can cause fining and siltation at site and downstream.
16	G1, G2	Incision into bedrock, narrow gorges; controlled by faults or joints; or within coarse alluvial fans, landslide debris; debris wedges below talus fields; colluvial deposits.	Step/pool with erratic spacing.	Moderate energy; high channel-derived sediments; high sediment transport capacity. Bedload often exceeds 50% of total sediment load.	Very stable channel; transfers watershed-derived sediment downstream.	Gully-like channel; poor connection with riparian vegetation or flood plain processes due to channel entrenchment.
17	G3,G4, G5,G6	Depositional, Unconsolidated cobbles, gravels sands; often associated with rejuvenated lateral tributaries through fluvial terraces.	Step/pool.	Moderate energy; high channel-derived sediments; high sediment transport capacity. Bedload often exceeds 50% of total sediment land.	Vertical and lateral instability; frequent degradation. Finer grained channels often cause grade control problems and are prone to excessive bank erosion.	Same as above; in addition disturbance can cause shifting and fining at site and down-stream.

themes used to stratify the Basin into areas having similar channel forming processes and, therefore, similar stream type group compositions included:

- Continuous geoclimatic subsection group maps that were used to describe similarities in climate, potential vegetation, and geomorphic processes and valley fill materials across the Basin.
- Classification maps of slopes by four classes (0-10%, 11-30%, 31-50%, >50%) that were displayed within each subsection group polygon.
- 1:100,000 hydrography intersected with the subsection group/slope class maps.

A panel of FS, BLM, NRCS, and USGS hydrologists (chosen on the basis of their familiarity with stream types and extensive field experience within the seven provinces of the Basin) reviewed this GIS product, and on the basis of their field experience estimated the composition of the dominant stream type groups that occurred within the four slope categories of each subsection group. The objective of this estimation procedure was to identify the probable distribution of dominant stream type groups throughout the Basin to discriminate among watersheds on the basis of their similarities and differences. No attempt was made to identify rare or locally "vulnerable" stream types in this assessment. Due to time constraints, the estimated distributions of stream type groups were not verified in the field or with existing data. These stream groupings, however, showed statistically significant differences among hydrologic subregions as classified on the basis of direct biophysical environment variables expected to influence channel form (Jensen and others in press). Stream type group compositions of subsection/slope class maps were associated by GIS to each 6th-field subwatershed of the Basin to facilitate subsequent hydrologic analysis of subbasins and subwatersheds.

The implications for management associated with the stream type groups used in this study follow Rosgen (1994) and are displayed in table 2.10. These resource interpretations include sensitivity of the channel morphology to increases in streamflow and sediment, the potential of the channel to recover following disturbance, the characteristic supply of suspended and bedload sediment from channel-derived sources and stream-adjacent slopes, streambank erosion potential, and the contribution of riparian vegetation to maintaining characteristic width/depth ratios (Rosgen 1994). For analysis purposes, these resource interpretations were converted to a numerical scale, as follows: very low (very poor) = 0, low (poor) = 25, moderate (fair) = 50, high (good) = 75; and very high (very good, excellent) = 100. The percent composition of each stream type group and its corresponding numerical ratings were used in assigning weighted average scores (that is, values from 0 to 100) to each subsection group/slope class setting. These values were then associated to each 6th-field subwatershed of the basin based on a weighted average of the subsection group/slope class composition (and their related scores) within each subwatershed (see Appendix 2A).

Ecological Process Interpretations

Various ecological process interpretations were associated to the different biophysical environment maps described in this document. The primary map themes used in associating this information to other biophysical environments (for example, 6th-field HUCs) were subsection/slope class maps for most soil erosion, mass failure, debris avalanche, and sediment hazard ratings; and subsection group/slope class maps for stream channel sensitivity and resiliency ratings. DEM data (90m) were used to create slope class (that is, 0-10%, 11-30%, 31-50%, and greater than 50%) vector maps of subsections and subsection groups in this analysis.

Information generated from the different types of ecological process modeling described below was summarized by 4th- and 6th-field HUCs for use in a variety of subbasin and subwatershed assessment efforts. A listing and brief description of the ecological process interpretations that were generated for each 4th- and 6th-field HUC in this project are presented in Appendix 2A of this chapter. Due to the fact that the types of information available to this project for calculation of many of the interpretations were not appropriate to landscape (or finer) levels of application, relative ratings of

Table 2.10—List of stream type groups identified within the Basin and their associated management interpretations (follows Rosgen 1994).

Stream Group Type	Stream Types	Sensitivity to Disturbance	Recovery Potential	Sediment Supply	Streambank Erosion Potential	Vegetation Controlling Influence
SG-00	A1, A2	Very low	Excellent	Very low	Very low	Negligible
SG-01	A3	Very low to very high	Very poor	Very low to very high	Very low to very high	Negligible
SG-02	A4, A5	Very high to extreme	Very poor	Very high	High to very high	Negligible
SG-03	A6	High	Poor	High	High	Negligible
SG-04	B1, B2, B3	Very low to low	Excellent	Low to very low	Low to very low	Negligible to moderate
SG-05	B4, B5, B6	Moderate	Excellent	Moderate	Low to moderate	Moderate
SG-06	C1, C2	Low	Very good	Low to very low	Low	Moderate
SG-07	C3	Moderate	Good	Moderate	Moderate	Very high
SG-08	C4, C5, C6	Very high	Fair to good	High to very high	High to very high	Very high
SG-09	D3, D4, D5, D6	High to very high	Poor	High to very high	High to very high	Moderate
SG-10	DA4, DA5, DA6	Moderate	Good	Low to very low	Low to very low	Very high
SG-11	E1, E4, E5, E6	High to very high	Good	Low to moderate	Moderate to high	Very high
SG-12	F1, F2	Low	Fair	Low to moderate	Moderate	Low
SG-13	F3	Moderate	Poor	Very high	Very high	Moderate
SG-14	F4	Extreme	Poor	Very high	Very high	Moderate
SG-15	F5, F6	Very high	Poor to fair	High to very high	Very high	Moderate
SG-16	G1, G2	Low to moderate	Fair to good	Low to moderate	Low to moderate	Low
SG-17	G3, G4, G5, G6	Very high to extreme	Very poor to poor	High to very high	High to very high	High

interpretive values were often calculated for broader scale use. Cumulative frequency distributions of actual 4th- and 6th-field HUC interpretation scores were calculated across different comparison areas in the development of the relative ratings (for example, each subwatershed was assigned a percentile number between 0 and 100 that reflected the percent of other subwatersheds within the comparison area that had an equal or lower value for a given type of interpretation). Comparison areas used in the generation of relative interpretation values included the Basin, geoclimatic provinces, ERUs, rangeland theme environments, and forestland theme environments.

The following is a brief description of the methods used in calculating biophysical environment-based ecological process interpretation ratings for the Basin.

Soil Erosion, Mass Failure, and Sedimentation

Various soil erosion, mass failure, and sediment hazard ratings were developed for each subsection following general procedures described in "An Approach to Water Resources Evaluation of Nonpoint Silvicultural Sources" [a procedural handbook (WRENS)] (Environmental Protection Agency 1980) with required modifications to facilitate use of general erosion/sediment process models at broader spatial scales. These hazard ratings and their primary input variables were also associated with each 6th-field watershed to facilitate development of affected environment descriptions and scenario projections of erosion and sediment processes by watershed classifications and ERUs. Such information was also used in developing descriptions of relative erosion and sediment hazard differences across the Basin. Use of absolute values concerning soil erosion and sediment was considered inappropriate due to the broad scale (such as subsections) at which these processes were modeled. Instead, the relative differences in these processes across the various subbasins or subwatersheds of a given comparison area (such as an ERU) were used in related assessment efforts. The following is a brief description of the approaches used in determining soil erosion, mass failure, and sedimentation ratings across the Basin.

Soil Erosion

Broad- and mid-scale analysis of surface soil erosion hazard used an approach similar to the U.S. Environmental Protection Agency's (EPA) Modified Universal Soil Loss Equation (MUSLE). In this model (EPA 1980), surface soil erosion in tons per acre per year was estimated based on slope/length (LS), soil erodibility (K), rainfall intensity (R), and vegetation management (cover) (VM). The vegetation management factor of the MUSLE was the only parameter that changed under the different alternatives and scenarios evaluated in this project. In the case of roads or large stand-consuming fires, the VM factor was set to 1 in MUSLE calculations (that is, no ameliorating effect from vegetation cover). The 90-meter DEM data were assigned to four slope classes (0-10%, 11-30%, 31-50%, and greater than 50%) and stored by midpoint of the slope classes in initial calculation of slope for the model. The slope/length factor (LS) of the MUSLE was assigned to each midpoint value using a default slope length of 90 meters. Slope classes were overlain on subsection maps to derive a vector map of subsection/slope phases for subsequent erosion predictions. This map served as the primary erosion modeling unit with other MUSLE variables attributed to this theme.

The soil erodibility factor (K) of the MUSLE was estimated for each subsection based on its dominant surficial geology and modified (if appropriate) based on local soil knowledge. Five classes of K values were used in this analysis. The rainfall factor (R) of the MUSLE used the long-term average 30-minute storm intensity that was displayed as a vector map. This map was obtained from the NRCS for this project. The baseline vegetation management (VM) factor of the MUSLE was

calculated based on canopy cover, ground litter cover, and ground bare soil cover values that were associated with broad-scale vegetation cover type classifications. Cover types, determined by using the Normalized Difference Vegetation Index from AVHRR satellite data, were used as baseline VM factor input (that is, version one of the broad-scale existing vegetation map was used in displaying cover types for erosion modeling). For the broad-scale analysis, estimated baseline erosion rates in tons per acre per year were summarized to subsection/slope phases and as weighted averages to 4th-field subbasins. These same parameters were used for mid-scale analyses; however, in this situation, weighted averages of subsection/slope phase values were associated to each 6th-field subwatershed.

CRBSUM scenario projections for changes in vegetation cover type patterns were used to assign new vegetation management factors to each subbasin (4th-field HUC) or subwatershed (6th-field HUC) based on a weighted average of the vegetation types present. Erosion rates were recalculated to reflect changes in vegetation in such analyses. Average density of road networks were assigned to a watershed in some analyses, and the attributes for vegetation management (VM) were modified accordingly (that is, set to 1.0, no influence). Erosion rates were recalculated in terms of erosion rate per mile of road to reflect initial road density effects on surface erosion.

Road erosion hazard ratings were also calculated for each subbasin and subwatershed based on groupings of lithology and their relative erosion rates following road construction.

Various maps of relative soil erosion hazard were produced in this project for different types of assessment needs and contextual settings. For example, map 2.9 displays the nonvegetated surface soil erosion hazard of subbasins (4th-field HUCs) across the assessment area. In constructing this map, the actual value for this interpretation by each subbasin was converted to a cumulative frequency distribution percentile (that is, from 0 to 100), which expressed the percent of other subbasins within the Basin that had the same or smaller value for the interpretation. The classes displayed on this map are a grouping of these cumulative frequency numbers as follows: low (0-25), low to moderate (26-50), moderate to high (51-75), and high (76-100). A similar convention was used in producing the other relative interpretation maps.

The nonvegetated surface soil erosion hazard map (map 2.9) illustrates relative differences across the Basin when all vegetation cover is removed from a site. This type of characterization displays how erosion relations may change in an area following large-scale stand replacement fires. A more realistic description of current relative surface soil erosion differences across the Basin is illustrated in map 2.10 which considers existing vegetation cover in erosion hazard estimation.

Mass Failure

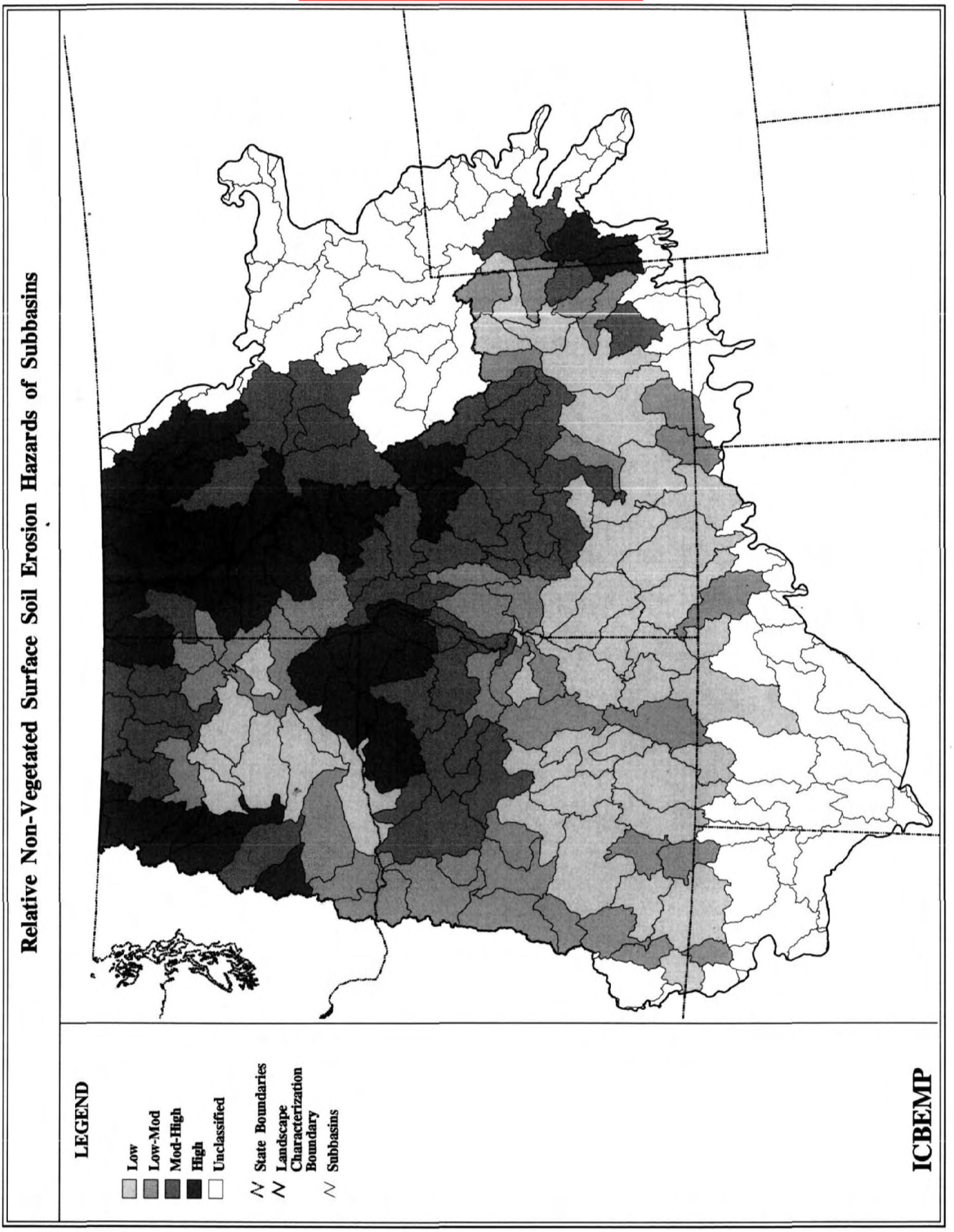
Broad- and mid-scale analyses of debris avalanches and earthflow hazards used similar parameters and approaches to those identified in surface soil erosion hazard analysis; however, parameter weights were adjusted to follow suggested WRENS procedures. Specific parameters used in earthflow hazard calculation included slope, probable soil texture and permeability, and average annual precipitation. Parameters used in debris avalanche hazard calculation included slope and average annual precipitation.

Baseline debris avalanche and earthflow hazard ratings were assigned to each subbasin and subwatershed of the Basin by overlaying the model output (that is, low, medium, and high hazard) to the base subsection/slope phase unit map and calculating a weighted average of these values for each subbasin and subwatershed. Relative differences in these hazard ratings across subbasins are presented on map 2.11 for earthflow and map 2.12 for debris avalanche.

Continue

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Map 2.9—Relative non-vegetated surface soil erosion hazards of subbasins.

Map 2.10—Relative vegetated surface soil erosion hazards of subbasins.

Map 2.11—Relative earth flow hazards of subbasins.

Map 2.12—Relative debris avalanche hazards of subbasins.

Sedimentation

Broad- and mid-scale analyses of sediment delivery hazard were based on a potential sediment delivery index, which was used to adjust both nonvegetated and vegetated surface soil erosion hazard values to better reflect the probability of hillslope erosion reaching a stream network.

Sediment delivery potential indices were calculated for each subbasin and subwatershed of the Basin by:

- Overlaying the 1:100,000 scale hydrography map onto each subwatershed delineation and calculating its drainage density.
- Calculating the average slope of each delineation with 90-meter DEM data.
- Multiplying drainage density by the average slope of each delineation to obtain its initial sediment delivery index.

These HUC sediment delivery index values were, in turn, converted into a cumulative frequency distribution number between 0 and 100 that reflected the percent of other subbasins or subwatersheds with the same or lower index value.

These relative sediment delivery index scores were then multiplied by the average nonvegetated or vegetated surface soil erosion hazard value of each subbasin or subwatershed in determining its sediment delivery hazard. In this approach, the estimated erosion rate of an area was adjusted based on its steepness and dissection characteristics in the calculation of sediment that might possibly reach a stream. For example, areas with high hillslope erosion and gentle slopes with low dissection commonly displayed lower sediment delivery hazard scores than those with moderate hillslope erosion and steep slopes with high dissection. Relative differences in these ratings across subbasins are presented for sediment delivery potential (map 2.13), nonvegetated sediment delivery hazard (map 2.14), and vegetated sediment delivery hazard (map 2.15).

The road erosion hazard ratings mentioned above were also adjusted in this analysis based on relativized sediment delivery potential ratings. Map 2.16 displays the basic differences in road erosion hazard across the Basin based on the lithologic composition of each subbasin. These relationships changed, however, when road sediment delivery hazard was considered (map 2.17) due to the effects that slope and dissection have on sediment hazard ratings.

Hydrologic Function

Peak Flows

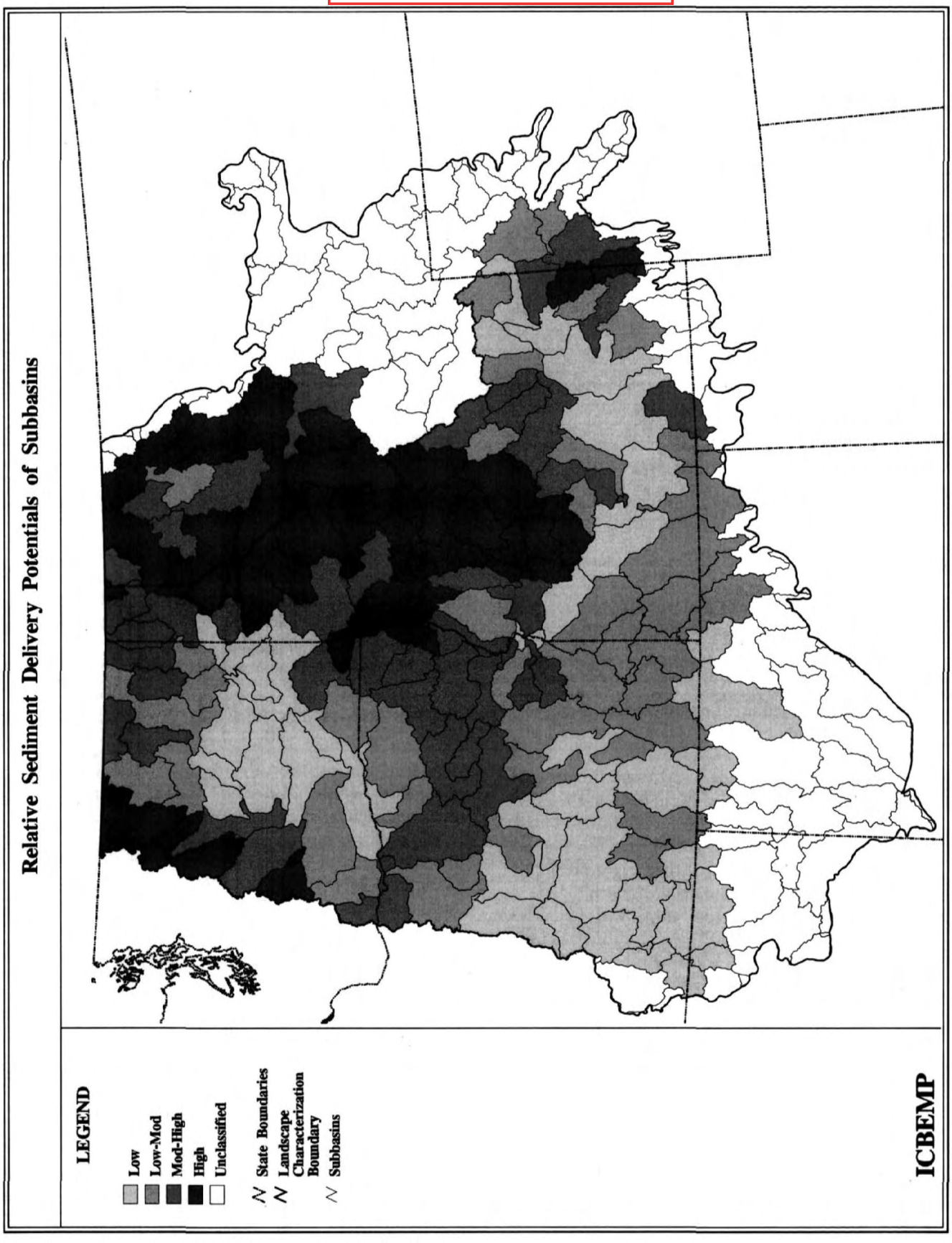
Streamflow discharges associated with frequent floods (those having recurrence intervals of approximately 1 to 10 years) strongly influence channel morphology, the interaction of the stream channel with its floodplain, and the temporal character of instream habitats (Eash 1993, Nash 1994, Poff and Ward 1989, Leopold and others 1963). In this analysis, several measures were used to characterize 6th-field subwatersheds in terms of flood flows and drainage characteristics. These measures included drainage density; the intensity of the expected 2-year, 24-hour storm event; and the expected discharge associated with a 10-year flood.

Drainage density affects the routing and timing of flood flows within a watershed. Relative drainage density characteristics were estimated from 1:100,000 hydrography for each of the approximately 7,500 6th-field subwatersheds within the assessment area. The 2-year return interval, 24-hour storm event describes the amount of precipitation that an area can be expected to receive within a 24-hour interval, every 2 years, on average. While this precipitation cannot be directly linked to a 2-year recurrence interval flood discharge, its use as an indirect, relative surrogate for a 2-year flood flow has been proposed for use in other watershed analyses (Eash 1993, Washington Forest Practices 1993). Regionalized flood equations applicable to the Basin have been developed (Jennings and others 1994), but do not include

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Map 2.13—Relative sediment delivery potentials of subbasins.

Map 2.14—Relative non-vegetated sediment delivery hazards of subbasins.

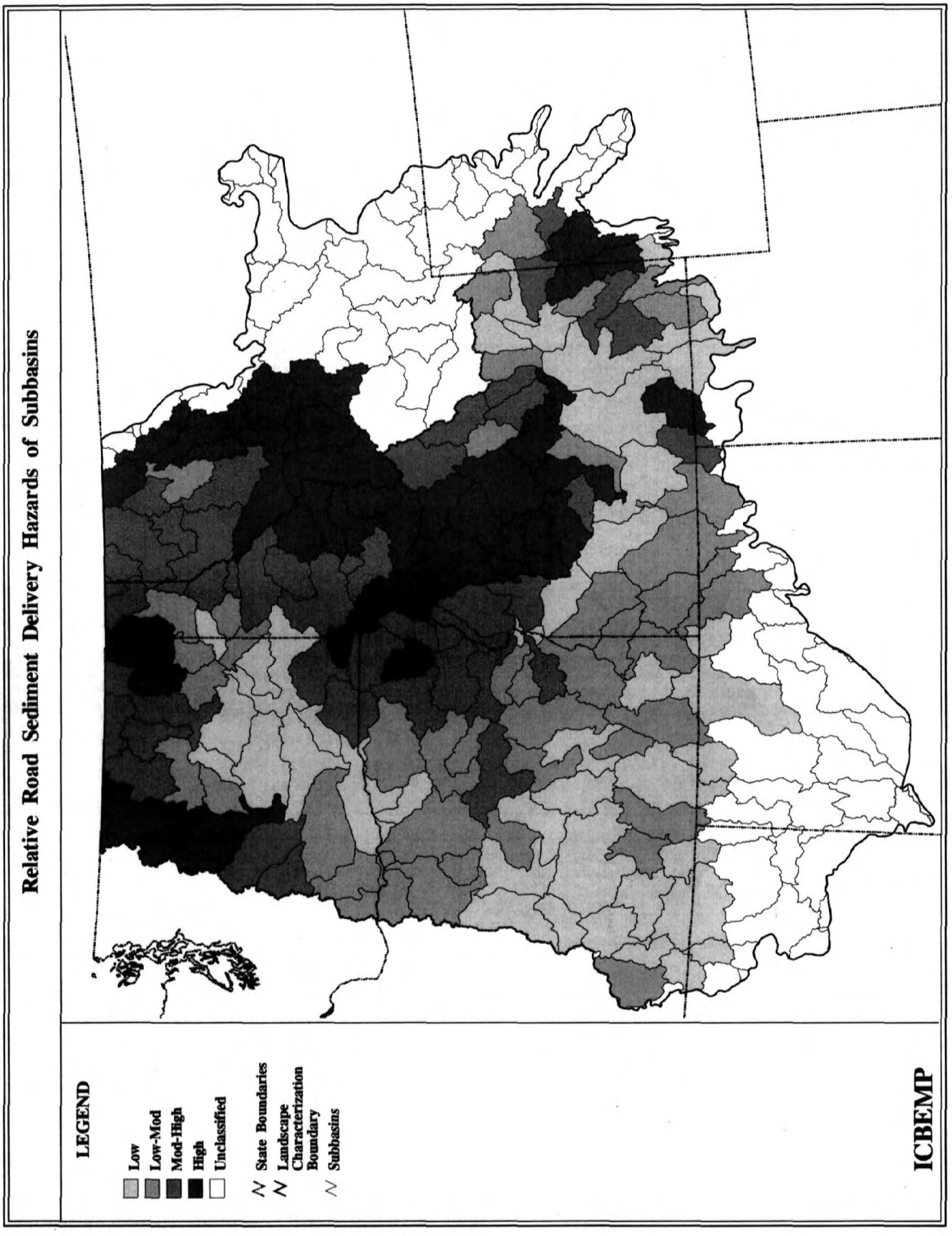
Map 2.15—Relative vegetated sediment delivery hazards of subbasins.

Map 2.16—Relative road erosion hazards of subbasins.

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Map 2.17—Relative road sediment delivery hazards of subbasins.

estimation methods for a 2-year flood flow continuously across the Basin. Consequently continuous estimation of the 2-year return interval 24-hour rainfall developed from weather atlases (Miller and others 1973) was used as a surrogate measure in this analysis. Within the study area, the depth of the estimated 2-year 24-hour rainfall varied from 1.8 centimeters in the Columbia Plateau and the Snake River Plain, to 17.8 centimeters along the eastern crest of the Cascade Mountains.

In describing flood discharges most associated with channel morphology and flood plain interactions in this study, Nash (1994) calculated the discharge associated with the 10-year recurrence interval flood for the pour-point of each subwatershed within the Basin using regionalized regression equations (Jennings and others 1994). Within the study area, the streamflow discharge associated with the 10-year flood event varied from 1.42 cubic meters per second in certain subwatersheds within the interior of the Basin, to 124.52 cubic meters per second for some subwatersheds located along the Snake and Columbia Rivers.

Drainage density, 2-year 24-hour storm event, and estimated 10-year flood discharge values were attributed to each subwatershed for use in hydrologic subregion classification efforts. Each of these variables was found to be highly significant in explaining variations in valley bottom forms and stream types within the hydrologic subregions identified for the Basin (Jensen and others in press).

Runoff Characteristics

Streamflow characteristics control many important structural attributes of streams, such as habitat volume, current velocity, channel morphology, substrate stability, and inundation of floodplains (Poff and Allen 1994). Streamflow fluctuations and overbank flows are the primary sources of environmental variability and disturbance to stream environments (Stanford and Ward 1983).

To estimate the reference variability of streamflow conditions, this analysis characterized the streamflow regimes of 128 gauge stations within the Basin. These stations were selected because they represented, as nearly as possible, unregulated streamflow regimes and because they had daily streamflow data over at least a 20-year period of record.

Fourteen measures of streamflow variability were calculated for this analysis:

- Baseflow index (defined as the ratio of the lowest daily flow to the average daily flow).
- Coefficient of variation in flow (defined as the average of the ratios between annual mean daily flow and the standard deviation of daily flows).
- Predictability of flow (an index of constancy and periodicity of flows).
- Flood frequency (defined as the average number of discrete flood events per year having a magnitude equaling or exceeding the discharge associated with an expected recurrence interval of 1.67, based on a log-normal distribution using annual peak flows). This flood frequency is often associated with bankfull stage, but such stage may vary regionally and with climate.
- Interflood interval (defined as the average number of days between individual flood events).
- Flood duration.
- Seasonal predictability of flooding (defined as the maximum proportion of floods over the period of record that fall in any 60-day "seasonal window").
- Timing of flooding (the day of the water year marking the beginning of the 60-day period having the most predictable floods).
- Seasonal predictability of non-flooding.

- Extent of intermittent flow.
- Low flow frequency (defined as the average number of discrete low flow events per year having a magnitude less than a 5-year low flow value).
- Seasonal predictability of low flows.
- Timing of low flows.
- Seasonal predictability of non-low flow [defined as the maximum proportion of the year (number of days divided by 365) during which no greater than 5-year return interval low flows have ever occurred over the period of record].

Multivariate statistical methods (Poff and Allen 1994, Poff and Ward 1989) were used to classify the streamflow regimes from 128 gauge sites into five categories:

- 11 groundwater-dominated streams
- 55 snowmelt streams
- 40 rain on snow streams
- 22 winter rain streams
- 1 harshly intermittent stream

The high degree of engineered alterations, such as dams and water diversions within certain streams precluded the use of all gauge sites for the Basin in the characterization of streamflow regimes. Specifically, appropriate gauge stations were unavailable for the Southern Cascades ERU, Upper Klamath ERU, Northern Great Basin ERU, and Snake Headwaters ERU. In addition, the existing locations of appropriate gauges for analysis precluded characterization of watersheds of similar spatial scales. Despite these facts, the streamflow analyses conducted in this study revealed significant differences among streamflow regimes. Across the Basin, these differences included:

- Snowmelt, snow plus rain, and winter rain streamflow regimes had much higher flow regime coefficients of variation than did groundwater-dominated regimes.
- The daily streamflow of groundwater and snowmelt streams was more predictable than snowmelt and winter rain streams.
- Snow and rain streamflow regimes had higher median flood frequencies.
- Snowmelt streams had much higher seasonal predictability and the greatest flood-free period.
- Flood timing was clearly different between snowmelt streams (floods begin about May), rain-on-snow streams (floods begin in March to April), and winter rain streams (floods begin in December and January).
- Groundwater streams displayed the greatest variability in flood timing values (although not significantly different than the other runoff categories studied).
- Groundwater-dominated streams possessed the highest baseflow index, followed by snowmelt streams, winter rain streams, and rain on snow streamflow regimes.

Results of this streamflow analyses were used in the description of ERUs. These results were also used in an independent test of the hydrologic region classification that was developed based on biophysical environment similarities between 4th-field subbasins.

Stream Channel Sensitivity and Resiliency Ratings

Various stream channel sensitivity and resiliency ratings were developed to facilitate comparison of relative differences in subbasins and subwatersheds at Basin, ERU, and hydrologic subregion levels of analysis. All of these ratings were derived from the estimated composition of Rosgen (1994) Stream Type Groups within each subbasin and subwatershed (see above discussion concerning Stream Type Settings).

The weighted average scores of these resource interpretations (see table 2.10) by individual subwatershed were used to generate the hydrologic interpretation ratings described below. The following is a listing of stream channel sensitivity and resiliency ratings calculated in this analysis:

- Sensitivity to increased sediment and flow at a site.
- Sensitivity to increased sediment and flow downstream from a site.
- Sensitivity to decreased sediment and flow at a site.
- Sensitivity of streambanks to disturbance.
- Sensitivity (or dependency) of channel form to adjacent riparian vegetation.
- Recovery potential following disturbance.

Cumulative frequency distributions of average subwatershed resource interpretation scores were calculated across different comparison areas in the development of hydrologic sensitivity and resiliency ratings for this study (that is, each subwatershed was assigned a number between 0 and 100 that reflected the percent of other subwatersheds within a comparison area that had an equal or lower value for a given type of interpretation).

Maps of these relative ratings were then produced that displayed class groupings of cumulative frequency scores as follows: low (0-25), low to moderate (26-50), moderate to high (51-75), and high (76-100). Examples of these relativized hydrologic sensitivity and resiliency ratings across the Basin are provided in maps 2.18-2.21. A master watershed sensitivity index was also calculated for each subwatershed used that was based on the combined relative scores of sediment hazard without vegetation and stream recovery potential. This rating is displayed by subbasins across the Basin in map 2.22.

Vegetation Response to Climate Change

A critical part of any ecological assessment is the determination of biotic distributions and biotic-environmental relations. Rarely, however, are complete inventories of the biota within an area of interest available to managers. Statistical methods have been developed to predict biotic distributions based on correlation of biotic responses to environmental attributes. Application of developed models results in:

- Quantification of the response of species and communities to environmental driving variables.
- The ability to predict biotic distributions over unsampled areas.
- The ability to predict the effects of environmental changes on biotic distributions over large areas.

To construct effective models, environmental variables that directly constrain the distribution of species are first described. These variables are termed driving variables and include thermal, moisture, radiation, and nutrient regimes. The class of statistical models known as generalized linear models are commonly used to predict species responses to driving variables in this type of analysis (Nicholls 1989).

To assess current and predicted ecological conditions in the Basin, it was necessary to have maps of continuous distribution maps of species and communities over the entire analysis area. Such maps however, generally did not exist for the Basin or did not provide for the prediction of future distributions under a given scenario of environmental change. Therefore, the results of predictive modeling of biotic responses to climate attributes were required to map distributions of selected species and communities under current and predicted climate change in this study.

Modeling Approach

The biotic information used in modeling vegetation response to climate change consisted of presence or absence data for selected species and communities. A vegetation plot database (ECADS) that had approximately 38,000 spatially located plots assembled for this assessment was used in this modeling effort. The membership of a plot in a given class (community) was determined using threshold canopy cover levels of diagnostic species.

Map 2.18—Relative sensitivity of streams to increased sediment and flow as summarized by subbasins.

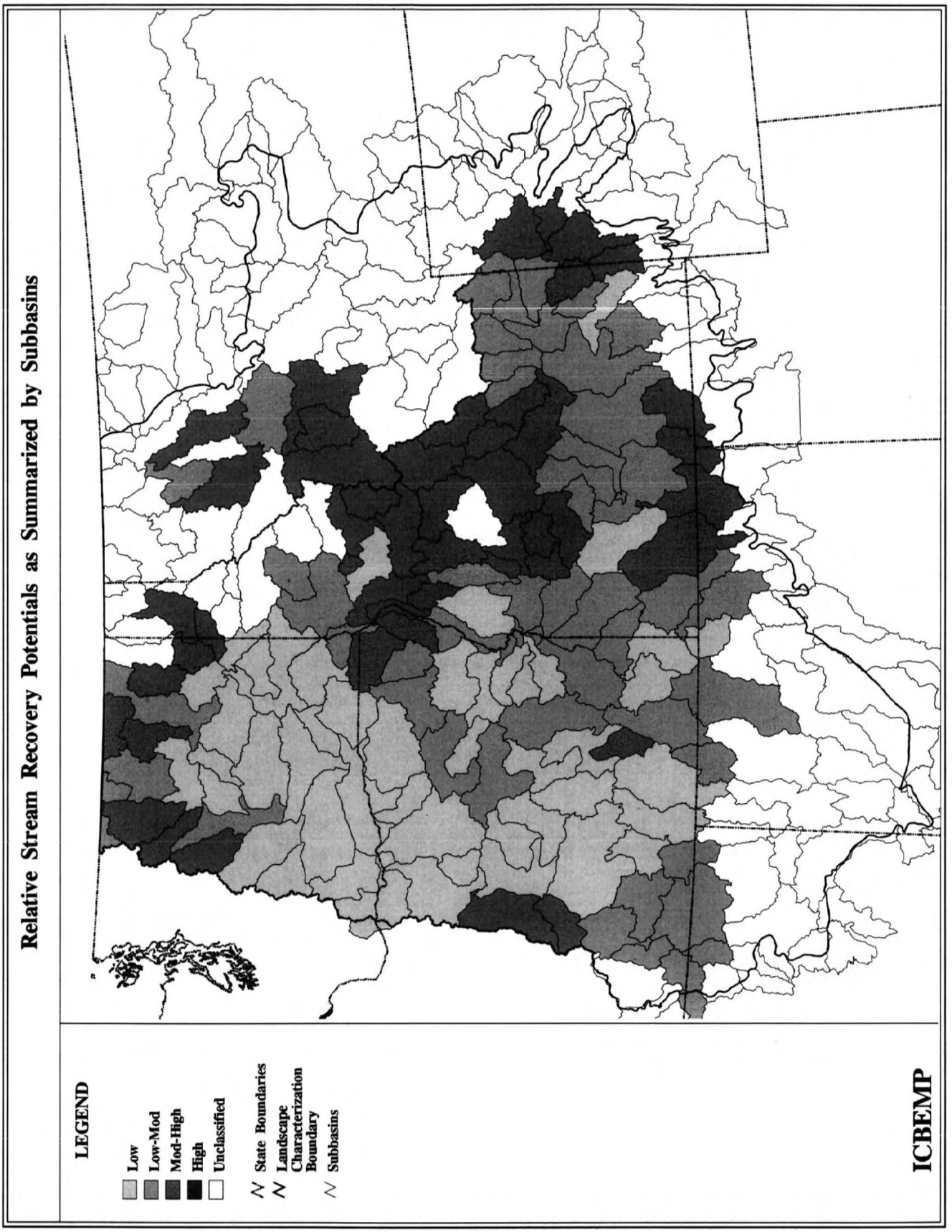
Map 2.19—Relative stream bank sensitivity as summarized by subbasins.

Map 2.20—Relative sensitivity of streams to riparian vegetation alteration as summarized by subbasins.

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Map 2.21—Relative stream recovery potentials as summarized by subbasins.

Map 2.22—Master watershed sensitivity index of subbasins.

Thresholds were derived from information contained in the existing vegetation classification (Bourgeron and Engelking 1994) used in potential vegetation mapping. Four plant species and four plant communities were selected for this predictive modeling effort in consultation with the SIT Terrestrial Staff. Species were chosen from among those listed as used by Native Americans in the interior Pacific Northwest, and included a tree, Ponderosa pine *(Pinus ponderosa),* and three shrubs: blue huckleberry *(Vaccinium membranaceum/V. globulare),* chokecherry (*Prunus virginiana),* and serviceberry *(Amelanchier alnifolia).* Communities studied included Western redcedar/queencup beadlilly *(Thuja plicata/Clintonia uniflora),* ponderosa pine/common snowberry *(Pinus ponderosa/Symphoricarpos albus),* big sage *(Artemisia tridentata)* series, and subalpine fir/bluejoint *(Abies lasiocarpa/Calamagrostis canadensis).*

Environmental variables used in species distribution modeling included daily values for temperature, precipitation, and solar radiation, which were available for a normal year (1989) and for a climate change scenario (doubled CO_2) over the assessment area at a 2 km^2 cell size (Thornton and Running 1996; Thornton and others, in press). These daily values were combined into nine climate attribute predictor variables in this study: annual average temperature, maximum July temperature, minimum January temperature, annual precipitation, winter precipitation (January-March), spring precipitation (April-June), summer precipitation (July-September), fall precipitation (October-December), and annual solar radiation. Plot locations (accurate to within 2 km) were used to assign values for the climate attribute values to each plot with a GIS ARCINFO software.

Predictive models of species or community presence or absence were developed using a generalized linear model formulation appropriate to binomial distributions. Model structures consisted of a linear combination of environmental attributes linked to the predicted response by a nonlinear logic function that constrained predicted values between 0 and 1 (McCullagh and Nelder 1989). Models of biotic response were constructed using a forward stepwise procedure in which, at each step, a climate attribute was selected whose addition to the model produced the largest significant change in deviance. A one percent significance level was used as the criterion for adding an attribute to the model. Attributes could enter as either linear or linear plus quadratic terms. The significance of interactions between attributes and for the addition of cubic terms was also tested.

Predicted distributions of the four species and four communities studied were generated under current climate conditions and for the climate change scenario using modeling results. Equations were applied to GIS outputs of the nine climate attribute values for each 2-km^2 cell. Results were displayed in two ways:

- Probabilities of occurrence were mapped as one of four classes (0 to 0.25, 0.26 to 0.50, 0.51 to 0.75, and 0.76 to 1.00) to reflect probability statements about the distribution of species and communities.
- Probabilities were converted to presence or absence values for mapping.

Model accuracy was assessed by constructing "confusion" matrices indicating numbers and percentages of plots falling within one of the following four categories. A species or community was:

- Observed and predicted to be present (correct prediction).
- Observed and predicted to be absent (correct prediction).
- Observed present and predicted absent (incorrect prediction).
- Observed absent and predicted present (incorrect prediction).

Modeling Results

Among the four species models, the percentage of plots in which the presence or absence of a species was correctly predicted varied from 68 to 76 percent. Three climate attributes were significant predictors in

all four models: annual average temperature, spring precipitation, and summer precipitation. All species models contained interaction terms and only the model for *P. virginiana* lacked a cubic term for at least one climate attribute (indicating a skewed response).

Three of the four community models were successful in predicting community presence or absence. Correct prediction varied from 80 to 85 percent for *T. plicata/C. uniflora, P. ponderosa/S. albus,* and *A. tridentata* series. A lower percentage of correct predictions was observed for *A. lasiocarpa/C. canadensis* (63%). The distribution of a riparian community such as *A. lasiocarpa/C. canadensis* may be determined by environmental attributes not included in the model, such as subsurface soil moisture. In addition, the 2-km^2 cell size used to estimate climate attributes is probably too broad a scale to represent riparian and wetland conditions. Three of four community models included a climate attribute as a cubic function, and one model contained an interaction term.

Four maps were produced for each species and community studied: predicted probability class and presence/absence under current climatic conditions, and predicted probability class and presence/absence under the doubled CO_2 climate change scenario. Probability class maps are shown for the community *T. plicata/C. uniflora* for current (map 2.23) and climate change (map 2.24) conditions. The predicted distributions of all species and all communities, except *A. lasiocarpa/C. canadensis,* were in general agreement with known occurrences, although prediction errors were also detected. In many cases, errors in predicted distributions could be attributed to the influence of environmental factors not included in the models, such as the effect of geological substrate, which was not available as a regional map when modeling was performed. The distribution of *A. lasiocarpa/C. canadensis* was systematically overestimated throughout the area.

Changes in predicted biotic distributions under doubled CO_2 included both range expansions, (for example, *V. membranaceum/V. globulare* and *T. plicata/C. uniflora)* and range contractions, (for example, *P. virginiana* and *A. tridentata* series) that such changes were considered to indicate that an increase in mesic conditions would generally be found across the climate change scenario modeled. Results suggest that simple species/environment relationships (for example, bell-shaped responses), frequently accepted as appropriate by land managers and scientists, should be used with caution in devising management strategies. Modeling results also demonstrate the importance of the environmental attributes used in analysis and the scale at which they are estimated. For example, species and communities may respond to environmental attributes not included in modeling and/or attributes at a finer scale of resolution.

Development of Ecological Reporting Units

Early in of the Interior Columbia Basin Ecosystem Management Project, both the Science Integration Team and the EIS Team recognized the need for a strategy to subdivide the Basin into geographic areas or provinces to facilitate integrated reporting of assessment results. The first version of the project's "Scientific Framework" addressed the potential utility of provinces as a means "to facilitate assessment, decision making, monitoring, and dissemination of information at a finer scale... Also, provinces can facilitate multi-agency, multi-ownership, multi-government collaboration." (Eastside Ecosystem Management Project, Science Integration Team 1994). The term "province" is used in the "Scientific Framework" generically as any subunit of the Basin. The Northwest Forest Plan (1993) also uses the term "province" as does the *Ecological Subregions of the United States: Section Descriptions* (McNab and Avers, compilers 1994). The province system in the Northwest Forest Plan is a watershed-based delineation for western Washington and Oregon and for northern California. The province system in *Ecological Subregions of the United States* is the third level of the Forest Service national hierarchical framework of ecological units. To avoid confusion regarding other uses, intents, and definitions of the term "province," the Science Integration Team decided to use the term

Map 2.23—Predicted distribution of *Thuja plicata/Clintonia uniflora* plant communities under current climate conditions.

Map 2.24—Predicted distribution of *Thuja plicata/Clintonia uniflora* plant communities under a doubled CO_2 climate change scenario.

"Ecological Reporting Unit (ERU)" to refer to the geographic subdivisions of the Basindescribed in this section. These ERUs were constructed to facilitate common reporting of ecological assessment results by various science team staffs at a broad level (that is, regional and subregional assessment scales).

As discussed earlier in this document, geology and climate are some of the principal factors that influence ecosystem patterns and processes at broader analysis levels (for example, regional and subregional assessment scales). Climate supplies energy and water to all ecosystems, and geologic structure supplies the material from which the forces of climate carve landforms and form soils (Lotspiech 1980). Vegetation patterns, in turn, are largely determined by these coarser level components of the biophysical environment. The geoclimatic properties of river basins and subbasins, in a similar manner, influence the physical processes (such as flooding and mass wasting) and finer-scale physical patterns (such as stream types and channel units) that create habitat for aquatic species. Given these relations, importance was placed on the use of biophysical environments (such as geoclimatic sections and hydrologic regions) in the identification of ERUs for various science team assessment efforts.

The identification and delineation of ecological reporting units in the ICBEMP was an "integrated" exercise accomplished via participation of all disciplines on the ICBEMP Science Integration Team. The final ERU map produced in this project resulted from an integration of three primary map themes through a series of iterative steps, which are described below.

The first map theme considered in ERU delineation emphasized terrestrial ecosystem components and was based primarily on the section and subsection delineations described in this document. These delineations were, however, adjusted to follow the nearest 6th field subwatershed boundary in this effort.

The second map theme considered in ERU delineation emphasized human uses of ecosystem components and was based primarily on socioeconomic criteria attributed to counties. Grouping of counties into geographic clusters for mapping was based on the dominant human use of natural resources, as well as some selected biophysical factors that related to human use of the land. These geographic clusters were displayed by county boundaries and state lines in map preparation.

The third map theme considered in ERU delineation emphasized aquatic ecosystem components and was based primarily on a regional classification of 4th-field hydrologic units with similar hydrologic characteristics and geoclimatic properties. This map theme approximated the distribution of aquatic species as determined by zoogeographic province data.

These three map themes provided remarkably similar delineations which were integrated (through visual inspection) following 6th-field subwatershed boundaries in ERU map theme construction (that is, coincident lines were adjusted to follow subwatershed boundaries). The final ERU map produced for the Basin identified 13 settings that are listed below and discribed later in this chapter. These ERUs were used extensively by various science team staff in describing biophysical environments, ecological processes, effects of management activities, and landscape management opportunities.

- Northern Cascades
- Southern Cascades
- Upper Klamath
- Northern Great Basin
- Columbia Plateau
- Blue Mountains
- Northern Glaciated Mountains
- Lower Clark Fork
- Upper Clark Fork
- Owhyee Uplands
- Upper Snake
- Snake Headwaters
- Central Idaho Mountains

Description of Basic Ecosystem Components

Geology Features

A general characterization of selected geologic information by ERU is provided in table 2.11. Given the diversity of rock types, ages, and other properties of the geologic environments within the Basin, the classifications listed in table 2.11 should be viewed as simplified generalizations and approximations. Many substantial geologic patterns and processes that are common to all ERUs or are of limited areal extent are not listed in this table. For example, erosion and sedimentation are processes that occur in all ERUs; however, calculations of actual rates are dependent on local variables outside the range of this discussion. Additionally, most industrial minerals are not listed because sand and gravel deposits are important in all ERUs. Locally important products such as stone, abrasives, and zeolites were not addressed in the mineral resource assessment of the Basin (Box and others, in press).

Geologic Processes

Geologic processes and their interaction with atmospheric and hydrologic processes operating at many spatial and temporal scales have shaped, and continue to shape, the landscapes of the Basin. Recognition of the role of geologic processes and their rates provides a needed context in understanding the role of human-induced changes in any ecosystem. At the broadest scale, sea-floor spreading and continental drift [2 to 15 centimeters(cm)/yr] determine the locations and physiography of the continents. Intermediate-scale geologic processes operate at temporal scales of tens of millions to thousands of years and represent responses of the earth's crust to the larger forces of plate tectonics. Examples of intermediate-scale geologic processes include faulting, volcanism, and mountain building. These intermediate-scale processes formed the physiography of the Basin which, in turn, interacted with atmospheric processes to create the climatic conditions, landforms, and drainage patterns present today.

At the scale of a watershed and valley bottom, the processes operable during the Pleistocene ice ages [1.6 million to 10,000 years Before Present (B.P.)] have greatly influenced the topography and surficial materials seen today. At a finer scale of hill slopes and channels, modification of physiography is controlled primarily by recent (last 10,000 years) geomorphic processes. Catastrophic processes or disturbances (for example, volcanic eruptions, floods, landslides, and earthquakes) that last from minutes to days have continually modified the current physiography and drainage patterns of the Basin throughout geologic history and continue to influence the system today. Most geologic processes that directly affect the current structure, function, and composition of Basin ecosystems tend to be catastrophic. On a human time scale, such processes occur infrequently but cause substantial change in affected areas. These processes include individual volcanic eruptions, earthquakes, floods, land movement, and large-scale erosion and sedimentation. Although these processes cannot be managed, responses to them can be planned.

Changes in the rate of geologic processes that may be caused by human activities can be recognized and accounted for in land management planning. For example, human-induced changes to land surfaces have increased erosion rates and altered evapotranspiration rates, water movements, and toxic element fluxes in some areas of the Basin. Additionally, point-source increases in toxic element flux (including both metals and acidic or other chemical drainage) and increased sedimentation may result from future development of renewable and non-renewable resources, recreational development, urbanization, and agricultural practices within the Basin.

Continue

Table 2.11—Geoclimatic characteristics of ecological reporting units.

ERU	Landforms	Bedrock & Surficial Material	Elevation Range (m)	Mean Annual Precip. & Temp.	Major Potential Vegetation Groups
North Cascades	Glaciated and unglaciated mountains; with some hills, plains, buttes and plateaus.	Crystalline rocks: granitic, gneiss, schist, serpentine, volcanic rocks, sedimentary rocks; glacial, fluvial and mass wasting deposits.	600-2,896	250 to 4,000 mm 1 to 9° C.	Ponderosa pine, Douglas-fir and sagebrush; white fir and western red cedar; silver fir and mountain hemlock.
South Cascades	Mountains, plateaus, lava plains, buttes, shield volcanos, and some high elevation glaciation.	Volcanic and sedimentary rocks; ash, and pumice.	91-2,743	250 to 3,000 mm 2 to 10° C.	Ponderosa pine, Douglas-fir, sagebrush, white fir, and silver fir.
Upper Klamath	Mountains, plateaus, rolling hills, floodplains, and terraces.	Metamorphic and volcanic rocks, and alluvium.	1219-2,438	300 to 875 mm 4 to 10° C.	Sagebrush, ponderosa pine, Douglas-fir, white fir, red fir, and silver fir.
Northern Great Basin	Basin and range.	Volcanic rocks.	1,200-2,200	100 to 790mm 5 to 10° C.	Salt desert shrub, sagebrush, and juniper.
Columbia Plateau	Plateaus, hills, and plains.	Basalts and volcanic rocks; loess, glacial outwash, and flood deposits.	61-1,220	180 to 450 mm 4 to 14° C.	Sagebrush, and bluebunch wheatgrass Idaho fescue.
Blue Mountains	Dissected plateaus, foothills, mountains, canyons, and valleys.	Granitics, metamorphics, volcanics, and serpentenite.	300-3,300	230 to 460 mm -2 to 11° C.	Sagebrush, grasslands, ponderosa pine, Douglas-fir, grand fir, and minor subalpine fir.
Northern Glaciated Mountains	Glaciated mountains, foothills, basins, and valleys.	Granitic, gneiss, schist, siltite, shale, quartzite, carbonate; glacial till, and outwash.	244-3,081	410 to 2,540 mm -1 to 14° C.	Douglas-fir, ponderosa pine, grand fir, western hemlock, and subalpine fir.

Previous

This file was created by scanning the printed publication. Mis-scans identified by the software have been corrected; however, some errors may remain.

Table 2.11 (continued).

ERU	Landforms	Bedrock & Surficial Material	Elevation Range (m)	Mean Annual Precip. & Temp.	Major Potential Vegetation Groups
Lower Clark Fork	Dissected mountains, breaklands, foothills, and valleys; some alpine glacation.	Metasedimentary, granitic metamorphic carbonate rocks.	366-2,135	1,020 to 2,030 mm 2 to 7° C.	Douglas-fir, ponderosa pine, grand fir, western red cedar, and subalpine fir.
Upper Clark Fork	Glaciated and unglaciated mountains; valleys, and canyons; glacial and lacustrine basins.	Granite, gneiss, schist, sandstone, shale, carbonate, and rocks.	915-3,111	360 to 2,030 mm 2 to 8° C.	Grassland, sagebrush, Douglas-fir, ponderosa pine, and subalpine fir.
Owyhee Uplands	Dissected mountains, plains, plateaus, and foothills.	Volcanic basaltic flows and pyroclastic rocks.	641-2,501	200 to 400 mm 2 to 8° C.	Salt desert shrub, sagebrush, and juniper.
Upper Snake	Basins, valleys, mountains, plateaus and plains.	Volcanic- basalt to rhyolite; and carbonate, phosphate, clastic sedimentary rocks.	397-2,288	100 to 790 mm 4 to 13° C.	Salt desert shrub, sagebrush, and juniper.
Snake Head Waters	Overthrust mountains, valleys, foothills, and basins.	Volcanic- basalt to rhyolite; and carbonate, phosphate, clastic sedimentary rocks.	1,524-4,202	400 to 1,015 mm 2 to 7° C.	Douglas-fir, lodgepole pine, sagebrush, and subalpine fir.
Central Idaho Mountains	Dissected mountains, breaklands, canyons, basins, foothills, and valleys, and some alpine glaciation.	Granitics, gneiss, schist, shale, carbonate rocks, and volcanic rocks.	427-3,861	250 to 2,030 mm 3 to 10° C.	Douglas-fir, grand fir, sagebrush, grasslands, and subalpine fir.

Plate tectonics—The oldest rocks of the Basin include granite and gneisses in western Montana and Wyoming that cooled and crystallized deep within the earth as long as 2.7 billion years ago (Hoffman 1989). The Belt basin, in the eastern portion of the Northern Glaciated Mountains (ERU 7), formed by rifting and subsidence of the older granitic and gneissic rocks of the continental crust over 1.5 billion years ago. The sediments that filled the resulting basin formed a thick sequence of siltstones, quartzites, and carbonates that are now exposed at the surface in part of ERU 7. During the Late Cretaceous Period, about 100 million years ago, continental and oceanic crustal fragments were joined to the western edge of the North American continent; the trace of this junction now lies in western Idaho (Oldow and others 1989). This junction is buried under younger rocks in southern Oregon and Washington and has been deformed by subsequent tectonic events. All rocks west of this junction (that is, rocks located in ERUs 1-4, 6, and parts of 5, 7, and 10) have been added to the continent by plate tectonic processes in the last 100 million years.

Volcanic processes and hazards—Volcanism has been and continues to be a profound agent of change for the landscapes of the Pacific Northwest. Volcanic rocks underlie most of the assessment area in southern Washington, Oregon, and southern Idaho (ERUs 1-6 and 10-12).

Arc volcanism, which is the process that leads to construction of linear chains of cones and flows such as the volcanic Cascade Mountains (ERUs 1-3), has occurred continually for at least 25 million years. Arc volcanoes form in response to subduction, which is the overriding of oceanic crust by the edge of the continent. The physiography of the Cascade Mountains (ERUs 1-3) is the result of the eruption of lava flows, domes, and cones from the hundreds of volcanoes in the Cascade arc. Eruptions of Glacier Peak, Mt. Mazama, and other Cascade mountain volcanoes have deposited extensive blankets of volcanic ash throughout the Basin (Sarna-Wojcicki and Davis 1991).

The eruption of Mt. Mazama about 7,000 years ago dispersed about 120 cubic kilometers of tephra over the entire Basin (Bacon 1983). Compacted unconsolidated volcanic ash (tephra) deposits from the Mazama eruption are as thick as 50 millimeters (mm) at 1,000 kilometers east of the crater and as thick as 4 meters at 20 kilometers from the crater (Hoblitt and others 1987). Lahars (volcanic mud flows) may also affect large areas and may be caused by very small eruptions. Melting of large volumes of glacial ice from volcanic eruptions may produce deposits that travel many kilometers downstream and can blanket large areas with deposits of mud.

During the last 4,000 years, volcanoes of the Cascade mountains have erupted, on average, twice per century (Dzurizin and others 1994). Such return frequencies are also similar to those associated with very large forest fire events. The tephra deposits of these volcanoes are easily eroded. Management practices in areas underlain by such ash deposits may greatly affect erosion and sedimentation rates. Tephra deposits also modify the water-holding capacity of soils into which they are incorporated. Additionally, tephra deposits typically provide a readily available source of mineral nutrients to terrestrial and aquatic ecosystems. The glassy nature and fine-grain size of volcanic ash permits rapid chemical weathering of its mineral components and release of contained nutrient elements for uptake by plants (Gough and others 1981).

About 1 km^3 of tephra was ejected from the volcanic eruption of Mt. St. Helens on May 18, 1980 (Sarna-Wojcicki and others 1981). Areas nearest the volcano were most affected by this eruption and currently provide a natural laboratory for the study of ecosystem response to disturbance. The pyroclastic surge of the eruption of Mt. St. Helens leveled trees as far as 28 kilometers from the crater and affected an area of 600 square kilometers (Moore and Sission 1981). Ash from the main eruption of Mt. St. Helens and subsequent eruptions was deposited over most of eastern Washington and much of central Idaho and western Montana (ERUs 1, 5, and 8). Ash deposits in

Ritzville, Washington, 175 kilometers northeast of the volcano, were as thick as 50 millimeters (Sarna-Wojcicki and others 1981). The landslide and proximal deposits from this eruption filled most of the Spirit Lake Basin on the north side of the mountain and raised the lake's surface about 61 meters (Voight and others 1981).

Lahars and floods caused by the Mt. St. Helens eruption and by rapid melting of glaciers and snow pack on the mountain affected both aquatic and riparian environments and the human populations living in the floodplains on the north side of the mountain (Janda and others 1982). The re-establishment and development of both aquatic and terrestrial communities following this eruption has been rapid. An excellent compendium of papers on the volcanic processes and short-term effects of the 1980 eruption of Mt. St. Helens is contained in Lipman and Mullineaux (1981). Although the site, size, and time of the next volcanic eruption from the volcanoes of the Cascade mountains cannot be predicted, such events will continue to occur sporadically in the foreseeable future.

Estimated likelihoods of tephra deposition of 1 centimeter thicknesses in a single year vary from 1 in 100 in the Cascades ERUs (1, 2, and 3), to less than 1 in 1,000 in the eastern part of the Basin. The likelihood of thicker deposits in a single year are correspondingly lower (Hoblitt and others 1987). Although there is little likelihood for thick deposits of ash in any given location in the western part of the Basin in a given year, it is certain that within a 200-year timeframe there will be a substantial eruptions within or adjacent to the Basin. The eruption from Mt. St. Helens in 1980-1985 deposited ash over an area equal in size to Washington State; furthermore, eruptions of the size of Mt. Mazama blanketed the entire Basin and beyond. Although the probability of very large eruptions in any given year is low, the potential effects of such an eruption would be substantial to all physical, biological, and social components and processes of the Basin.

The Columbia River basalts form the cliffs of the central Columbia plateau (ERUs 5 and 6) in southern Washington, northern Oregon, and western Idaho. These flood basalts erupted between 17 and 6 million years ago; however, approximately 95 percent of the 174,000 cubic kilometers of basalt were erupted within a 2-million year time period (Swanson and others 1979, Tolan and others 1989). These basalts represent gigantic outpourings of lava, which are widespread between Lewiston, Idaho and Portland, Oregon as well as from Wenatchee, Washington to Walla Walla, Washington. Individual flow units exceed 100 meters in thickness and 1,000 cubic kilometers in volume. Some traveled many hundreds of kilometers from their vents (Reidel and others 1989). Erosion of these basalts by Pleistocene floods produced many of the cliffs found within the Columbia Gorge, Dry Falls, and the Channeled Scablands.

Volcanism began about 16 million years ago in eastern Oregon and northern Nevada (Pierce and Morgan 1992) and has shifted systematically northeast at about 3 centimeters/year to its present location in the Yellowstone area. This hot spot has been a major source of silicic volcanic rocks and is responsible for much of the present topography in the Snake River plain (ERUs 10 and 12) (Pierce and Morgan 1992). The topographic depression of the eastern Snake River plain is supported by silicic calderas that are covered by basalt flows. The largest known caldera eruption in or near the Basin occurred about 2 million years ago in the Yellowstone area (Christiansen 1979). About 620,000 years ago, eruption of approximately 1,000 cubic kilometers of tephra led to collapse of the Yellowstone caldera (Christiansen 1979). This eruption deposited volcanic ash over much of the present-day United States and Canada. The basalt flows of the eastern Snake River Plain represent the youngest volcanic activity following passage of the Yellowstone hot spot (that is, a few thousand years ago).

Earthquake hazards—Earthquake hazard risk is not uniformly distributed within the Basin. The map presented by Algermissen and others (1990) displays the maximum potential horizontal acceleration due to an earthquake not likely to be exceeded in 50 years. This map provides a reasonable regional assessment of earthquake hazard risk. Although urbanized areas west of the Basin have the highest probability for occurrence of substantial earthquakes, other parts of the Basin have experienced substantial earthquakes in recent times. In 1872, an earthquake of estimated Richter magnitude 7.4 occurred near Lake Chelan in Washington (Yelin and others 1994). In Montana, the Hebgen Lake earthquake of 1959 (Richter magnitude 7.3) produced fault scarps as high as 3 meters and triggered a landslide that dammed the flow of the Madison River, creating Quake Lake. The Borah Peak earthquake of 1983 (Richter magnitude 7.0) in Idaho produced a 36-kilometer long fault scarp along which the Lost River Range was uplifted between 1 and 2 meters (Stein and Barrientos 1985). Southeastern Idaho, the Yellowstone Park area, and the overthrust belt of Montana (parts of ERUs 7, 9, and 11-13) are also subject to earthquake risk (Algermissen and others 1990).

The effects of major earthquakes on human populations and social infrastructures are beyond the scope of this discussion. Less obvious is the likelihood for substantial change in aquatic ecosystems due to landslides caused by earthquakes. Despite the fact that earthquakes cannot be accurately predicted, the probability for future earthquakes in parts of the Basin are high.

Pleistocene Epoch Glacial and Flood Processes

At the watershed scale, much of the present landscape of the Basin was shaped by processes and events during the Pleistocene epoch (1.6 million years to 10,000 years ago). The Pleistocene epoch was a time of multiple cycles of major climate variation, ranging from ice ages to warm interglacial periods. The climax of the last cold period was 20,000 to 14,000 years ago when average summer temperatures in the Pacific Northwest were 5° to 7° C cooler and winter temperatures were about 10° to 15° C less than today (Barry 1983). During these cooler and moister times, large ice sheets formed in the northern hemisphere and covered most of Canada and the northern tier states of the United States (map 2.25) (Mickelson and others 1983, Waitt and Thorson 1983). The Pleistocene lobes of the ice sheet originating in Canada advanced into and retreated several times from the United States and excavated and molded valleys in ERUs 1 and 7 (Waitt and Thorson 1983).

Alpine glaciers shaped valleys along the entire east flank of the Cascade Range, the Klamath Mountains, the central Idaho Mountains, the mountains of western Montana, the Blue Mountains, Steens Mountain, and in the Yellowstone area of the Snake River headwaters (Porter and others 1983). Much of these glaciated landscapes are now covered with a mantle of glacial till. Downstream of glacier termini (and in the wake of retreating glacier termini), thick sedimentary sequences of silt, sand, and gravel outwash were left as valley fill and terraces that now flank most rivers with glaciated headwaters. Valley bottoms that were inundated by glacier-dammed lakes, such as much of the Clark Fork River drainage (ERUs 8 and 9) and the Columbia River upstream of Grand Coulee (ERUs 5 and 7), as well as pluvial lakes developed in closed basins (ERUs 4,10, and 11) during wet periods, now have thick mantles of fine-grain lacustrine deposits (Benson and Thompson 1987).

During the Pleistocene ice ages, silt and fine-sand outwash from alpine and continental glaciers and glacial floods were redeposited by wind as thick blankets of loess. These loess deposits locally dominate many of the landscapes of the Basin. For example, the rolling hills of the Palouse in eastern Washington are entirely composed of loess that has been deposited over the last 2 million years and is

Map 2.25—Regional map showing aspects of the late Pleistocene paleogeography of the Pacific Northwest.

locally over 75 meters thick (Busacca 1991, Busacca and McDonald 1994). Sequences of loess mantle much of the Columbia Plateau (ERU 5) and Snake River plain (ERUs 10 and 11) (Malde 1991). These loess deposits are highly productive, and most agriculture in these ERUs are dependent on soils developed from loess.

The wetter climate of the last ice age led to the formation and expansion of large freshwater lakes in closed basins throughout the western United States (Benson and Thompson 1987). The presence of these lakes resulted in deposition of silt and clay on inundated valley floors and substantially altered the patterns of hydrologic connectivity between now-separated basins. This situation strongly affected the distribution of many aquatic species within the Basin. In the Basin and Range province of Oregon, there were nine major pluvial lakes, the largest of which was pluvial Lake Modoc that covered 2,800 square kilometers and included Upper and Lower Klamath lakes. Additionally, Summer Lake and Lake Abert were connected into the 1,200-square-kilometer, pluvial Chewaucan Lake. Goose Lake expanded and fully integrated into the Sacramento River system. In a similar manner, the Warner Lakes are remnants of pluvial Coleman Lake, the Harney-Malheur Lakes are the remnant of pluvial Malheur Lake, and Alvord Lake (in the Alvord Desert) is a remnant of pluvial Lake Alvord (Allison 1982, Orr and others 1994). Each of these pluvial lakes covered about 1,300 square kilometers at their maximum extent, between 15,000 and 13,500 years ago (Benson and others 1990). All of these lake systems rapidly evaporated at the end of the Pleistocene, and by 10,000 years ago, most lakes approximated their present size.

During the last ice age, the drainage systems of Big Lost River, Little Lost River, Birch Creek, Medicine Lodge Creek, Beaver Creek, and Camas Creek (which are all now influent into the basalts that underlie the Snake River Plain) combined to form pluvial Lake Terreton, a large shallow lake on the Snake River Plain (Pierce and Scott 1982). Between 14,500 and 13,000 years ago, an even more profound drainage integration occurred when much of the eastern Great Basin was temporarily connected to the Columbia River drainage as a result of pluvial Lake Bonneville overtopping its lowest divide between the closed Bonneville basin and the Portneuf River drainage in southeastern Idaho (Gilbert 1980, O'Conner 1993). Rapid breaching of ice-dammed lakes and the pluvial Lake Bonneville spillover led to cataclysmic flooding that dramatically affected the physiography of the Columbia Plateau and Snake River Plain.

The Bonneville Flood resulted from the filling and consequent spillover of Pleistocene Lake Bonneville into the Snake River drainage about 14,500 years ago. About 4,750 cubic kilometers of water was released from this flood within a period of a few weeks near Red Rock Pass, Idaho and traveled down the present courses of Marsh Creek and the lower Portneuf River before entering the Snake River Plain north of Pocatello. For the most part, this flood route followed the present course of the Snake River, locally widening and deepening the canyon. Some of the large falls, such as Shoshone and Twin Falls (anadromous fish blockages), are parts of large cataract complexes that formed during the flood. The Bonneville Flood substantially modified the valley of the Snake River as far downstream as Lewiston, Idaho. Downstream of Lewiston, Bonneville Flood features are buried by subsequent Missoula Flood deposits (Malde 1968, O'Conner 1993).

Between 15,000 and 12,000 years ago, a lobe of the Cordilleran Ice Sheet advanced down the Purcell Trench and blocked the Clark Fork River near the present site of Lake Pend Oreille. At its maximum extent, the resulting glacial Lake Missoula inundated as much as 10,000 square kilometers with 2,500 cubic kilometers of water (Craig 1987). Repeated formation and failure of the ice dam led to flooding that overwhelmed normal drainage routes in northern Idaho and eastern Washington. As the Missoula floods spread

through eastern Washington, they carved the "channeled scabland" by stripping loess off basalt surfaces and eroding river courses and large falls and depositing immense gravel bars (map 2.25).

Dry Falls in central Washington, now abandoned by the Columbia River, was the site of an immense waterfall created by Lake Missoula flooding. Falls created by eroded basalts on the Spokane and the Palouse Rivers from this flooding created fish migration blockages. Tributary valleys such as the Snake, Yakima, Walla Walla, Tucannon, John Day, Klickitat, and Hood Rivers (ERU 5) were mantled by sand and silt carried by floodwater backed-up into these side valleys. Large basins such as the Quincy, Pasco, and Umatilla Basins were filled with immense volumes of sand and gravel. There were as many as 100 Lake Missoula flood events between 15,000 and 12,000 years ago as the ice dam repeatedly formed and failed (Atwater 1986, Baker 1983, Baker and Bunker 1985, Bretz 1923, Waitt 1980, Waitt 1985).

Minerals and Mining Impacts

Mineral resource needs have contributed to the exploration and development of metallic and industrial minerals within the Basin. Important metallic and industrial mineral resources within the Basin include gold, silver, lead, zinc, molybdenum, copper, sand, gravel, and stone. Even though there are thousands of mineral deposits, prospects, and occurrences in the Basin, a small number of world-class deposits account for most of the production and resource base. (Refer to the Economic Assessment for a discussion of mineral development in the Basin.)

Mineral deposits are not distributed uniformly through the Basin and tend to occur in clusters or belts, which ultimately reflect the underlying geological processes that control their distribution. The locations of substantial metallic deposits and mines (defined as having past production and/or known reserves of greater than a threshold value) within the Basin and adjacent regions have been described by Bookstrom and others (in press b).

The USBM estimated that there are nearly 14,000 inactive or abandoned mining sites in the Basin. Although environmental effects from mining may be substantial, they tend to be restricted in areal extent. Mining activities have also resulted in locally important landscape, aquatic, atmospheric, and visual disturbances.

In undisturbed areas, aquatic and terrestrial ecosystems have adapted to the fluxes of metal and mineral deposits exposed at the earth's surface. Mining, however, can expose large volumes of rock to physical and chemical weathering, which may increase the rates of introduced metals, acid drainage, or sediment to the environment if unmitigated.

Past mining activities within the Basin have had profound effects on some aquatic and riparian ecosystems. The Clark Fork River in Montana, for example, has four distinct but contiguous Environmental Protection Agency (EPA) Superfund National Priority List sites covering 8,100 hectares along 235 kilometers of river. As a result of mining discharges at the Clark Fork River's headwaters near Butte and Anaconda, Montana, this river is considered to be of concern for metal exceedences under section 303(d) of the Clean Water Act for 200 kilometers downstream to where it is joined by the Flathead River (EPA 1980). The South Fork of the Coeur d'Alene River basin in Idaho is host to a world-class lead-zinc-silver mining district. Mining began in this area in the 1800s; from that time to as recently as 1968 spent tailings from some mills were discharged directly into the river (Horowitz and others 1993). Mining of placer deposits has also locally modified aquatic habitat in parts of the Basin. The extraction of most resources, including gold and industrial minerals, was processed by gravitational separation from the waste rock, although mercury was used to amalgamate gold in some historical placers. Most placer mining has been for gold, although there are numerous garnet sand placers in parts of ERUs 5, 7, and 8. Exploitation of sand and gravel resources has also locally modified aquatic condition in some drainages.

In addition to potential increases in the release of metals such as zinc, lead, cobalt, copper, arsenic, or other metals, some mineral deposit types are more prone to produce acid rock drainage than others (Plumlee and others 1994). Deposit types high in pyrite and other acid-producing sulfide minerals and low in acid-buffering minerals such as calcite, aragonite, or dolomite have a high potential for producing acid rock drainage (Kwong 1993, Plumlee and others 1994). When mined and exposed to air and water, weathering of naturally acid-producing minerals is accelerated and appropriate remediation technologies must be employed to prevent acid-rock drainage problems. Acid-rock drainage for a given deposit type will also have a greater or lesser probability, depending on the amount of water available, to react with the contained minerals.

The USGS has classified the areas that are favorable for mineral development according to their risk of acid rock drainage if remediation technologies are not employed (Zientek and others, in press b). In this classification, areas are subdivided (Kwong 1993; Plumlee and others 1994; Zientek and others, in press b) into three groups:

- Those deposit types with a high risk of generating acid rock drainage (that is, they have a high sulfide mineral content and a low buffering capacity of the characteristic host and alteration mineralogies).
- Those that may generate acid rock drainage depending on local climatic, hydrologic, and site-specific deposit characteristics.
- Those that have low potential for acid rock drainage due to low sulfide mineral content and/or high buffering capacity of the characteristic mineralogies.

Potential impacts from unmitigated resource extraction and processing of ores include release of metals, acid-rock drainage, atmospheric emissions, and increased sediment loads to the environment. Map 2.26 shows a compilation of the areas favorable for metallic mineral deposit types in the Basin, ranked according to the worst-case inherent potential for deposits in those areas to generate acid rock drainage (Zientek and others, in press b). Individual site characteristics must be evaluated before a given prospect or deposit can be classified as having high, moderate, or low potential for generating acid rock drainage.

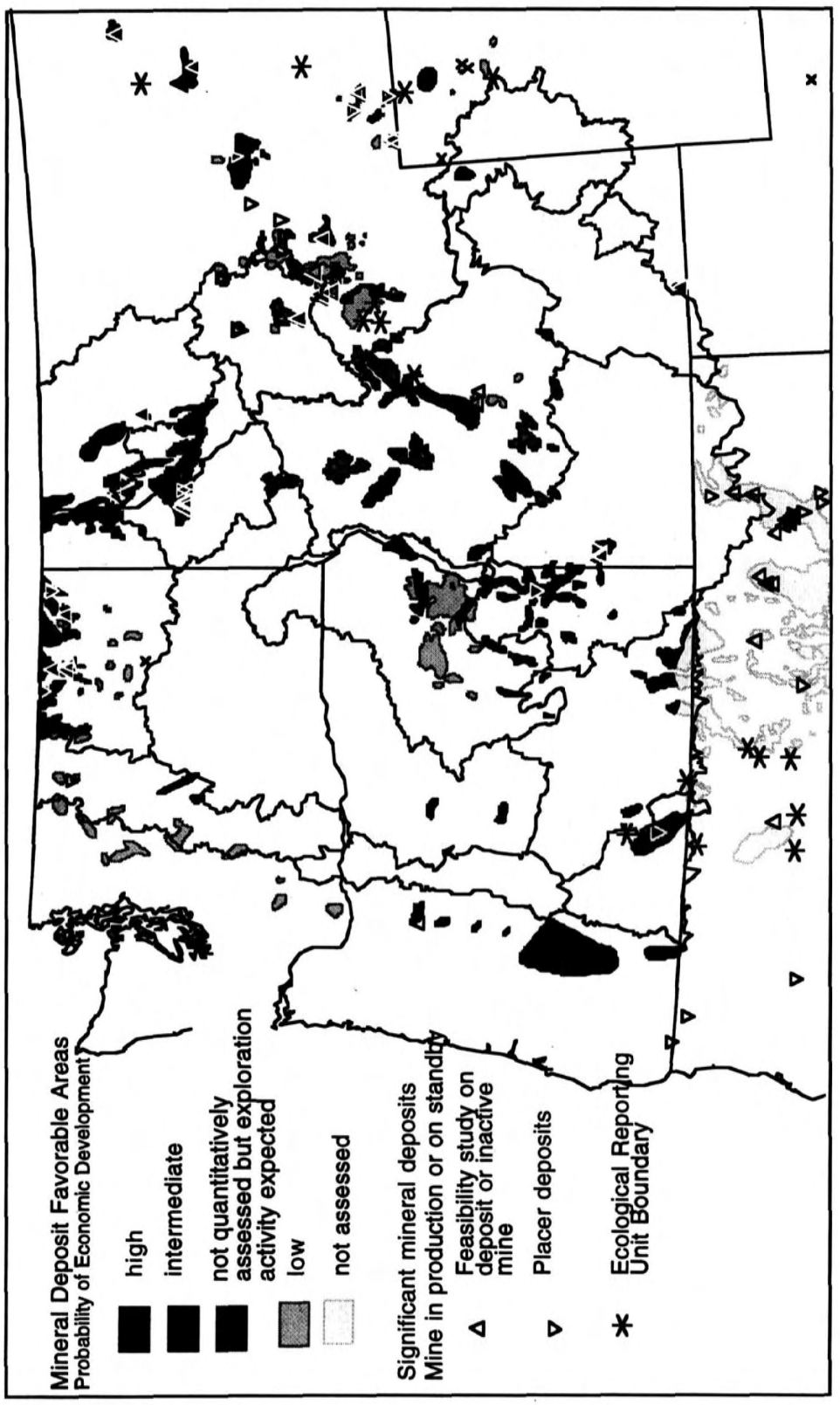
Climate Features

The Basin is in a transition-type climate zone. It is influenced by three distinct air masses:

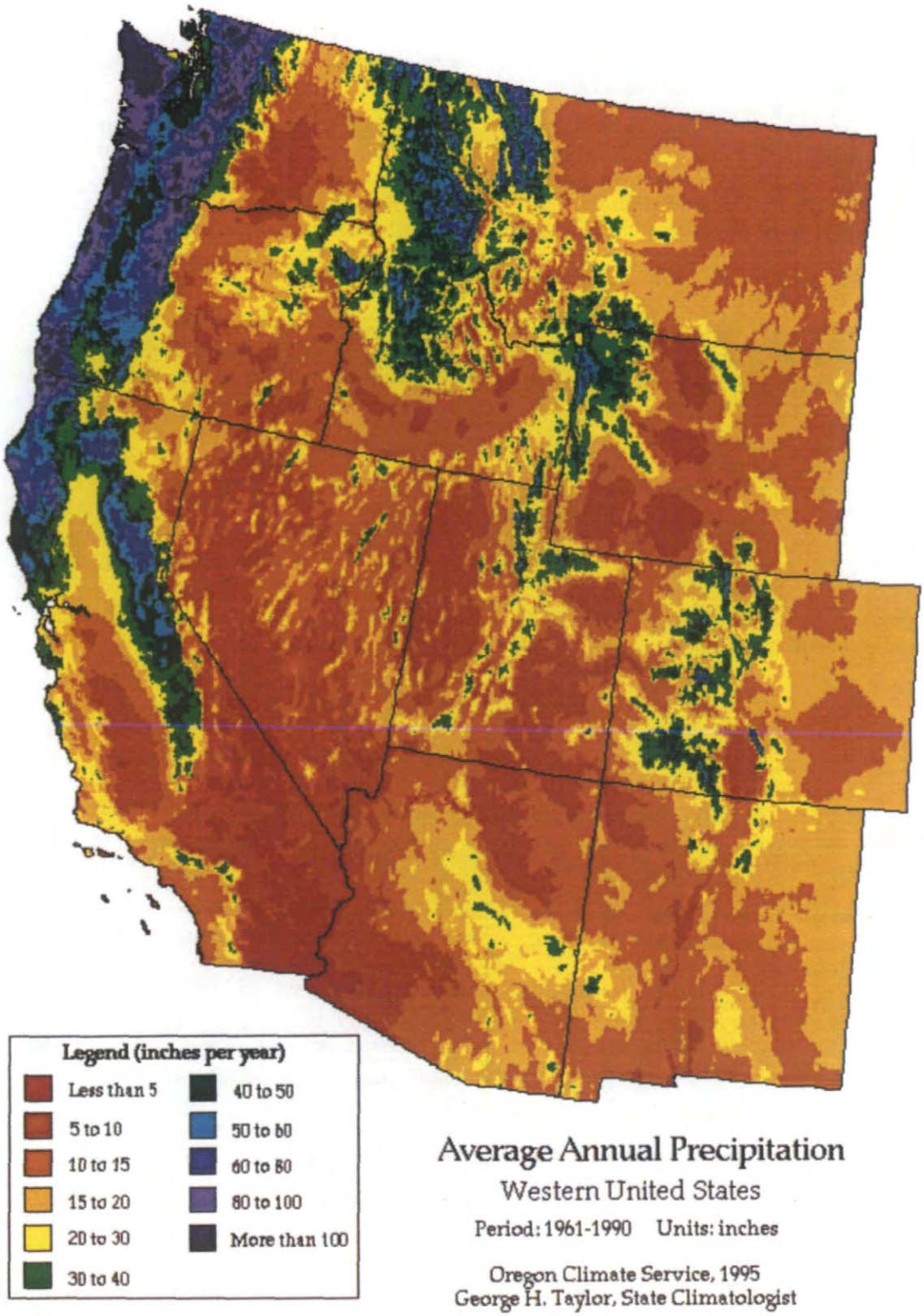
- Moist, marine air from the west that moderates seasonal temperatures.
- Continental air from the east and south, which is dry and cold in winter and hot with convective precipitation and lightning in summer.
- Dry, arctic air from the north that brings cold air to the Basin in winter and helps cool the Basin in summer.

These air mass types interact with each other in a region of complex topography. Most precipitation accumulates during winter (75 to 125 cm in the Eastern Cascades, 25 to 95 cm in the Northern Rockies, and 20 to 40 cm in the Central Columbia and Snake River Plateaus)(map 2.27). The mountain snowpack acts like a natural reservoir and supplies the Basin with most of its useable water. Only the eastern and southern parts of the Basin have summer maximum precipitation, which is associated with significant thunderstorm activity. Summer precipitation throughout the Basin ranges from about 20 to 50 centimeters. Since the 1970s, winter precipitation generally has decreased to a level comparable to the 100-year historical mean. Summer precipitation has increased during the last 30 years, similar to 1910 values.

Temperatures are generally mild in the Basin because of periodic influxes of moderating Pacific moisture. Winter mean monthly temperatures



Map 2.26—Map showing mineral deposit favorable areas ranked by anticipated levels of economic activity.



Map 2.27—Average annual precipitation (western United States).

range from minus 10° to minus 3° C while summer temperatures range from 10° to 15° C. Trends in the last 100 years indicate a slight increase in temperatures during all seasons.

The timing and extent of competing air masses is controlled largely by synoptic weather patterns and local terrain features that vary across the Basin. Prolonged periods of drought occur when Pacific storms are deflected around the region, preventing the intrusion of moist, marine air. At these times dry, continental conditions prevail. Damaging frosts and freezing conditions commonly occur when Arctic air invades the Basin before winter hardening in autumn or after budbreak in spring. Cold damage also may occur in winter if a warm, marine intrusion is followed by a sweep of Arctic air. In addition, the unique interplay between air mass types results in dramatic changes during transition. The most unique of these transitions is rain-on-snow flooding that occurs when warm, wet marine air displaces cold, Arctic conditions in winter. Lightning and gusty winds also occur during transitions between continental and marine air masses, mainly in spring and summer.

An interesting analysis of temperature found two major frontal zones in the Basin (Mitchell 1976). A Pacific air mass boundary, which dominates during summer, extends diagonally across the Basin from northwest California to northwestern Montana. Relatively moist, marine air exists north of the boundary and drier, continental air is common south of the boundary. Mitchell noted that the Pacific boundary coincides with the eastward extension of coastal vegetation found in northern Idaho and northwestern Montana. A westerlies-anticyclone boundary, which dominates during the winter, was found to stretch east-west along the Oregon-Nevada border and across northern Utah. It marks the boundary between a region of prevailing westerly winds in the north and southerly winds in the south, caused by circulation around a persistent center of high pressure (anticyclone) over southern Nevada. This frontal zone also coincides with the northern or southern extent of several tree species.

Bryson and Hare (1974) and Mock (1996) have found that while large-scale climate controls (such as the polar jet stream, Pacific subtropical high, and subtropical ridge) play important roles in precipitation variability, small-scale climate controls (such as the complex topography, thermal troughs, confined mixing heights, and convective systems) can dominate.

Weather Data

Recorded weather observations began in the western United States during the late 1800s. Because population was relatively sparse at that time, only eight stations within the Basin have continuous, quality-controlled records approaching 100 years. These are Spokane WSO, Washington; Dufur, Oregon; Fortine, Kalispell WSO, and Haugan, Montana; and Priest River Experiment Station, Caldwell, and Saint Ignatius in Idaho.

High quality measurements of temperature, dew point, relative humidity, wind, precipitation, and radiation data are collected from the National Weather Service first-order stations that are operated by trained observers. Another source of daily precipitation and temperature measurements is maintained by the National Weather Service, Cooperative Observer Network (COOP)(National Climatic Data Center 1991). Data from COOP stations provide the highest spatial resolution of daily measurements although consistency and quality can be somewhat lacking. Observation sites for these two types of stations are usually located near population centers or airports away from the wildland areas of forests and mountains.

Significant additions to high elevation data occurred in the mid-1930s as snow course observations increased and in the late 1970s with the installation of SNOTEL sites and remote automated weather systems (RAWS). Snow course and SNOTEL sites are commonly placed near the headwaters of major river basins. Snow water equivalent measurements are available from both

types of stations. SNOTEL sites additionally transmit precipitation and temperature. RAWS stations are designed to support fire weather forecasting so they operate mainly during summer and are located in forest clearings on hill slopes and ridges. RAWS stations transmit hourly information on air temperature, precipitation, fuel temperature, relative humidity, and wind. There are about 200 RAWS, 200 SNOTEL, and 200 snow course sites in the Interior Columbia River Basin.

A northwest cooperative agricultural weather network (AgriMet) is maintained by the Bureau of Reclamation in Boise, Idaho as part of the Pacific Northwest Hydrometeorological Network for river and reservoir management.[1] Historical data since 1983 include daily soil moisture, soil and air temperatures, crop water use, and evapotranspiration.

A consistent network of radiosonde observations (RAOBs) began in the mid-1930s (U.S. Department of Commerce 1964). RAOB sensors measure wind, temperature, dew point, and height at mandatory atmospheric pressure levels (such as surface, 850 mb, 700 mb, 500 mb) and other significant levels twice a day. Stations at Spokane, Washington and Boise, Idaho are the only stations within the Basin that regularly report these data.

There are over 600 mountain weather and snowpack observations in the Basin, but the stations are spaced too far apart (50 to 150 km) to represent small-scale climate caused by complex topography in the region. Consequently, model-generated data play an increasing role in climate analyses of the mountainous west. Three sets of model-generated data were available for this study:

- Historical means of monthly and annual precipitation at 2.5-minute (about 5 km) and 5-minute (about 10 km) latitude/longitude spatial resolution from the PRISM model (Daly and others 1994).
- Daily temperature and precipitation for three characteristic years (1982, 1988, and 1989) at 2-kilometer resolution from the MTCLIM-3D model (Thornton and Running 1996).
- Monthly mean winds at 5-minute latitude/longitude resolution from the WINFLO model (Ferguson, in review).

[1] Personal communication. 1996. Monte McVay, Bureau of Reclamation, 1150 N. Curtis Road, Boise, ID 83706.

Trends in Regional Climate Patterns

Prior to about 1900, climatic trends in the Basin could only be determined using proxy data such as that evident from tree rings, glacier fluctuations, ice cores, deep sea sediments, lake levels, and fossil pollens. Several major epochs in modern climate have been manifested globally (Intergovernmental Panel on Climate Change 1990). (Moderate climate is considered by many to have begun after the last major ice age, about 10,000 years ago.) A thermal maximum occurred between about 9,000 and 5,000 years ago (Holocene period) when temperatures were 1° to 2° C greater than today. Another warm period occurred between A.D. 1000 and 1250, known as the Medieval Climatic Optimum, with temperatures about 0.5° C warmer than today. A "Little Ice Age" between A.D. 1550 and 1850 caused low snow levels and advancing mountain glaciers.

Regional trends in ancient climate also are noteworthy. For example, fossil-pollen data show variable responses to alternating warm, dry and warm, wet climates in the Holocene period (NOAA 1992 and 1993; Whitlock and Bartlein 1993) with the spatial heterogeneity controlled primarily by topography (Davis and others 1986; Whitlock and Bartlein 1993). In more recent times, local tree-ring chronologies (for example, Briffa and others 1992) suggest periodic warm periods in 1630s, between 1640 to 1660, 1790s, and the 1920s, with temperatures about 0.5° C greater than the 1881 to 1982 average. Alternating cold periods also are apparent in the chronologies, with the most significant from 1870 to 1900 (about the time of the Little Ice Age) having

temperatures 0.2° to 0.5° C less than the 1881 to 1982 average.

Historical weather observations within the Basin began in the late 1800s around the time that the Little Ice Age ended. Since then, mountain glaciers have generally retreated (Ferguson 1992, Meier 1984), which is a sign of general warming. Drought occurred in the 1930s, 1950s, and 1980s. There appear to be decadal trends in regional climate that could be related to the El Niño Southern Oscillation (ENSO) and Pacific North American (PNA) indices (Cayan and Peterson 1989, Redmond and Koch 1991, Ropelewski and Halpert 1986, Yarnal and Diaz 1986). These trends are most obvious in streamflow fluctuations, which aggregate precipitation and temperature signals over large areas of the catchment and drainage basin of the stream.

Disturbance Climate Events

Climate patterns that disrupt ecosystem processes are common and often critical components in the natural cycle of events. Although the Basin is not known for extreme climate events, many climatic features that are ordinary to the Basin (such as summer cold fronts fanning wildfires or rain-on-snow floods) cause significant disruption of ecosystem processes.

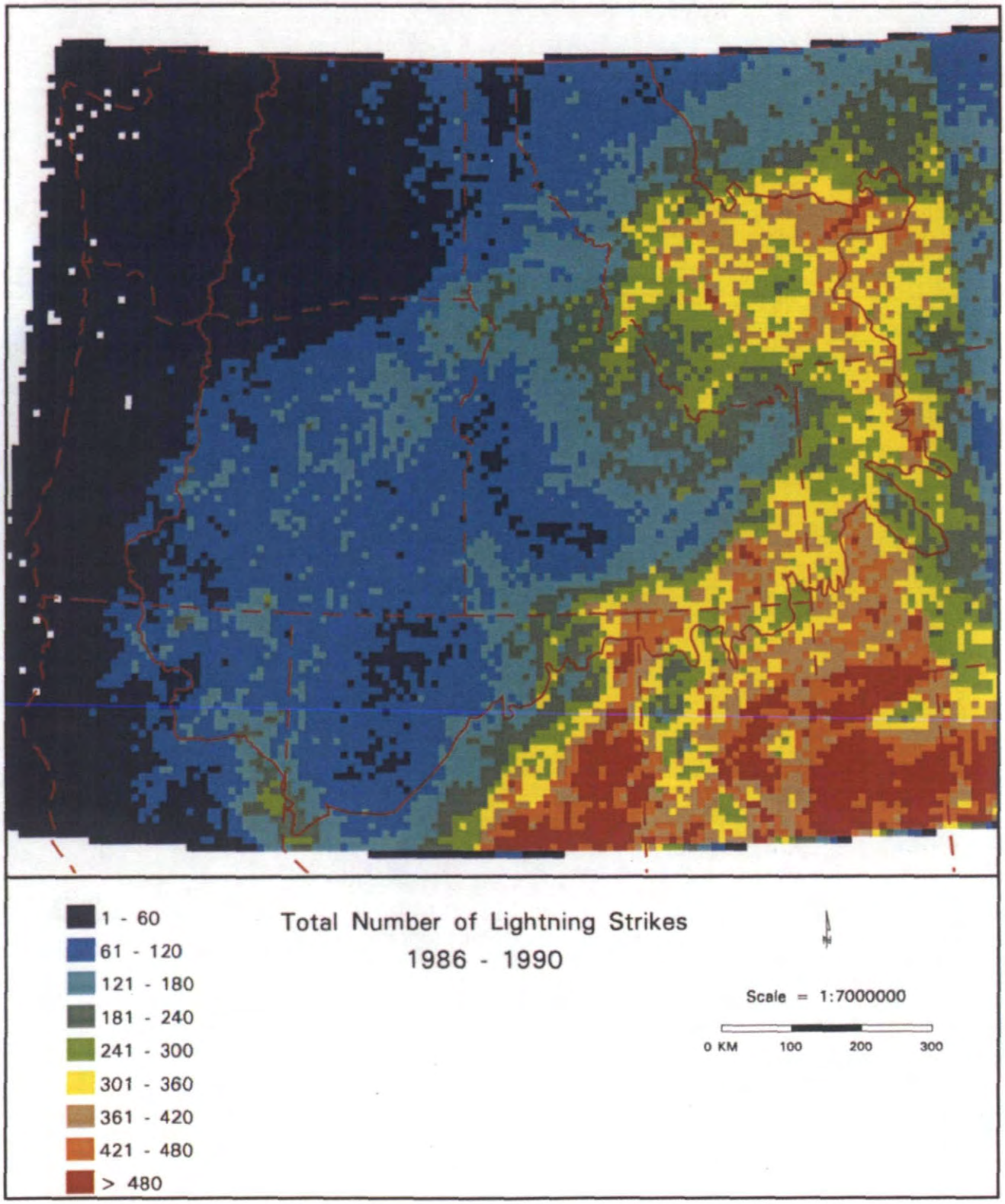
Lightning—Cloud-to-ground lightning strikes are the most common cause of wildfires in the western United States. Although the number of lightning strikes in the Pacific Northwest is low compared to elsewhere in the Nation (Orville 1994), their fire ignition potential is no less significant.

Until 1983, the best lightning occurrence data were available from fire lookouts. The data from more that 2,600 storms that were observed from 404 fire lookouts in Washington and Oregon from 1925 to 1931 were analyzed in a classic study by Morris (1934). He found that most lightning storms occurred on the south side of the Blue Mountains in eastern Oregon and in the Colville district of northeast Washington. Smaller areas of high frequency lightning occurred on the east slopes of the Cascade mountains in the Okanogan and Deschutes forest districts.

With the advent of an automated lightning detection system (Krider and others 1980, Latham 1983, Rasch and Mathewson 1984), more detailed and ongoing analysis of lightning strike frequency patterns became possible. Hill and others (1987) analyzed lightning frequency pattern in Idaho with automated lightning data from 1985 and 1986. The greatest number of strikes were found to occur in Idaho's southeast corner.

A summary of lightning frequency during the period 1986 to 1990 (map 2.28) shows that the highest lightning frequencies occur near the perimeter and outside the boundary of the Basin, in the higher elevations of Nevada, Utah, Wyoming, and Montana. Within the Basin, highest frequencies are observed in western Montana, the Idaho panhandle, and eastern Oregon. Very few lightning strikes were recorded throughout the period of record in most of Washington and the western half of Oregon, except a relatively high number of strikes occurred in the Oregon Cascades in 1989 and 1990. It is important to note that higher frequencies observed in regions where lightning is typically rare are likely the result of one or two individual storms, rather than a higher occurrence of lightning throughout the course of the year. Also, detectors only record about 70 percent of total strikes (Orville 1994) so numbers of strikes should be viewed in relative terms instead of exact magnitudes.

The number of lightning strikes in a given area does not directly correspond to the number of wildfires. Most lightning-caused fires in the Basin occur in the Blue Mountains of northeast Oregon and Sawtooth-Bitterroot ranges of central Idaho and far-western Montana (map 2.29), whereas most lightning strikes occur in southern Idaho and the Montana Rockies. This is somewhat contrary to the 1934 work of Morris, who found that lightning-caused fire locations agreed relatively well with lightning storm locations reported for the same period in Washington and Oregon.

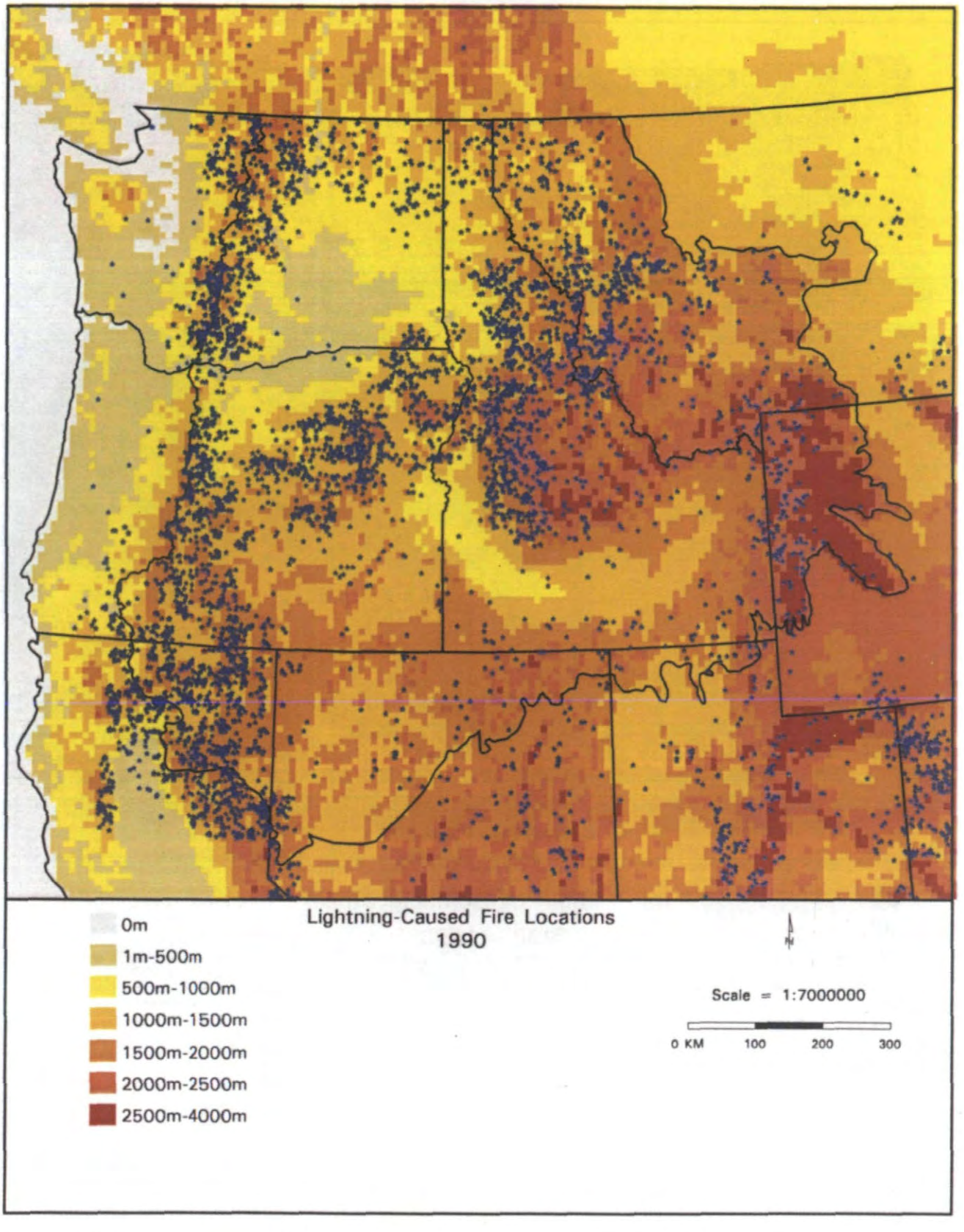


Map 2.28—Total number of lightning strikes (1986-1990).

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however, some errors may remain.



Map 2.29—Lightning-caused fire locations (1990).

Morris noted, however, that some storms ignited many more fires than others. Certainly fuel condition plays a significant role in flammability. Efforts to distinguish between dry lightning, which occurs with little or no precipiation, and wet lightning, with accompanying precipitation, show promise for determining lightning ignition potential (Peterson and others, in preparation).

Frontal passage and the spread of wildfire—Weather fronts often are associated with strong, gusty winds. This especially is true of cold fronts. During typical years (as in 1989), five to seven significant frontal events are possible during the fire season. In cool wet years (as in 1982), only two to four cold fronts appear to pass over the area.

In warm dry years (such as the 1988 fire season), 8 to 20 gusty wind events can occur. During these seasons, the continental air mass heats and dries out. The cool moist air masses from Pacific storms that progress eastward are dramatically different from the hot, dry continental air masses. As the air masses meet, associated fronts can be very strong. This effect is most significant when the seasonal upper-level flow pattern includes frequent meridional, or northerly flow, over the Basin. During the 1988 fire season, the most severe of the century, it was observed that the frequency of dry cold fronts passing over the northern Rockies in August and early September caused ongoing wildfires to make major runs (National Weather Service 1988).

Blow-down—Strong winds that cause forest damage are common in the Pacific Northwest. For example, around the outflow of the Columbia Gorge and Snake River plain, sustained wind speeds of 20 meters per second (about 45 mph) have two-year return intervals, and gusts with higher speeds are even more prevalent (Wantz and Sinclair 1981). In addition, many steep-walled valleys and canyons can channel and accelerate winds to damaging speeds.

Significantly strong winds and storm winds that occur in other than prevailing directions are the dominant climate components to blow-down potential (Boose and others, in review). Trees most susceptible to blow-down usually are exposed to recently created up-wind fetches like the edge of clearcuts made while harvesting timber or for agriculture and land development. Stand structure, tree health, soil stability, and accumulation of snow and ice can aid in blow-down potential (Lohmander and Helles 1987; Miller and others 1987; Schaetzl and others 1988).[2]

Trees at all elevations in the Cascade passes can become wind-hardened to the prevailing westerlies. During winter, the offshore flow is channeled through the Cascade passes and strong easterly winds result. Because the east winds are stronger and completely opposite to the wind-hardening westerly direction, blow-down is common in the passes during winter. Elsewhere around the Basin, trees at high elevation are wind-hardened to prevailing southwesterly upper-level flow patterns; trees at lower elevation usually are less wind-hardened.

A gap flow similar to that in the Cascade passes may play an important role for blow-down potential in northeastern Washington and northern Idaho. Here, deep river valleys funnel and help accelerate pressure gradient winds through the forests. The direction of these gap winds depends on whether storms pass over north or south of the area. Because trees are wind-hardened with dominating downslope flow in summer, the strength and direction of gap winds in the Colville, Okanogan, and Panhandle forests are significant enough to cause blow-down.

Strong winds in the upper Snake River plain result from converging air as the valley turns and narrows. The combination of high mountains and steep valleys contributes to strong wind patterns in far western Montana.

Drought—Drought in the Columbia River Basin is common, but is tempered by an abundant source of moisture that spills over the Cascade

[2] Also personal communication. 1996. Diana Sinton. Ph.D. candidate, Department of Geosciences, Wilkinson Hall 104, Oregon State University, Corvallis, OR 97331.

Range and through mountain gaps from the Pacific Ocean. Most often, drought is limited to small areas of the Basin or short periods. Severe, multiple year, Basin-wide droughts occurred in the 1930s and late 1980s. Because most summer water resources rely on winter snowpack, severe droughts occur with abnormally low winter and spring snowfalls (Namias 1983), which are correlated to El Niño southern oscillation in streamflow runoff patterns (Cayan and Peterson 1989). For example, the 1977 and 1988 winter droughts were associated with El Niño events. El Niño patterns occur every one to seven years (Philander 1983, Rasmusson and Wallace 1983). Therefore, it may be reasonable to expect that drought in the Basin would have a similar return interval.

To help determine the spatial pattern of drought events, Palmer Drought Severity Index (PDSI) data (Heddinghause and Sobol 1991, Palmer 1965) were obtained from the National Climate Data Center (NCDC). Drought frequency patterns from 1985 to 1994 were summarized for every season (map 2.30). During winter, drought is most common in places that typically have heavy winter precipitation, which is dependent on positioning of the jet stream and related storm tracks. During some years, the winter storm track remains west to northwesterly, and storms penetrating inland are too weak to maintain strength after crossing the coastal mountain barrier. This causes winter drought to be most frequent in areas that do not have enough topography to enhance lifting or convergence with weakened westerly winds: for example, on the east side of the Columbia Gorge (the coastal barrier's most significant gap), the Blue Mountains (which rely on abundant moisture from the southwest), and some of the lower-elevation inland areas in Idaho, and western Montana and Wyoming.

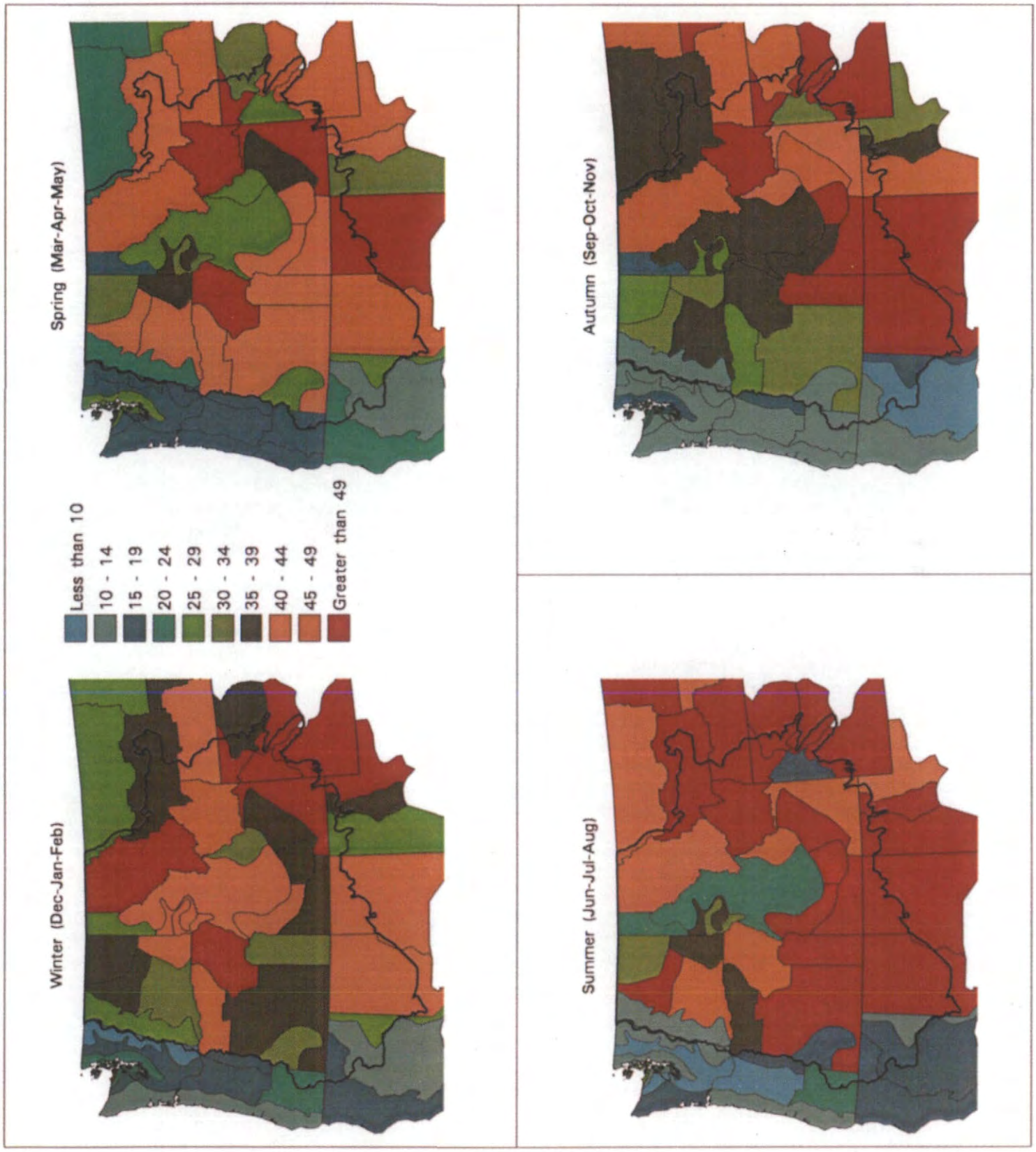
In spring, convective precipitation becomes important. Because convection is highly variable year-to-year, those places that depend on convective precipitation have more frequent periods of drought. This includes most of the Basin, except for some of the mountain areas near the Cascades, which benefit from spillover Pacific moisture, and places in northern Washington and Idaho, which collect moisture from a few storms that pass over Canada during summer. Winds at the head of the Snake River commonly converge, and this helps enhance lifting and precipitation to slightly reduce drought there.

During summer, the reliance on convective precipitation becomes even more apparent with a spatial pattern of drought similar to those of spring but with somewhat higher frequencies. In autumn, the winter storm tracks begin to establish, which helps to relieve much of the northwestern and mountainous parts of the Basin. The south and southeast portions, however, retain some reliance on the highly variable convective precipitation. Therefore, these regions of the Basin experience drought whenever autumn convection is minimal.

Cold damage potential—Very cold temperatures can damage vegetation and cause surface and ground water to freeze. Short-term freeze primarily affects new growth. Long-term freeze can affect lake and stream systems and cause sustained damage to mature vegetation.

Previously stressed trees are more likely to sustain damage from temperatures that normally cause no damage (Levitt 1980). Micro-scale topographic effects also are factors in cold damage. Trees on north- and west-facing slopes receive more damage during winter storms than those on south- and east-facing slopes (Porter 1959). On cold clear nights, saplings in hollows and valleys are much more prone to frost damage due to pooling of frigid air (Blennow 1992).

There are few cases of documented cold damage in the Basin. Therefore, to gain insight into the potential for cold damage, a model was designed to include many of the known causes for cold damage to trees (Westrick and others, in preparation). In winter, cold damage primarily occurs during a cold snap that immediately follows an unseasonably warm period. Spring damage occurs to trees when freeze follows budbreak.



Map 2.30—Total months with PDSI <-3.0 (1895-1994).

During autumn, damage occurs if freeze precedes cold hardiness. By applying this model with distributed temperature data that was generated by Thornton and Running (1996), the spatial extent of cold damage potential during three characteristic years becomes apparent.

During a characteristic cool, wet year (1982), low to moderate cold damage is possible for many areas around the Basin, mainly above 2,500 meters. Some damage to peach trees in east-central Oregon was reported during this time, but most other areas showing potential damage were above tree-line. A moist, zonal flow pattern commonly is associated with this type of climate in the Basin, causing moderately varying temperatures with few extremes.

A warm, dry year (1988) spawned a few more cold damage events. Weather patterns in this type of climate commonly are associated with a split upper-level flow that prevents frequent storms from crossing the Basin. Warmer overall temperatures allow a greater percentage of trees to come out of dormancy earlier in the spring season and to go into dormancy later in autumn. This makes them more susceptible to cold storms that can break through the split flow and pass over the area.

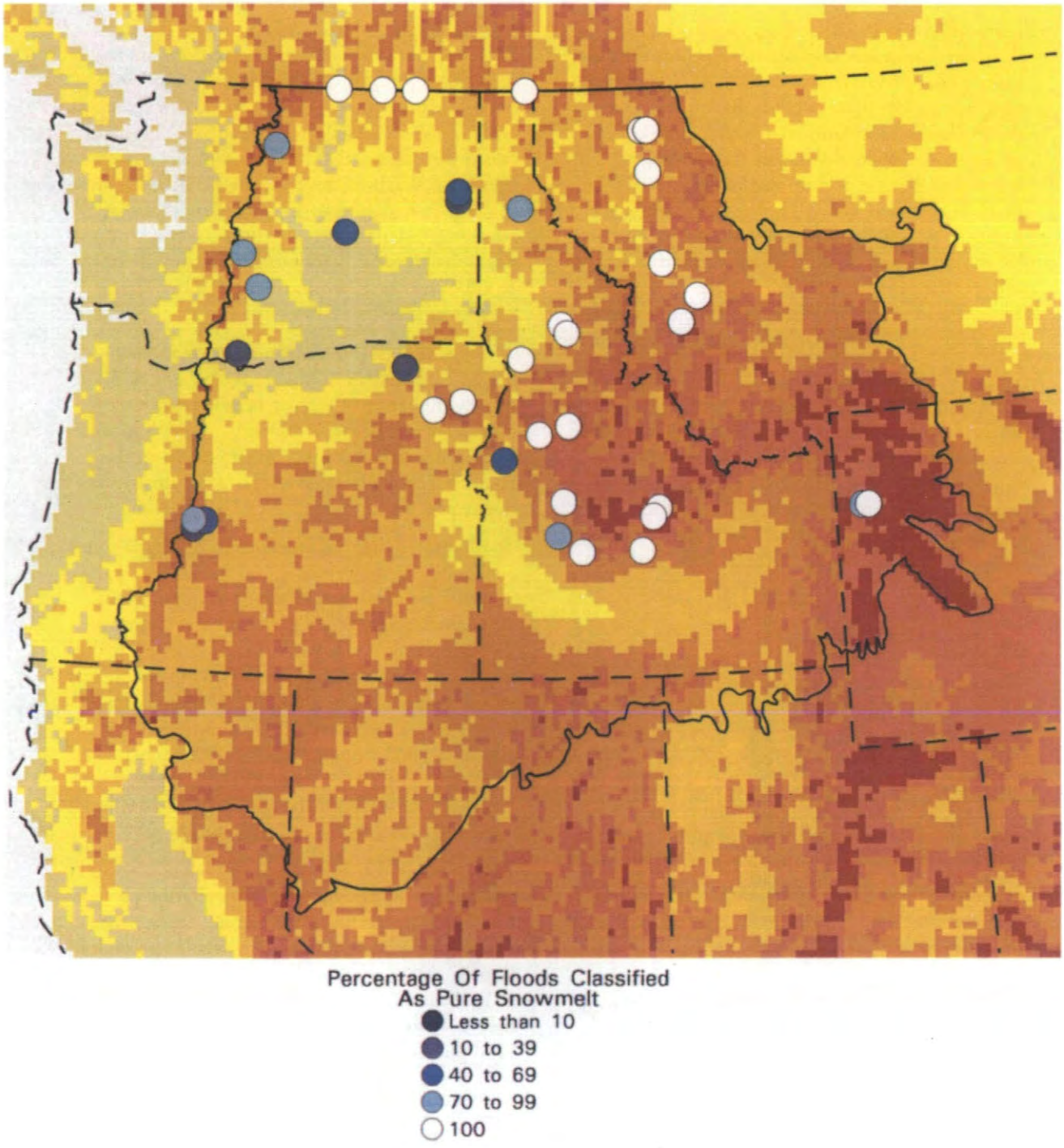
A more typical year is represented by temperatures in 1989. Typical northwest weather occurs when the upper-level flow pattern fluctuates between moist zonal flow and cold meridional flow. Although seasonal conditions allow normal timing of dormancy and budbreak, extremes in temperature also are possible. During this year, significant cold damage was reported in western Montana (Klein 1990).

Rain-on-Snow floods—When heavy rain falls and penetrates an existing snow cover, intense and damaging floods are possible. Harr (1981) indicated that 85 percent of landslides in western Oregon are associated with snow-melt during rainfall. Similar studies have been conducted in British Columbia (Beaudry and Golding 1985), California (Hall and Hannaford 1983), and western Washington (Harr and Cundy 1990).

Further away from the coast, a pervasive winter snow cover is typical and mid-winter rain is less common. Unlike other continental interiors, however, the Columbia River basin has a unique topographic configuration that allows frequent incursion of warm, moist air from the Pacific Ocean. This causes occasional rain to fall onto the existing snow cover. Resulting floods are less frequent but equally destructive (Cooley and Robertson 1983, MacDonald and Hoffman 1995, Zuzel and Greenwalt 1985, Zuzel and others 1983). Paleo-climate evidence suggests that ROS events caused significant flooding in the Columbia River Basin during several periods between 18,000- and 9,000-year B.P. (Chatters and Hoover 1992). Since 120 A.D., major floods (similar to the 1948 event) along the Columbia River system appear to have occurred every 140 years, except for a period between 1020 and 1390 A.D. when floods occurred at rates three to four times more frequently (Chatters and Hoover 1986).

To help understand the frequency and severity of ROS floods in the Basin, we reviewed unregulated stream gauges. All of the stations in the Wallis-Lettenmaier-Wood data set (1991) in the Columbia Basin above The Dalles were selected. Next, all floods that occurred during the months of October to February were classified as ROS events, and those that occurred in other months were classified as pure snow-melt (that is, dominantly radiation melt) events (map 2.31). Those stations in the Basin that were classified with a high percentage of ROS flood represent relatively low elevation catchments. This corroborates evidence that snow accumulations at low elevations can significantly enhance ROS floods (Harr and Cundy 1992). Even with a low percentage of ROS floods, it is interesting to note that several stations experience their heaviest floods during the infrequent ROS events (Ferguson and others, review a).

To illustrate the spatial distribution of ROS events, a simple algorithm (Ferguson and others, in review a) for determining when rain is falling on snow was applied to the Basin using available temperature and precipitation data for characteristic climate



Map 2.31—Percentage of floods classified as pure snowmelt.

years of 1982, 1988, and 1989. In all years, the model indicates rain-on-snow events are possible in many areas of the Basin. On closer inspection, areas most susceptible to ROS events are those where topography allows incursion of relatively warm, moist marine air that flows into the Columbia Plateau and up the Snake River valley from the Pacific Ocean. These areas include the Cascade mountains; northern Idaho, northeastern Washington, and northwestern Montana with valleys that open into the Columbia plateau; the Blue Mountains of northeastern Oregon; western Wyoming; and central Idaho adjacent to the Snake River.

Cool wet years (1982) are likely to have more rain-on-snow events. The cool temperatures allow low elevation snow to accumulate, whereas the frequent precipitation brings the possibility of mid-winter rain. Warm dry years (1988) are less likely to experience rain-on-snow flood events. There is little low elevation snow at these times and only occasional precipitation.

Air Quality Climate

Stagnant atmospheric patterns in the Columbia River Basin are dominated by topographic features. Surrounding mountain ranges impede mixing of air masses and create an isolated Basin atmosphere. Gaps through the mountains, however, allow a pattern of mixing that is unique to the Basin. Several components of climate that influence air quality include mixing height, precipitation, and upper level and surface winds. These components are discussed below, along with the implications of climate change on the Basin's air quality.

Mixing height—Mixing height may be considered as a level in the atmosphere above which vertical exchange of air is inhibited. Low mixing heights mean that the air is generally stagnant with very little vertical motion, and pollutants usually are trapped near the ground surface. High mixing heights allow vertical mixing within a deep layer of the atmosphere and good dispersion of pollutants. Mixing heights were calculated by the Western Regional Climate Center.[3] The stations analyzed included: Quillayute, Washington (58 m elevation), the only station on the Pacific coast; Salem, Oregon (61 m); Medford, Oregon (421 m), between the coast and Cascade mountain ranges; Spokane, Washington (722 m); Boise, Idaho (871 m), inside the Basin; and Winnemucca, Nevada (1,310 m), just south of the Basin in northern Nevada. Data included approximately 1,000 observations from the period between 1966 and 1989.

Within the Basin, the mean summer mixing height is about 1,800 meters at Spokane and Boise. The range of mixing heights, however, includes levels below 900 meters, especially at Boise where topographic constraints from the Snake River valley are even more dominant than the overall Basin topography.

To illustrate potential areal extent of stagnant air, constant height levels of 1,000 meters and 1,400 meters were plotted over the basin topography. Stagnant air may occur in the central plateau of the Basin and the lower Snake River valley if the mixing height is constant at 1,000 meters, near the lowest summer mixing heights. If the mixing height is constant around 1,400 meters, there is relatively good dispersion in the central plateau of the Basin. High basins and some high valleys in Oregon and western Montana may trap air, however, and cause pockets of stagnation.

Rain—Airborne pollutants may fall out of the atmosphere by attaching to precipitating particles. Liquid precipitation (rain) is more efficient at scavenging gas and particles than solid precipitation (such as snow and hail). Therefore, a simple analysis of rain days per month was conducted to help determine the frequency of wet deposition onto plants and into soils and snowcover.

To determine rain days in wildland regions, data from all National Weather Service (NWS) cooperative observation station sites above 900 meters

[3] P.O. Box 60220, Reno, Nevada 89506-0220.

elevation were selected. Days of rain were defined as those days with measured precipitation and mean temperatures greater than 5° C.

Rain days per month were calculated for January during three characteristic climate years: 1982, 1988, and 1989. In all years, there were few days of mid-winter rain at elevations above 900 meters. Although significant precipitation occurred during winter 1982, most fell as snow, and rain was confined to lower elevations in eastern Oregon and western Idaho. The "normal" year of 1989 again showed few mid-winter rain days, mostly at lower elevations.

The number of rain days per month became greater than snow days per month as seasonal temperatures increased. Slightly fewer stations observed rain during April in 1982 than other years because snowfall continued through spring that year. In 1988, several stations throughout the Basin experienced 50 to 75 percent days with spring rain. In 1989, most stations experienced at least 25 percent days with rain, which is typical of spring.

Summer precipitation in the Basin is dominated by atmospheric convection. During wet years such as 1982, a large number of stations experienced more than 50 percent days with rain, especially in places where summertime convection dominates precipitation. In 1988, no station measured significant precipitation as dryness pervaded the Basin. During a normal year, typical summer patterns of precipitation prevailed with most rain days occurring in places where convection is common such as eastern Idaho and western Montana.

During autumn, convection remains important in precipitation distribution. In addition, the significance of frontal and orographic precipitation begins to increase, but snow also may occur. In 1982, most of the mountain sites show over 25 percent of the days with rain. Cooler than normal seasonal temperatures also may have caused days with snow. In 1988, few stations measured more than a few days with rain. Most of those occurred in Idaho and western Montana where convection probably remained important. During a typical year, most stations observe about 25 percent of days with rain.

Upper level winds—Winds in the upper atmosphere may carry buoyant pollutants long distances. Land managers have shown concern about the possibility of pollutants from the Basin reaching the Grand Canyon. This may occur if upper level winds over the Basin are strong northerly.

Only two stations with the Basin regularly report upper-air data: Spokane, Washington and Boise, Idaho. The distribution of wind speed and direction was calculated by the Western Regional Climate Center[4] for Spokane and Boise. Winds at the 700 millibar (mb) level are shown because that level (about 3,000 m) usually is above the influence of terrain surrounding the Basin and is most likely to carry pollutants out of the Basin.

These results suggest that strong northerly winds are most common at both locations during winter. At Spokane, the mean winter 700 mb wind direction is westerly with a normal variation between SSW-W-NNW. Nine percent of the winds have a northerly component with speeds greater than 11 miles per second (m/s). Over Boise, winter winds prevail from the WNW, and 15 percent have a strong (greater than 11 m/s) northerly component. Although there is very little biomass burning in the winter, the northerly winds could scour away pollution trapped under the Basin's frequent winter inversion. Whether the scoured components reach the Grand Canyon or deposit along the way is unknown. Strong northerly winds are possible during spring and autumn burning seasons, but are rare. Summer northerly winds usually are too weak to transport material for long distances.

Surface winds—Winds near the earth's surface are most efficient at transporting pollutants that are either nonbuoyant or neutrally buoyant. These wind types can carry smoke from biomass burning into nearby towns and cities. In addition, surface winds can carry pollutants from industrial sources into wildland areas.

[4] P.O. Box 60220, Reno, Nevada 89506-0220.

Near the ground surface, winds are strongly influenced by small undulations in topography. There are not enough observations of surface wind to show the true variation in wind, so a simple mesoscale wind model was adapted to analyze the effect of surface wind on pollution transport (Ferguson and others, in review b).

Surface wind during winter primarily is controlled by pressure gradient forces between a persistent region of high pressure over the continent and frequent low centers from approaching Pacific storms. This pressure gradient causes strong easterly winds to persist through the Cascade mountain passes. It also causes much of the stagnant air, which is trapped under the frequent winter temperature inversion, to be pulled against the eastern Cascades (Steenburgh and others 1997). Passing storms cause winds to accelerate over the higher ridge tops, especially in the Rocky mountains. Converging winds are common, such as in the lee of the Blue mountains and head of the Snake River. Stagnant winds also occur, usually below the persistent inversions (see the discussion on central Columbia and Snake River plateaus).

During summer, surface winds are dominated by downslope flows caused by cooling air that drains into the valleys at night. An onshore flow also prevails, causing weak to moderate westerly winds through the Cascade passes. Areas of weak convergence or stagnation occur most frequently in valleys and basins where the downslope winds are trapped by surrounding topography.

Implications of global climate change on air quality in the Basin—Atmospheric concentrations of greenhouse gases are increasing. Major carbon constituents that contribute to the greenhouse effect are increasing at the following known rate: CO_2 - 0.4 percent or 1.5 parts per million (ppm) per year; CH_4 - 0.9 percent or 0.015 ppm per year; CFCs - 4.0 percent or 0.015 ppm [Intergovernmental Panel on Climate Change (IPCC) 1990 and 1992]. A recent report by the Pacific Global Change Research Program (PacGCRP) summarized the effective sources and sinks of greenhouse gases and discussed possible implications for management (Bytnerowicz and others, in press). For example, major sources for CO_2 are listed as decomposition, respiration, biomass fires, volcanic emissions, fossil fuel burning, and changes in land use. It also was recognized, however, that more nitrogen can produce a cofertilization effect in the terrestrial biomass, which would lead to sequestration of additional carbon. In addition, a discrepancy in the global nitrous oxide budget was attributed to emissions from forest soils, and certain management practices could minimize these emissions. The PacGCRP report also explains that sources of atmospheric methane include cattle, wetlands, and termites. Like CO_2 and nitrous oxides, CH_4 emissions can change by altering management practices.

Another implication of increasing greenhouse gases is their possible effect on global climate. Although uncertainty remains in the rate and magnitude of expected change, a general warming trend due to increasing concentrations of greenhouse gases is almost certain. We examined a climate change scenario that considered the regional effect of doubling the global atmospheric concentrations of carbon dioxide ($2xCO_2$) on regional climate (Ferguson 1997). The following list summarizes possible effects on air pollution:

- Greatest warming over high-latitude continents could result in less intense Arctic influence and thus weaker temperature inversions during winter.
- Continents could warm more than oceans, resulting in higher summer mixing heights.
- Decreased snow cover could cause less intense winter stagnation and earlier seasonal discharge of pollutants held in the snowpack.
- Increased convection over continents could lead to more wet deposition in spring and summer with less frequent drought in southeast portions of the Basin.

- Decreased soil moisture during summer could result in greater summer drought, especially in the central Basin.
- Fewer, but stronger, winter cyclones could cause less frequent but more significant disruption of winter stagnation.

Soil Features

Soil productivity is defined as the inherent capacity of a soil to support the growth of specified plants, plant communities, and soil biota (USDA Forest Service 1991). The Basin contains hundreds of soils that vary greatly in their parent material, climate, topography, vegetation, and age; this variation results in a broad range of productivity.

Soils were not mapped, nor productivity information collected, for this assessment due to the limited time available. Instead, indicator variables and an expert panel were used to evaluate soil productivity. Both a regional and a subregional assessment were completed and will be published in a separate technical paper.

Using ecoregions and subregions (map 2.4) delineated by Bailey and others (1994a), the panel divided the Basin into five distinct areas:

- Province M333
- Province M332, including eastern portion of Section 331A
- Province 342, including western portion of Section 331A
- Section M242C, including a small part of Section M261G
- Section M331D

The expert panel contributed to the assessment by providing the following information:

- A general productivity overview of each area.
- A description of the impacts of management activities on these indicators and processes.
- An estimation of productivity trends.
- Recommended actions for maintaining long-term soil productivity.

The findings of the expert panel are summarized below by province.

Province Descriptions

Province M333 Northern Rocky Mountain Forest-Steppe-Coniferous Forest-Alpine Meadow—Province M333 occurs in northeastern Washington, northern Idaho, and northwestern Montana. It is mountainous with elevations that range from approximately 370 to 3,000 meters. This area has a maritime-like climate, except in the east where a continental climate prevails. The average annual precipitation varies from about 400 to 2,500 millimeters. The dominant vegetation types are cedar hemlock pine, western white pine, and Douglas-fir forests. Volcanic ash covers most of the area.

Soil productivity of Province M333 is generally good because of the volcanic ash soils (Geist and Cochran 1991) and the presence of favorable temperatures and precipitation (maritime climate and low-to-moderate elevations). The most productive areas are the low- to mid-elevation sites where neither temperature nor moisture are considered limiting. The least productive soils occur west of the Columbia River and are shallow and stony, and lack volcanic ash.

Northern Rocky Mountain forests have generally low susceptibility to surface fuel accumulations because of their long fire cycles and relatively high productivity. Fuel accumulations remain close to historical norms. These systems are also more capable of replacing soil organic matter, coarse woody debris (larger than 10 cm in diameter), and nitrogen losses than lower productivity systems. In most cases, these forests can be considered moderately buffered against soil damage and in relatively good condition. However, where western white pine mortality from blister rust has been high and large amounts of dead material have accumulated,

these fuels can represent a substantial risk for causing soil damage if the site were to burn when fuels are dry.

Province M332 Middle Rocky Mountain Steppe-Coniferous Forest-Alpine Meadow Province—Province M332 occurs in central Idaho, westcentral and southwestern Montana, and northeastern Oregon. Elevations generally range from approximately 300 to 3,700 meters. This province includes mountains with narrow valleys, basins, alpine meadows, and breaklands. Most of the higher elevations have been glaciated. Maritime climate, westerly winds, and orographic precipitation yields less than 500 millimeters at the lowest elevations to over 750 millimeters in mountainous areas. Vegetation is dominated by Douglas-fir, ponderosa pine, grand fir, sagebrush steppe, and fescue/wheatgrass grassland.

The soils of Province M332 are only moderately productive because of their shallow depths associated with mountain locations, cold temperatures, and low precipitation in some areas. The most productive soils occur in valleys and basins where they are often deep, have high volcanic ash content, and receive higher precipitation.

Heavy fuel accumulations and dense stand conditions in some areas place long- and short-term soil productivity potential at risk from wildfire. In contrast, where high fuel and/or dense stand conditions are absent, the risk of potential damage to soils from wildfire is minimal. Where heavy fuels exist (especially on the most sensitive soils), future soil conditions are likely to degrade when wildfires do occur.

Province 342 Intermountain Semi-Desert—Province 342 consists of plains, tablelands, and plateaus in central Washington, southcentral and southeastern Oregon, and southern Idaho. Elevations range from approximately 60 to 2,400 meters. This area has a semi-arid, cool climate. Average annual precipitation varies from about 100 to 625 millimeters. Dominant vegetation types are sagebrush steppe and grassland.

Low productivity soils are common in Province 342 because of the sparse precipitation and low soil organic matter levels that occur throughout much of the province.

Even though moisture is the most limiting factor for these soils, organic matter and nitrogen values are also generally limiting. Organic matter amounts vary with moisture throughout the province. Riparian/wetland areas and high elevation forested and grass/shrub sites have the highest organic matter; the young lava flows, sand dunes, and saline-sodic soils have the least organic matter. In addition, extensive fires in some parts of the province have reduced organic matter and nitrogen contents to critical levels. This situation has often resulted in the expansion of cheatgrass monocultures, which are susceptible to repeated burn cycles that further degrade soil productivity. Although most forests in this area produce low amounts of fuels, high fuel accumulations that contribute to hot fires can occur on more productive sites.

Section M242C Eastern Cascades (including northern portion of Section M261G)—Section M242C occurs on the eastern slopes of the Cascades in Oregon and Washington. The upper Klamath portion of the Modoc Plateau in southern Oregon is also included in this discussion. Average annual precipitation of this area varies from about 250 to 4,000 millimeters and elevations range from approximately 90 to 3,000 meters. The dominant vegetation is a mixed coniferous forest dominated by Douglas-fir and ponderosa pine.

The soils of Section 242C have moderate to high productivity. The most productive soils of this area have formed from volcanic ash or pumice at low to moderate elevations with moisture and temperature regimes that are favorable for plant growth.

Large portions of this area accumulate substantial amounts of fuels and have high probabilities of stand replacement wildfires. Stands in this condition have a high risk for losses of organic matter, coarse woody debris, and nitrogen. The relatively

coarse woody debris, and nitrogen. The relatively low productivity of many of these forests and their soils means that lost organic matter will be replaced slowly, perhaps taking decades to centuries to replenish. However, in areas where high fuels and/or dense stand conditions are absent, the threat to organic matter loss from wildfire is less.

Section M331D Overthrust Mountains—Section M331D occurs in southeastern Idaho and western Wyoming. The landscapes of this area have been shaped by overthrust faulting and glaciation, which has created steep rugged mountains with narrow to broad valleys in a general north-south orientation.

Most of this area occurs within approximately 2,000 to 2,700 meters of elevation with some of the section extending to approximately 4,200 meters. The climate is a semi-arid steppe with most of the 400 to 1,000 millimeters of annual precipitation occurring in the fall and winter as snow. Vegetation is mixed, including coniferous forest and sagebrush/grassland with Douglas-fir, lodgepole pine, and aspen occupying the northern aspects. Alpine forb plant communities are common at higher elevations. The climate is cool, with cold soil temperature regimes and sagebrush/grassland communities in broad valley settings.

The soils of section M331D are generally moderately productive. The greatest productivity limitations are cool temperatures and short growing seasons due to the high elevations characteristic of this setting. Moisture is also limiting in some areas.

Although less extensive, similar conditions of fuel accumulation and dense stand conditions occur as in Section M242C. Where such conditions exist, both the long- and short-term productivity potential of the soil can be at risk from wildfire. Where high fuel and/or dense stand conditions do not exist, these forests are considered to be in good condition. Where heavy fuel loads exist on the most sensitive soils, future soil conditions are likely to degrade when wildfires occur.

General Effects of Management Activities

The importance of organic matter to long-term and short-term soil productivity is well documented. Organic matter is especially important for soil water retention, cation exchange, nutrient cycling, and erosion control (Page-Dumroese and others 1991). Organic matter buried in the soil improves aeration; increases structure, infiltration, percolation, and moisture retention; and protects the soil from compaction. As residues decay, they are incorporated into the soil and form organic reserves (Harvey and others 1987). Soil organic matter is an important source of nitrogen, sulfur, phosphorus, calcium, magnesium, and potassium for plant growth (Meurisse and others 1991, Page-Dumroese and others 1991).

Natural resource management activities can reduce soil productivity through the loss of organic matter and nutrients. These losses can be caused by erosion, topsoil displacement, damaging fires, and over-utilization. Management activities can also degrade the physical properties of soil, especially through compaction from equipment or livestock use.

Soil loss from erosion affects long-term soil productivity by reducing nutrient pools, water-holding capacity, and soil biotic populations, as well as by directly damaging vegetation (Megahan 1991, Swanson and others 1989). The most severe and long-lasting disturbances of soil erosion are deep-seated, mass erosional events. Surface erosion, however, on agricultural and mountainous lands is more widespread and can cause greater cumulative reductions in soil productivity. In addition, surface erosion reduces soil productivity disproportionately because the nutrients content and water-holding capacity of soils are highest near the surface in the organic layer and the uppermost soil horizon (O and A horizons) and decrease markedly with depth. Short-term growth is generally reduced when topsoil is removed, and effects are commonly greater on shallow soils than deep soils (Childs and others 1989).

Soil productivity can be reduced by natural and man-caused disturbances that accelerate soil erosion, including road construction, prescribed fire, grazing, cropping, and timber harvest. In non-intensively managed forests and rangelands, wildfires have the greatest potential of reducing soil productivity over large areas (Megahan 1991). Although the areal extent of soil displacement from logging activities rarely exceeds 30 percent within harvested areas, displacement of topsoil can decrease soil productivity dramatically (Childs and others 1989). Such displacement disrupts important biological activities and can increase surface erosion potentials by removing protective litter layers and reducing the infiltration capacity of the soil. Fire and displacement effects may leave soils in a condition with accelerated erosion potential for approximately a decade. Road construction increases the probability and size of mass erosion events and greatly accelerates surface erosion. Road effects commonly persist for the life of the road, although the amount of erosion normally decreases dramatically after the first few years (Megahan 1974).

Soil bulk density is the ratio of the mass of dry solids to the bulk volume of the soil. Soils that are loose and porous, such as volcanic ash soils, have low weights per unit volume; soils that are more compact have high values. Because the particles of sandy soils generally lie in close contact, they tend to have high bulk densities. The low organic matter content of sandy soils also contributes to their high bulk density. On the other hand, the particles of finer-textured surface soils are comparatively well-granulated, a condition encouraged by their relatively high organic matter content. As organic matter content increases, aggregation of the mineral soil particles increases and the soil becomes more porous, which results in lower bulk density values.

Maintenance of bulk density is crucial to sustaining long-term productivity (Froehlich and McNabb 1984). As management activities become more intense and concentrated in an area, bulk density commonly increases due to increased traffic. Increased traffic not only results in surface bulk density increases, but can be measured at depths of up to 30 centimeters in some cases. Recovery from surface compaction can occur within approximately 50 to 80 years after damage if there are sufficient organic matter inputs and freeze/thaw cycles to ameliorate compaction effects. Recovery of compacted subsoils probably requires upwards of 200 years. Increases in soil bulk density result in reduced seedling growth and less obvious reductions in the long-term nutrient content, porosity, and infiltration of affected soils.

According to Wells and others (1979), fire can have four generally negative impacts on soils:

- Removal of protective surface layer organic materials.
- Volatilization of large amounts of nitrogen and smaller amounts of other nutrients.
- Conversion of some nutrients into soluble forms that can be lost by leaching.
- Heating of the soil and alteration of its physical, chemical, and biological properties.

The burning of plant materials commonly volatilizes large amounts of nitrogen and lesser amounts of sulfur. Loss of nitrogen can potentially limit productivity because it is both the nutrient lost in the greatest amounts and the nutrient most frequently limiting for plant growth (McNabb and Cromack 1990). In general, the hotter the burn the greater the potential for soil damage and nutrient loss. Prescribed fires can normally be conducted during times when conditions will not result in substantial damage to the soil (that is, when soils and fuels are moist). However, wildfires can occur when soils and fuels are especially dry and can cause nutrient losses and water repellency (Debano and others 1970) resulting in overland flow, rill, erosion and soil productivity loss.

In addition to the soil productivity losses that can result from erosion, compaction, and severe burning, these disturbances can also lead to increased activity of endemic root pathogens. Soil distur-

bance can induce stress in the hosts of these pathogens and make them more susceptible to damage (Harvey and others 1989). This situation can lead to productivity losses and changes in vegetation composition and structure.

Estimate of broad productivity trends—The link between impacts on soil properties and long-term soil productivity change is not well-established. Because relatively little long-term data is available, most research results are for shorter periods of time, which limits their utility in understanding long-term soil productivity changes. Despite this fact, some shorter period research studies have documented soil productivity declines following soil disturbance (Froehlich and McNabb 1984, Helms 1983, Powers and others 1990). A National Long-Term Soil Productivity Research Program has been established within the FS to provide needed data to help understand the effects that management activities have on soil productivity (Powers and others 1990).

Expert panel estimates of soil productivity trends within the Basin ranged from stable to decreasing depending on the area examined. The trend for any particular area can generally be estimated based on the types and amounts of soil-disturbing activities that have occurred (that is, the greater the disturbance, the greater likelihood that soil productivity has been decreased).

From presettlement time to the present, the amount of soil in the Basin disturbed by land management activities has generally continued to increase. Some of these activities cause only minor soil disturbance while others cause long-lasting impacts. For example, soil productivity is probably relatively unchanged in most wilderness areas and other similar settings because there has been little physical disturbance or changes in organic matter levels. In contrast, some portions of the Basin have been intensively managed for many decades. Areas that have experienced substantial amounts of erosion, displacement, hot or multiple burns, or over-utilization of plant materials have generally experienced a decrease in soil organic matter and productivity. Similarly, areas that have had extensive equipment operations and/or livestock grazing have experienced increased soil compaction, which also decreases soil productivity.

Where fire suppression has been effective for long periods, soil productivity may be higher than historical ranges due to subsequent enrichment of organic matter and nitrogen. Intense fires will eventually burn such areas, however, and may result in high losses of organic matter, coarse woody debris, and nutrients through rapid oxidation, volatilization, and subsequent erosion by wind and water. Productivity will likely decline under these conditions.

In some localized areas, the productivity of soils may be increasing on sites that are not compacted, displaced, or severely burned, especially where nitrogen-fixing species (such as alder and ceanothus) contribute effectively to nitrogen enrichment.

Organic-matter levels of most soils within the Basin were generally in equilibrium with their environment prior to the initiation of logging, grazing, and farming. Organic matter and nutrients were balanced through recycling resulting in a situation where little loss in these elements occurred on most sites. Logging, grazing, and farming of soils within the Basin, however, typically resulted in some loss of organic materials and nutrients on a site due to removal of logs, herbivory, and agricultural development. After an area has been in management for some time, a new and lower equilibrium level of organic matter is reached. The exact level depends on the original amount and the management practices used. Areas where soil productivity conservation practices were implemented generally maintained higher levels of productivity than areas where such practices were not observed.

Recommended practices to maintain long-term soil productivity—Soil compaction is a major concern throughout all ERUs. A strategy that involves limiting the amount of compaction from equipment or livestock use would help

maintain long-term productivity. One such strategy is to limit operations to times when the least damage is likely to occur to soils (for example, when they are dry). Selecting equipment that will cause the least soil compaction can also help maintain productivity. Examples of minimal impact timber harvesting methods include use of low ground pressure equipment, grapple pile machines rather than dozers, and cable yarding systems or helicopters when possible.

Maintaining proper amounts of organic matter and coarse woody debris is also a major concern for all ERUs because of the importance of these materials to ecosystem function. In highly productive forests, a balance between too much and too little coarse woody debris is desirable. Too much fuel on a site often contributes to severe fires that may adversely impact soil productivity; however, too little fuel may also contribute to impaired long-term soil productivity. Examples of recommendations appropriate to coarse woody debris management are provided by Graham and others (1994).

Whole tree harvesting is generally not consistent with coarse woody debris management recommendations (Graham and others 1994) on most soils of the Basin. Similarly, the removal of slash containing tops and branches from most sites can negatively impact organic matter and nutrient cycles. Burning of these materials in place causes much less negative impacts to the soil, especially if they can be left on the ground for a winter season prior to burning. Leaving slash on the ground through the winter leads to a high probability that nitrogen and other nutrients in the foliage will be incorporated into the soil. Burning when soil surface layers are high in moisture can prevent development of water-repellent conditions.

Desirable site-preparation for tree regeneration includes burning or using mechanical treatments that cause no more disturbance than necessary to achieve sufficient seedling survival. Spot removal of surface soil layers (scalping) may decrease soil productivity; however, scalping may be required to alleviate special competing vegetation problems on certain sites.

Fire is an important tool for managing the organic component of soils. Severe intensity and/or long duration fires can cause organic matter loss, create hydrophobic soils, increase erosion, and consume nutrients. Desirable fire prescriptions are those that maintain as much of the surface organic layer as possible while meeting objectives for new vegetation establishment. In addition, prescribed fires that leave adequate amounts of coarse woody debris onsite maintain long-term productivity.

The following practices can protect soil organic matter and bulk density from livestock grazing:

- Leaving enough ungrazed plant material on site to sustain the supply of soil organic matter and litter.
- Placing salt away from riparian areas.
- Providing alternate water sources other than natural streams, if possible.
- Using grazing systems that keep livestock out of riparian areas during hot summer months.
- Herding or fencing livestock out of riparian areas.
- Delaying grazing following fire until the rangeland vegetation has recovered.

Soil productivity restoration—Preventing soil damage and productivity loss is usually easier than restoring soil productivity. In those situations where soil productivity restoration is required, two treatment approaches are commonly used dependent on management objectives. The first of these approaches is to restore organic matter and coarse woody debris to the soil. This objective could be accomplished by leaving areas undisturbed and allowing sufficient time for organic matter recovery to occur. Where organic matter loss is the result of erosion, controlling the erosion is often necessary before recovery can begin. The second common approach used in restoring soil productivity is to ameliorate increased bulk densities created by compaction. This objective is com-

monly achieved through use of subsoiling equipment designed to break compacted layers, which results in more favorable soil bulk densities for plant growth. Despite the fact that lower soil bulk densities can often be achieved through such treatments, not all of the physical properties of the soil are commonly restored to pre-disturbance conditions by such treatments.

Hydrology Features

Primary objectives for the hydrologic analysis of the Basin included:

- Basic description of the hydrologic environments present.
- Identification of relative hydrologic hazard and management potential differences across the Basin.
- Evaluation of recent hydrologic pattern and process changes.
- Description of probable effects of management on hydrologic system integrity.

Realization of these objectives involved characterization of each 6th-field subwatershed within the Basin using the following general types of data:

- Morphometric attributes
- Probable peak flows
- Biophysical environment composition
- Climatic attributes
- Stream type group composition
- Hydrologic hazard ratings
- Stream channel sensitivity ratings.

A subsample of 357 6th-field subwatersheds was also used to facilitate description of current stream and valley bottom type composition and to illustrate recent historic changes in riparian vegetation by different valley bottom type settings. Available fishery habitat data were also analyzed to describe finer scale channel unit characteristics by generalized stream type groups.

Information concerning each 6th-field subwatershed was aggregated into two levels of hierarchical aquatic ecological unit description for analysis:

- Hydrologic subregions (Jensen and others in press).
- Hydrologic regions or ERUs.

Basic descriptions of hydrologic pattern and process relations across the Basin are provided for the regional or ERU level of analysis conducted. Summarizations of hydrologic pattern and process relations at the subregional scale are being developed and will be published at a later date.

To facilitate synthesis of hydrologic data with other SIT staff information, 6th-field subwatershed data were summarized by ERU and displayed in various tables and figures. The following discussion provides a brief description of how these ERU data tables and figures were constructed. A description of the general effects of management activities on selected hydrologic patterns and processes follows that discussion.

ERU Characterization Procedures

Biophysical environment variables were used to develop an initial hydrologic region map of 14 settings within the Basin. These hydrologic regions were further modified in the development of ERUs as described previously in this chapter. Initial analysis of the hydrologic regions indicated significant differences in unregulated 4th-field subbasin stream hydrograph characteristics across the Basin. Classifications were developed for each unregulated, gauged 4th-field subbasin of the Basin based on its hydrologic flow type response characteristics (for example, ground-water or snow-melt dominated). Relativized percent composition of these flow type classifications were then attributed to each ERU based on subsample subbasin information (table 2.12).

Table 2.12—Relativized percent composition of different hydrologic flow type regimes by ERU, as determined by unregulated subbasin samples.

	Stream Flow Regime				
Ecological Reporting Unit	Ground Water Influenced	Snowmelt Influenced	Snow and Rain Influenced	Winter Rain Influenced	Harsh Intermittent Influenced (seasonally dry)
Northern Cascades	8	38	54	--	--
Southern Cascades					
Upper Klamath					
North Great Basin					
Columbia Plateau	9	27	9	54	--
Blue Mountains	--	25	75	--	--
North Glaciated Mountains	10	57	33	--	--
Lower Clark Fork	--	10	90	--	--
Upper Clark Fork	--	100	--	--	--
Owyhee Uplands	--	50	38	--	12
Upper Snake	--	33	67	--	--
Snake Headwaters			--		
Central Idaho Mountains	3	71	23	3	--

The composition of different biophysical environments that have strong relations to the hydrologic characteristics of each ERU are presented in tables 2.13a and b (lithology), table 2.14 (subsection groups), and table 2.15 (regional potential vegetation types). Construction of these tables involved summarization of average biophysical environment composition values for each 6th-field subwatershed within an ERU. Results are reported as:

- Constancy (the percent of the 6th-field subwatersheds in which a particular environment was present).
- Average composition when present (the average composition of a particular environment found in the 6th-field subwatersheds).
- Total average composition (the average composition of an environment across all 6th-field subwatersheds of an ERU, which includes 0 values).

Selected 6th-field subwatershed morphometric and climatic variable summaries are presented by ERU in table 2.16. These values reflect aggregation of average 6th-field subwatershed data as determined by PRISM average annual precipitation maps, 24-hour storm intensity maps, 2-kilometer raster-based climatic data extrapolations from the mountain climate simulator, regional USGS peak flow regression models, and 90-meter digital elevation modeling.

Table 2.13a—Primary lithologic composition of subwatersheds by Ecological Reporting Unit.

ERU Name	Lithology Code[1,2]	Percent Constancy	Average Composition When Present	Total Average Composition
Northern Cascades	36	43	34	15
	25	43	60	26
	4	57	45	26
	2	41	10	4
Southern Cascades	36	37	30	11
	25	98	47	46
	23	61	8	5
	6	54	23	12
Upper Klamath	36	34	14	5
	25	100	55	55
	23	69	5	4
	17	42	19	8
	10	51	29	15
	2	60	9	6
N. Great Basin	39	37	13	5
	25	94	45	42
	17	48	20	9
	2	75	13	9
Columbia Plateau	25	88	47	42
	19	47	54	25
	2	34	11	4
Blue Mountains	25	93	60	56
	2	45	9	4
N. Glaciated Mountains	34	37	5	2
	29	44	37	16
	4	41	32	14
	2	73	24	18

Table 2.13a (continued).

ERU Name	Lithology Code[1,2]	Percent Constancy	Average Composition When Present	Total Average Composition
Lower Clark Fork	30	51	43	22
	29	59	40	24
	3	41	38	16
	2	57	14	8
Upper Clark Fork	29	60	39	24
	12	47	19	9
	4	53	40	21
	2	86	15	13
Owhyee Uplands	25	81	46	38
	10	68	34	23
	2	68	21	14
Upper Snake	25	52	46	24
	10	48	29	14
	2	84	37	31
Snake Headwaters	37	52	19	10
	36	56	17	10
	31	39	13	5
	10	37	28	10
	7	64	25	16
	2	88	19	17
Central Idaho Mountains	4	58	57	33
	3	33	40	0
	2	47	18	9

[1] See table 2.13b for lithology descriptions.

[2] Only those lithologic types having constancy values greater than 33 percent are displayed in this summary table.

Table 2.13b—Description of lithology codes presented in table 2.13a.

Code	Lithology Description	Code	Lithology Description	Code	Lithology Description
1	Alkalic intrusive	15	Granitic gneiss	29	Meta-siltstone
2	Alluvium	16	Interlayered meta-sedimentary	30	Metamorphosed carbonate & shale
3	Argillite & slate	17	Lake sediment and playa	31	Mixed carbonate & shale
4	Calc-alkaline intrusive	18	Landslide	32	Mixed eugeosynclinal
5	Calc-alkaline meta-volcanic	19	Loess	33	Mixed miogeosynclinal
6	Calc-alkaline volcanoclastic	20	Mafic gneiss	34	Open water
7	Carbonate	21	Mafic intrusive	35	Quartzite
8	Conglomerate	22	Mafic meta-volcanic	36	Sandstone
9	Dune sand	23	Mafic pyroclastic	37	Shale and mudstone
10	Felsic pyroclastic	24	Mafic schist & greenstone	38	Siltstone
11	Felsic volcanic flow	25	Mafic volcanic flow	39	Tuff
12	Glacial drift	26	Meta-conglomerate	40	Ultramafic
13	Glacial ice	27	Meta-sandstone	41	Unclassified
14	Granite	28	Meta-sedimentary phyllite & schist		

Table 2.14—Primary geoclimatic subsection group composition of subwatersheds by Ecological Reporting Unit.

ERU Name	Subsection Group Code	Percent Constancy[1]	Average Composition When Present	Total Average Composition
Northern Cascades	M242-01	78	84	65
	M242-05	31	67	21
Southern Cascades	M242-05	74	44	32
	M242-01	56	59	33
	342-07	29	49	14
Upper Klamath	M261-02	47	64	30
	M242-02	45	71	32
	M261-04	42	55	23
Northern Great Basin	342-05	68	70	48
	342-04	43	37	16
	342-06	25	63	16
Columbia Plateau	342-07	38	63	24
	342-03	32	55	18
	331-02	23	64	15
	342-04	22	48	11
	342-05	22	61	13
Blue Mountains	M332-08	46	57	26
	M332-07	30	57	17
	M332-02	26	59	15
Northern Glaciated Mountains	M333-03	75	83	62
	M333-02	36	49	18
	M333-04	24	53	13
Lower Clark Fork	M333-04	91	92	84
Upper Clark Fork	M332-05	38	69	26
	M332-07	37	69	25
	M332-08	33	69	22
	M332-04	21	36	7
Owyhee Uplands	342-02	41	67	27
	342-06	38	71	27
	342-03	35	73	26
Upper Snake	342-02	66	78	51
	342-06	49	63	31
Snake Headwaters	M331-06	45	74	33
	M331-02	35	42	15
	M331-03	24	61	15
	M331-04	24	72	17
Central Idaho Mountains	M332-07	48	66	31
	M332-05	34	57	19
	M332-01	27	50	13

[1]Only those subsection groups having constancy values greater than 20 percent are shown in this summary table.

Table 2.15—Primary regional scale potential vegetation type composition of subwatersheds by Ecological Reporting Unit.

ERU Name	Potential Vegetation Type Code	Percent of Constancy[1]	Average Composition When Present	Total Average Composition
Northern Cascades	F22	74	29	22
	F12	61	17	10
	F33	57	25	14
	F14	54	15	8
	F23	50	18	9
	F34	45	15	7
	F13	39	15	6
Southern Cascades	F33	69	27	18
	F22	67	20	13
	F24	59	31	18
	F23	54	12	7
	F34	38	18	7
	F42	34	21	7
Upper Klamath	F34	80	18	15
	F42	79	15	12
	F44	62	27	17
	F33	44	12	5
	F24	42	48	20
	F23	33	14	5
	F22	33	12	4
Northern Great Basin	S33	88	70	61
Columbia Plateau	S33	47	47	22
	H23	45	40	18
	S22	36	34	12
Blue Mountains	F33	76	47	35
	S22	50	27	13
Northern Glaciated Mountains	F33	76	29	22
	F22	75	35	27
	F23	56	17	10
	F11	40	21	8
Lower Clark Fork	F23	77	17	13
	F22	73	22	16
	F33	71	33	24
	F32	65	53	35
	F12	37	16	6
Upper Clark Fork	F33	94	29	27
	F23	60	14	8
	F11	58	27	16
	F12	45	19	9
	F22	40	13	5
	F43	39	16	6

Table 2.15 (continued).

ERU Name	Potential Vegetation Type Code	Percent of Constancy[1]	Average Composition When Present	Total Average Composition
Owyhee Uplands	S33	77	51	39
	S34	39	34	13
	S22	36	26	9
	S23	35	53	18
Upper Snake	S33	98	75	73
	S32	52	13	7
	F44	41	14	6
	S22	41	15	6
Snake Headwaters	S22	67	23	15
	F23	64	21	14
	F33	61	23	14
	S33	45	33	15
	F32	41	16	7
	F34	39	17	7
Central Idaho Mountains	F33	73	23	17
	F23	55	32	17
	F13	54	31	17
	S22	49	28	14

[1]Only those potential vegetation types having constancy values greater than 33 percent are shown in this summary table.

Estimated stream type group composition of each ERU is presented in table 2.17 which reflects averages across all the 6th-field subwatersheds within an ERU. These values were obtained from a series of workshops where local experts described dominant stream type group composition of previously mapped subsection group slope phases. This information was associated to each 6th-field subwatershed of the Basin by a GIS and used to produce channel sensitivity ratings across the Basin.

Average valley bottom type (table 2.18) and stream type (table 2.19) compositions were associated to each ERU based on subsample information obtained within 357 6th-field subwatersheds. These data were used primarily in the identification of key biophysical environment variables for watershed classification efforts (Jensen and others in press).

Selected fishery habitat variables were analyzed by relating habitat components to stream type settings for each ERU. These data were also further stratified by watershed disturbance classes inferred from road density criteria. Fishery habitat components represent a finer-scale aquatic pattern. Therefore, only general relationship trends were detected in the interpretation of this data at the ERU level. Increasingly detailed observations of trends in this data set were achieved by hydrologic subregion stratification; however, space limitations preclude description of these results in this document. Results of fishery habitat analysis by ERU and hydrologic subregion will be presented in future publications.

Relative differences in hydrologic hazard and stream sensitivity indices between ERUs were described in this study. An example of this characterization is provided in figure 2.4, which displays hydrologic recovery potential differences by ERU. The box plot presented in figure 2.4 displays averages, 95 percent confidence levels, and ranges of relative interpretation ratings for each ERU, based on a summary of the 6th-field subwater-sheds within an ERU.

Table 2.16. Mean values for selected morphometric and climatic attributes of subwatersheds by Ecological Reporting Unit.

ERU	1	2	3	4	5	6	7	8	9	10	11	12	13
August Temp. (°C)	13.8	14.5	14.8	15.8	17.8	15.0	14.8	14.6	13.6	18.0	17.3	13.7	13.1
Growing Season Precip.(cm)	19.8	22.7	17.4	13.2	14.2	23.5	33.9	35.3	32.4	8.5	11.5	22.3	22.7
Growing Season Temp. (°C)	10.9	11.9	12.0	13.2	15.0	12.4	11.9	11.8	10.6	15.0	14.1	10.3	10.2
Annual Precip. (cm)	95.2	100.0	57.0	32.4	39.6	55.3	86.7	111.1	76.9	29.7	30.8	69.3	71.4
Summer Precip. (cm)	3.3	6.7	7.4	5.9	4.7	9.9	14.7	14.5	15.0	3.6	5.9	8.1	7.9
Summer Temp. (°C)	13.5	14.1	14.6	15.9	17.3	14.8	14.6	14.7	13.7	18.0	17.2	13.7	13.3
Winter Solar Radiation (Long.)	108	142	195	192	124	170	107	97	151	188	188	199	185
Winter Temp (°C)	-2.8	-0.3	-2.0	-1.3	0.1	-2.5	-4.1	-3.1	-5.1	-1.4	-4.0	-6.1	-5.0
Winter Max. Temp. (°C)	1.3	4.0	2.4	3.4	4.5	2.8	0.1	0.6	-0.3	3.6	1.4	-0.3	0.5
Winter Precip. (cm)	41.0	50.7	28.3	14.2	17.0	23.4	26.1	40.9	25.0	15.2	13.5	31.5	32.4
Average Elevation (ft)	4,004	3,618	5,134	5,152	2,488	4,259	3,882	4,146	5,805	4,742	5,495	7,206	6,211
Average Slope (%)	27	13	10	9	10	17	21	26	22	9	10	18	26

[1] ERUs: (1) Northern Cascades, (2) Southern Cascades, (3) Upper Klamath, (4) Northern Great Basin (5) Columbia Plateau, (6) Blue Mountains, (7) Northern Glaciated Mountains, (8) Lower Clark Fork, (9) Upper Clark Fork, (10) Owyhee Uplands, (11) Upper Snake, (12) Snake Headwaters, (13) Central Idaho Mountains.

Table 2.17—Estimated stream type group composition of subwatersheds by Ecological Reporting Unit.

ERU Name	Stream Type Group	Percent of Constancy	Average Composition When Present	Total Average Composition
Northern Cascades	0	96	36	35
	1	43	6	3
	2	12	8	1
	3	--	--	--
	4	97	28	28
	5	97	11	11
	6	25	3	1
	7	12	11	1
	8	99	14	14
	9	12	1	<1
	10	--	--	--
	11	44	2	1
	12	14	5	1
	13	13	2	<1
	14	39	4	2
	15	14	5	1
	16	12	5	1
	17	33	7	2
Southern Cascades	0	89	7	6
	1	69	3	2
	2	--	--	--
	3	--	--	--
	4	95	28	26
	5	97	20	19
	6	35	3	1
	7	--	--	--
	8	99	21	21
	9	--	--	--
	10	--	--	--
	11	86	4	3
	12	41	7	3
	13	18	2	<1
	14	89	3	3
	15	50	20	10
	16	10	2	<1
	17	78	6	5
Upper Klamath	0	12	5	1
	1	65	3	2
	2	65	3	2
	3	--	--	--
	4	99	17	17
	5	99	11	11
	6	47	9	2
	7	69	4	3
	8	99	21	21

Table 2.17 (continued).

ERU Name	Stream Type Group	Percent of Constancy	Average Composition When Present	Total Average Composition
Upper Klamath cont'd	9	--	--	--
	10	--	--	--
	11	52	3	2
	12	69	1	1
	13	69	3	2
	14	97	27	26
	15	79	9	7
	16	--	--	--
	17	69	6	4
Northern Great Basin	0	31	9	3
	1	38	2	1
	2	9	5	<1
	3	--	--	--
	4	98	7	7
	5	98	6	6
	6	9	3	<1
	7	15	1	<1
	8	99	17	17
	9	--	--	--
	10	--	--	--
	11	42	6	3
	12	20	4	1
	13	95	5	5
	14	97	12	11
	15	91	46	42
	16	29	5	2
	17	27	11	3
Columbia Plateau	0	78	8	6
	1	66	5	3
	2	63	3	2
	3	10	<1	<1
	4	97	11	11
	5	88	9	8
	6	2	2	<1
	7	86	9	3
	8	100	21	21
	9	11	<1	<1
	10	--	--	--
	11	97	14	14
	12	12	1	<1
	13	67	3	2
	14	49	5	3
	15	96	16	15
	16	27	5	1
	17	96	11	11

Table 2.17 (continued).

ERU Name	Stream Type Group	Percent of Constancy	Average Composition When Present	Total Average Composition
Blue Mountain	0	78	8	6
	1	66	5	3
	2	63	3	2
	3	10	<1	<1
	4	97	11	11
	5	88	9	8
	6	2	2	<1
	7	86	9	3
	8	100	21	21
	9	11	<1	<1
	10	--	--	--
	11	97	14	14
	12	12	1	<1
	13	67	3	2
	14	49	5	3
	15	96	16	15
	16	27	5	1
	17	96	11	11
Northern Glaciated Mountains	0	30	2	1
	1	96	26	25
	2	97	8	8
	3	--	--	--
	4	96	19	18
	5	95	11	11
	6	97	3	3
	7	97	8	8
	8	100	12	12
	9	92	1	1
	10	88	<1	1
	11	97	8	1
	12	2	4	<1
	13	8	3	<1
	14	7	6	<1
	15	8	33	3
	16	75	1	1
	17	90	1	1
Lower Clark Fork	0	92	3	3
	1	100	19	19
	2	100	30	30
	3	3	<1	--
	4	100	14	14
	5	100	13	13
	6	98	7	7
	7	100	2	2
	8	100	7	7

Table 2.17 (continued).

ERU Name	Stream Type Group	Percent of Constancy	Average Composition When Present	Total Average Composition
Lower Clark Fork cont'd	9	16	1	<1
	10	98	1	1
	11	100	2	2
	12	3	<1	<1
	13	4	4	<1
	14	3	5	<1
	15	4	2	<1
	16	20	2	<1
	17	99	2	1
Upper Clark Fork	0	98	15	98
	1	85	12	85
	2	81	6	81
	3	--	--	--
	4	100	18	100
	5	87	11	87
	6	22	2	22
	7	95	5	95
	8	100	13	100
	9	18	2	18
	10	22	<1	22
	11	90	9	90
	12	--	--	--
	13	54	1	54
	14	32	3	32
	15	59	9	59
	16	37	9	37
	17	100	7	100
Owyhee Uplands	0	41	10	7
	1	37	1	<1
	2	1	4	<1
	3	--	--	--
	4	85	9	8
	5	85	9	8
	6	35	4	2
	7	44	25	11
	8	100	26	26
	9	--	--	--
	10	--	--	--
	11	46	3	1
	12	63	8	5
	13	83	5	4
	14	84	9	8
	15	57	19	11
	16	65	4	3
	17	70	15	11

Table 2.17 (continued).

ERU Name	Stream Type Group	Percent of Constancy	Average Composition When Present	Total Average Composition
Upper Snake	0	56	11	6
	1	53	1	1
	2	9	2	<1
	3	4	1	<1
	4	66	10	7
	5	67	11	7
	6	12	3	<1
	7	72	30	21
	8	100	37	37
	9	8	<1	<1
	10	7	4	<1
	11	58	1	1
	12	59	2	1
	13	62	3	2
	14	62	8	5
	15	30	10	3
	16	61	6	4
	17	76	6	4
Snake Headwaters	0	96	4	4
	1	95	11	11
	2	90	11	10
	3	33	1	<1
	4	97	7	7
	5	99	12	12
	6	9	3	<1
	7	97	17	16
	8	100	22	22
	9	82	3	2
	10	61	5	3
	11	93	5	4
	12	15	6	1
	13	12	3	<1
	14	71	2	1
	15	42	4	2
	16	30	4	1
	17	51	8	4
Central Idaho Mountains	0	91	15	14
	1	90	16	15
	2	70	10	7
	3	3	<1	<1
	4	99	14	14
	5	96	11	11
	6	12	1	<1
	7	89	3	3
	8	98	14	14
	9	14	2	<1
	10	12	<1	<1
	11	87	6	6
	12	6	<1	<1
	13	53	2	1
	14	52	3	2
	15	65	7	5
	16	20	9	2
	17	95	8	8

Table 2.18—Observed valley bottom type composition of sampled subwatersheds by Ecological Reporting Unit.

ERU Name	Valley Bottom Setting[1]	Percent of Constancy	Average Composition When Present	Total Average Composition
Northern Cascades	1	64	44	28
	2	70	44	31
	4	29	6	2
	5	60	18	11
	6	61	21	13
	8	44	10	4
	9	58	20	11
Southern Cascades	1	46	23	10
	2	58	30	17
	4	35	8	3
	5	69	32	22
	6	39	14	5
	8	62	20	12
	9	77	39	30
Upper Klamath	1	100	12	12
	2	75	7	6
	4	100	5	5
	5	75	19	14
	6	75	13	10
	8	100	38	38
	9	100	17	17
Northern Great Basin	1	75	17	13
	2	100	20	20
	4	75	8	6
	5	100	35	35
	6	75	11	8
	8	88	15	13
	9	63	10	7
Columbia Plateau	1	80	36	29
	2	73	10	7
	4	68	17	12
	5	82	23	19
	6	70	7	5
	8	84	20	17
	9	72	17	12
Blue Mountains	1	71	33	24
	2	63	26	16
	4	57	14	8
	5	77	26	20
	6	59	13	8
	8	66	20	13
	9	60	18	11
Northern Glaciated Mountains	1	85	38	33
	2	72	22	16
	4	69	11	8
	5	83	17	14
	6	69	11	7
	8	74	12	9
	9	80	17	13

Table 2.18 (continued).

ERU Name	Valley Bottom Setting[1]	Percent of Constancy	Average Composition When Present	Total Average Composition
Lower Clark Fork	1	100	51	51
	2	51	100	14
	4	89	13	11
	5	78	3	3
	6	100	13	13
	8	89	4	3
	9	88	9	8
Upper Clark Fork	1	100	50	50
	2	94	11	10
	4	88	9	8
	5	100	13	13
	6	88	7	6
	8	91	7	6
	9	88	9	8
Owyhee Uplands	1	92	16	14
	2	44	8	3
	4	96	21	20
	5	96	17	16
	6	68	8	5
	8	100	25	25
	9	92	17	16
Upper Snake	1	64	27	17
	2	43	4	2
	4	93	18	17
	5	79	18	14
	6	21	8	2
	8	100	29	29
	9	86	23	20
Snake Headwaters	1	82	28	23
	2	100	27	27
	4	76	6	4
	5	100	17	17
	6	94	7	6
	8	94	7	7
	9	100	15	15
Central Idaho Mountains	1	95	51	48
	2	88	15	14
	4	78	7	6
	5	95	13	13
	6	76	6	5
	8	86	9	8
	9	72	10	7

[1]Valley Bottom Settings:

1 = Gradient > 6%; width = 0 to 50 ft

2 = Gradient > 6%; width > 50 ft

4 = Gradient ≥ 2% and ≤ 6%; width = 0 to 50 ft

5 = Gradient ≥ 2% and ≤ 6%; width = 51 to 200 ft

6 = Gradient ≥ 2% and ≤ 6%; width = > 200 ft

8 = Gradient < 2%; width = 0 to 200 ft

9 = Gradient < 2%; width > 200 ft

Table 2.19—Observed stream type composition of sampled subwatersheds by Ecological Reporting Unit.

ERU Name	Stream Type Code	Percent of Constancy	Average Composition When Present	Total Average Composition
Northern Cascades	A	88	72	64
	B	58	17	10
	C	54	23	12
	D	28	5	1
	SD	12	2	<1
	E	15	8	1
	F	19	12	2
	G	18	4	1
	T	13	4	<1
	DA	16	4	<1
	W	23	7	2
	L	40	8	3
	BD	4	2	<1
Southern Cascades	A	77	49	38
	B	54	32	17
	C	35	42	14
	D	27	9	2
	SD	4	3	--
	E	31	15	5
	F	23	10	2
	G	27	9	2
	T	12	8	1
	DA	15	8	<1
	W	31	6	2
	L	54	21	11
Upper Klamath	A	100	21	21
	B	100	17	17
	C	75	14	11
	E	50	10	5
	F	50	4	2
	G	25	12	3
	T	50	3	2
	W	75	7	6
	L	75	17	12
Northern Great Basin	A	100	49	49
	B	100	27	27
	C	63	8	5
	D	13	2	<1
	SD	25	1	<1
	E	63	12	8
	G	25	1	<1
	W	13	1	<1
	L	63	4	3

Table 2.19 (continued).

ERU Name	Stream Type Code	Percent of Constancy	Average Composition When Present	Total Average Composition
Columbia Plateau	A	95	49	46
	B	80	21	17
	C	58	13	7
	D	42	4	2
	SD	19	2	<1
	E	24	3	1
	F	34	11	4
	G	34	3	1
	T	47	8	4
	W	19	13	--
	L	46	11	5
Blue Mountains	A	86	57	49
	B	74	23	17
	C	48	15	7
	D	30	6	2
	E	35	15	5
	F	30	18	5
	G	30	6	2
	T	22	7	2
	W	21	3	1
	L	44	7	3
	BD	1	1	<1
Northern Glaciated Mountains	A	94	58	55
	B	85	19	16
	C	65	8	5
	D	37	4	2
	SD	15	1	<1
	E	50	5	2
	F	15	16	2
	G	17	2	<1
	T	20	7	1
	W	52	13	7
	L	70	7	5
	BD	24	4	1
Lower Clark Fork	A	100	71	71
	B	67	12	8
	C	100	18	18
	D	22	4	1
	E	11	2	<1
	F	11	5	1
	G	11	3	<1
	W	44	22	--
	L	22	2	<1
	BD	11	1	<1

Table 2.19 (continued).

ERU Name	Stream Type Code	Percent of Constancy	Average Composition When Present	Total Average Composition
Upper Clark Fork	A	100	67	67
	B	100	15	15
	C	55	8	4
	D	52	2	--
	SD	3	2	1
	E	48	6	3
	F	6	8	<1
	G	18	2	<1
	T	24	3	1
	W	61	4	2
	L	67	6	4
	BD	24	2	<1
Owyhee Uplands	A	100	27	27
	B	100	24	24
	C	92	19	17
	D	88	9	8
	SD	20	5	1
	E	52	8	4
	F	52	11	6
	G	76	5	4
	T	32	4	1
	DA	40	3	<1
	W	12	1	<1
	L	80	2	2
	BD	4	1	<1
Upper Snake	A	79	39	31
	B	93	28	26
	C	21	6	1
	D	43	7	3
	SD	7	3	<1
	E	29	6	2
	F	21	5	1
	G	71	4	3
	T	57	7	4
	W	21	18	4
	L	64	--	--
Snake Headwaters	A	100	54	54
	B	94	13	12
	C	100	18	18
	D	59	4	3
	SD	29	2	<1
	E	47	4	2
	F	17	2	<1
	G	47	5	3
	T	12	3	<1
	W	59	3	2
	L	76	6	5
	BD	6	1	<1

Table 2.19 (continued).

ERU Name	Stream Type Code	Percent of Constancy	Average Composition When Present	Total Average Composition
Central Idaho Mountains	A	100	66	66
	B	93	13	12
	C	71	8	5
	D	45	3	1
	SD	22	2	<1
	E	45	7	3
	F	33	5	2
	G	21	5	1
	T	22	4	1
	W	34	4	2
	L	62	5	3
	BD	5	2	<1

The numbers presented in this figure range from 0 to 100 percent and reflect cumulative frequency values, which indicate the percent of other 6th-field subwatersheds within the Basin that possess similar or smaller absolute values for a given interpretation rating.

Interpretation ratings were further summarized through calculation of Sorensen similarity coefficients between each ERU (table 2.20). These ratings display the total similarity between the ERUs, based on all subwatershed hydrologic hazard and stream channel sensitivity ratings. Values of 48 to 65, 66 to 82, and 83 to 99 percent similarity are expressed by low, moderate, and high class ratings, respectively, in this table. Narrative summaries of the hydrologic feature information described above are presented by ERU later in this chapter..

Effects of Management Activities on Hydrologic Systems

> "Although the river and the hillside do not resemble each other at first sight, they are only extreme members of a continuous series, and when this is appreciated, one may fairly extend the 'river' all over the basin and up to its very divides. Ordinarily treated, the river is like the veins of a leaf; broadly treated, it is like the entire leaf."

This lucid observation of William Morris Davis in 1899 on watershed process forms the basis for this discussion of the effects of management activities on hydrologic systems.

In both aquatic and terrestrial systems, the quantity and quality of water and its rate of movement determines the primary characteristics of the ecosystem. In most terrestrial habitats, water is the limiting factor to primary productivity and is the primary mechanism for the movement of energy and material through the ecosystem. Given these pivotal roles of water in the ecosystem, the careful management of the hydrologic system is critical to the human use of any ecological system.

"Hydrology is the study of the interrelationships and reactions between water and its environment in the hydrologic cycle" (U.S. Civil Service Commission USGS 1966). In this context, "environment" is broadly defined to include all ecological processes that affect water in the hydrologic cycle. It follows, therefore, that any discussion of the effects of management activities on hydrologic systems should focus on the hydrologic cycle (fig. 2.5).

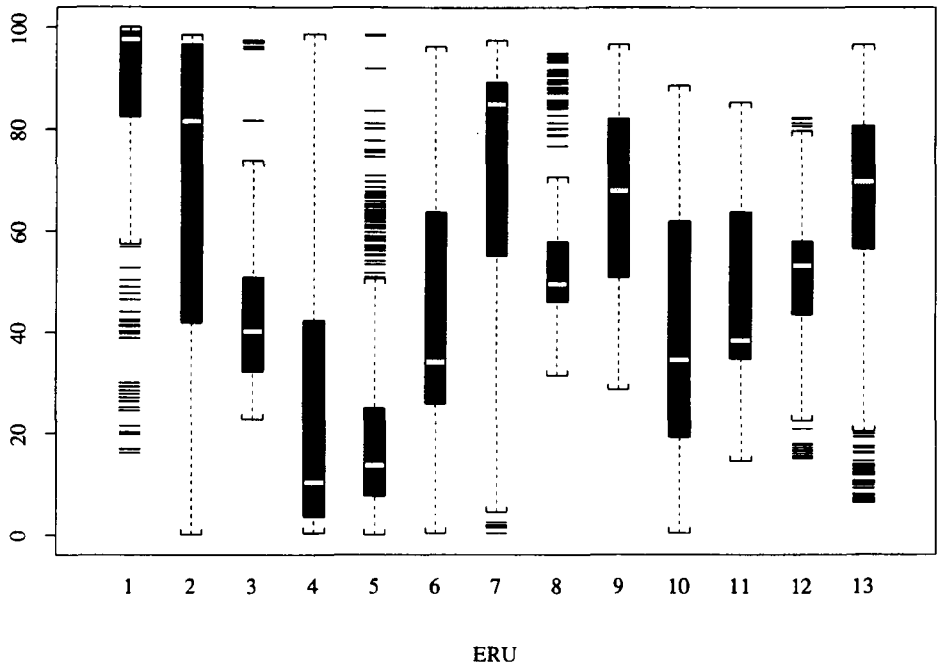


Figure 2.4—Box plot of hydrologic stream recovery potential following disturbance, based on average subbasin ratings by ERU.

Table 2.20—Average similarity ratings of subwatersheds based on hydrologic hazard and stream channel sensitivity criteria by Ecological Reporting Unit.

ERU	1	2	3	4	5	6	7	8	9	10	11	12	13
1	100	M	L	L	L	M	H	H	H	L	L	M	H
2	M	100	M	M	M	M	H	M	H	M	H	H	H
3	L	M	100	H	M	M	M	L	M	H	H	M	L
4	L	M	H	100	H	M	L	L	L	H	M	M	L
5	L	M	M	H	100	H	M	M	M	M	M	M	M
6	M	M	M	M	H	100	H	M	H	M	M	H	H
7	H	H	M	L	M	H	100	H	H	M	M	H	H
8	H	M	L	L	M	M	H	100	H	L	M	H	H
9	H	H	M	L	M	H	H	H	100	M	M	H	H
10	L	M	H	H	M	M	M	L	M	100	H	M	M
11	L	H	M	M	M	M	M	M	M	H	100	M	M
12	M	H	M	M	M	H	H	H	H	M	M	100	H
13	H	H	L	L	M	H	H	H	H	M	M	H	100

L = 48-65
M = 66-82
H = 83-99

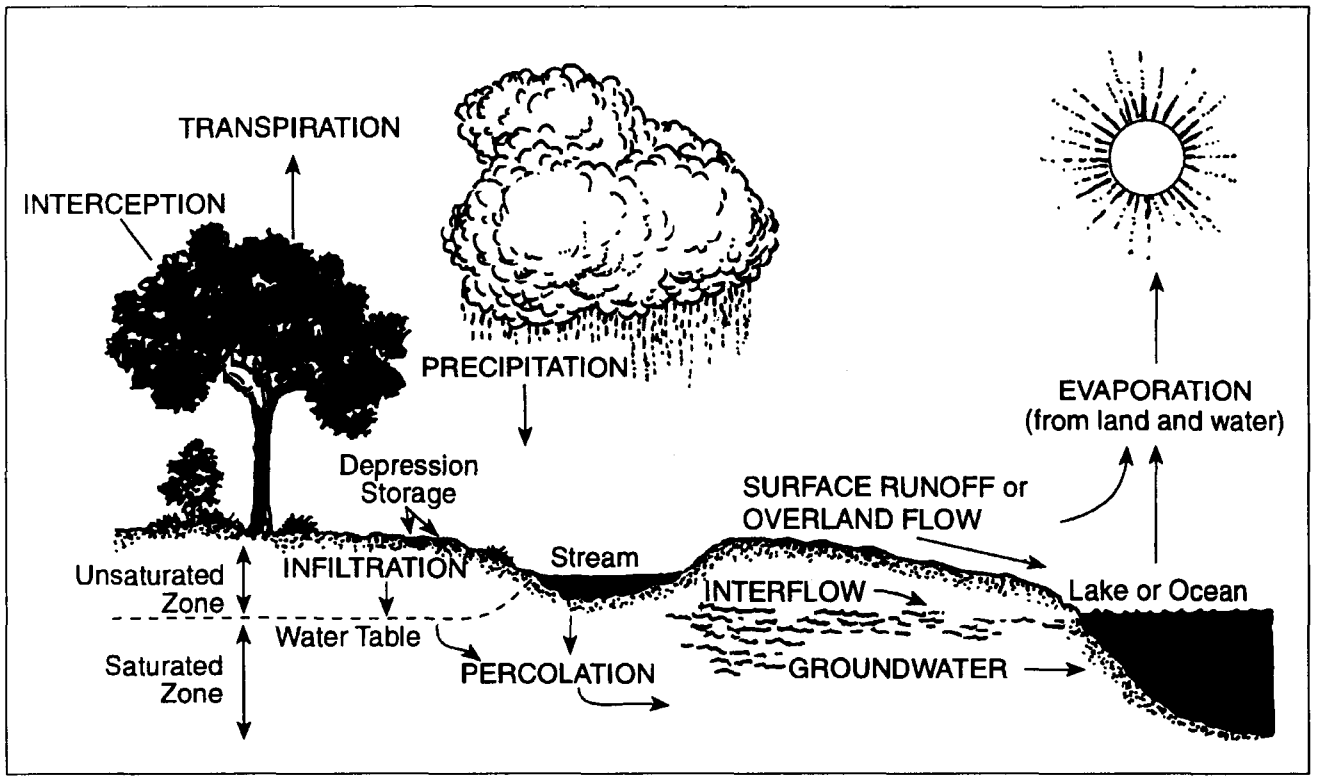


Figure 2.5—The hydrologic cycle.

The hydrologic cycle describes the pathways water follows as it moves in its endless cycle around the earth. Solar energy drives the system in many ways, primarily through evaporation of oceans and other surface water features. This water vapor then moves with winds over land areas and returns to earth as precipitation under a variety of conditions, as either rain or snow. Very few land and water management activities significantly affect precipitation on a large scale, but several kinds of activities common in the Basin do have localized effects. Extensive removal of vegetation cover and litter may cause a local increase in land surface reflectance of solar radiation, which in turn reduces the heat absorbed. Bare ground also tends to cool more at night than ground insulated by vegetation. Both of these factors contribute to a reduction in convective activity that forms cumulus clouds and thunderstorms. On a more local scale, openings in forest tree canopies can result in some redistribution and concentration of snow, which in turn changes the pattern and timing of snow melt.

Most precipitation is caught by vegetation with minor amounts of it stored on leaf surfaces, as well as by litter and debris on the ground surface. The remaining precipitation runs off the leaves and down stems or trunks, concentrating at the base of a plant. The portion of precipitation stored on leaf surfaces (interception) then evaporates or sublimates back to the atmosphere. Because interception is a function of vegetation cover, activities that reduce or increase vegetation affect this process. In a forested environment, tree canopy removal through harvest or fire reduces interception

surfaces; conversely, increasing tree canopy density through fire suppression increases interception surfaces. In a grassland or shrubland environment, grazing and fire reduce interception surfaces, whereas fire suppression with subsequent plant succession to increased shrub cover and woodlands increases interception. In an agricultural environment, perennial crops, particularly those with complex structure such as orchards, increase interception surfaces. Annual crops that only occupy the site for part of the year decrease interception surfaces. Another important aspect of interception is the effect it has on soil erosion and sediment production. Vegetation and litter layers dissipate the kinetic energy in rainfall, thereby reducing its erosive potential. Activities that increase vegetation or other soil cover reduce surface erosion and, therefore, the potential for sediment to be introduced into aquatic ecosystems. The relationship between interception and water are discussed along with transpiration later in this chapter.

The portion of precipitation not intercepted is delivered to the ground. Once on the ground, precipitation is affected by several processes including surface detention, infiltration, overland flow, subsurface flow, and percolation to ground water. Initially, surface detention is a principal factor in water movement. The amount and duration of surface detention is related to the micro-relief of a site. In a forested environment, micro-relief can result from many factors including woody debris on the ground, "pit mounds" from old windthrow events, animal digging activity, and soil disturbance from timber harvest activity. In a grassland or shrubland environment, grazing can increase micro-relief with hoofprints if grazing intensity is light to moderate, or decrease it if grazing intensity is heavy. In an agricultural environment, micro-relief can result from cultivation activities. When cultivation results in furrows, surface detention has a longer duration when furrows follow land contours.

Subsequent to surface detention is the infiltration process, which results in rain or snowmelt water seeping into the soil. The bulk density porosity, root mass and organic material present in the soil, are the principal factors affecting infiltration. Any activity that tends to compact the soil structure, forms crusts by clogging surface pores, and/or reduces the organic material present will reduce the infiltration rate of the soil. Such activities include: heavy equipment operations with timber harvest or agriculture, and excessive livestock grazing pressure. For a more detailed previous discussion of soil compaction, refer to the discussion about long-term soil productivity in this chapter.

Water that does not infiltrate into the soil and exceeds the capacity of a site's micro-relief for storage, runs downslope into streams as overland flow, which often generates floods. Overland flow is uncommon in the forested environments of the Basin because of the complex vegetation and litter present and the wide distribution of porous soils. A notable exception occurs when organic matter is removed and soils become hydrophobic following intense fires. Overland flow is also relatively uncommon in the grassland and shrubland environments of the Basin for many of the same reasons. Overland flow is a more common process in agricultural environments, especially where annual crops are grown on steep terrain, such as the Palouse. In general, overland flow events are not frequent in the Basin, but they have substantial effects on soils, stream channels, and riparian vegetation when they do occur. Such events can be quite erosive and often deliver considerable sediment to streams and other surface water systems.

Most water reaching the ground surface infiltrates to become soil moisture where it is held by capillary forces until it is accessed by plants or displaced by additional soil water movement. This displacement results in percolation laterally as subsurface flow into streams or vertically into the ground water zone (water table). Major effects on subsurface flows result from road construction on moderate to steep slopes. The cut-and-fill slopes created by roads commonly interrupt and concentrate subsurface flows in the road drainage ditch in all but the most porous subsoils. These

subsurface flows in the drainage ditch are then often delivered either directly to stream channels or drained across the surface as overland flows. This situation can deliver concentrated flows of water, along with sediment from the road surface and cut-slopes, to the stream channel. Such situations are evident in nearly all heavily roaded areas of the Basin. Steepness of the terrain, road density, and age and construction standards of roads, as well as whether Best Management Practices (BMPs) were followed, are the primary factors that determine the frequency and significance of this process.

The principal human activity affecting groundwater in the Basin is irrigation of agricultural lands. This activity has become increasingly common in the past few decades and accounts for substantial groundwater withdrawals in some areas. In other areas, irrigation with surface water from rivers has resulted in the establishment of a new water tables that commonly create areas of surface water in depressions.

Not all infiltrated water percolates into ground water. Instead some remains as soil moisture and either evaporates from the soil surface or is absorbed by plants into tissue or returned to the atmosphere through transpiration (the atmospheric return of water vapor through plant tissue). Because transpiration (much like interception) is a function of vegetation cover, activities that reduce or increase vegetation affect this process. Transpiration is also affected by the photosynthetic activity of the vegetation present; however, for general discussion purposes vegetation cover is primarily emphasized. In a forested environment, tree canopy removal through harvest, fire, insects, and pathogens reduces transpiration; conversely, increasing tree canopy density through fire suppression or reforestation increases transpiration. In grassland or shrubland environments, grazing and fire commonly reduce transpiration, whereas fire suppression with plant succession to increased shrub cover and woodlands increases transpiration. In an agricultural environment, perennial crops, particularly those with complex structure such as orchards, increase transpiration. Annual crops that only occupy the site for part of the year decrease transpiration. The amount of soil moisture transpired by the vegetation on a site influences the amount of water that percolates laterally and vertically into ground water and into stream channels and lakes. Therefore, the amount of transpiration, interception, and other evaporation returns to the atmosphere can increase or decrease water yield and streamflows. This fact is particularly important in evaluating the timing and duration of "spring runoff" peak flows and the volume and duration of "summer" base flows within streams.

Stream channels are the integrated products of the watershed that contains them, or as W. M. Davis (1899) observed "it is like the entire leaf." The ecological processes described above and the hydrologic effects of management activities all influence the pattern and character of rivers and streams. An important characteristic of hydrologic systems is that rivers, hillslopes, and floodplains are all parts of an integrated system. Uplands historically produce runoff and sediment within a certain range of levels. Stream channels, in turn, develop through time to move that range of runoff and sediment through the stream system and into larger streams, lakes, or oceans. Any activity that significantly changes the amount of runoff or sediment produced will result in stream channel changes. Large scale disturbances such as landslides and major floods do occur in the Basin and are important factors influencing watershed processes, however, the relatively smaller scale (yet widely distributed) changes in runoff and sediment following management activities are commonly the primary disturbance agents that influence the hydrologic integrity of aquatic systems within the Basin.

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SUMMARY CHARACTERIZATION OF CLIMATE, GEOLOGY, SOILS, AND HYDROLOGY INFORMATION BY ERU



The following discussion presents an overview of the major climate, geology, soils, and hydrologic patterns and processes within each ERU of the Basin (map 2.32).

Climatic summaries are presented first, by three regional scale groupings of ERUs (map 2.33):

- Eastern Cascades
- Northern Rockies
- Central Columbian and Snake River Plateau

A generalized description of the biophysical environment relations within each ERU is also presented which provides the following information:

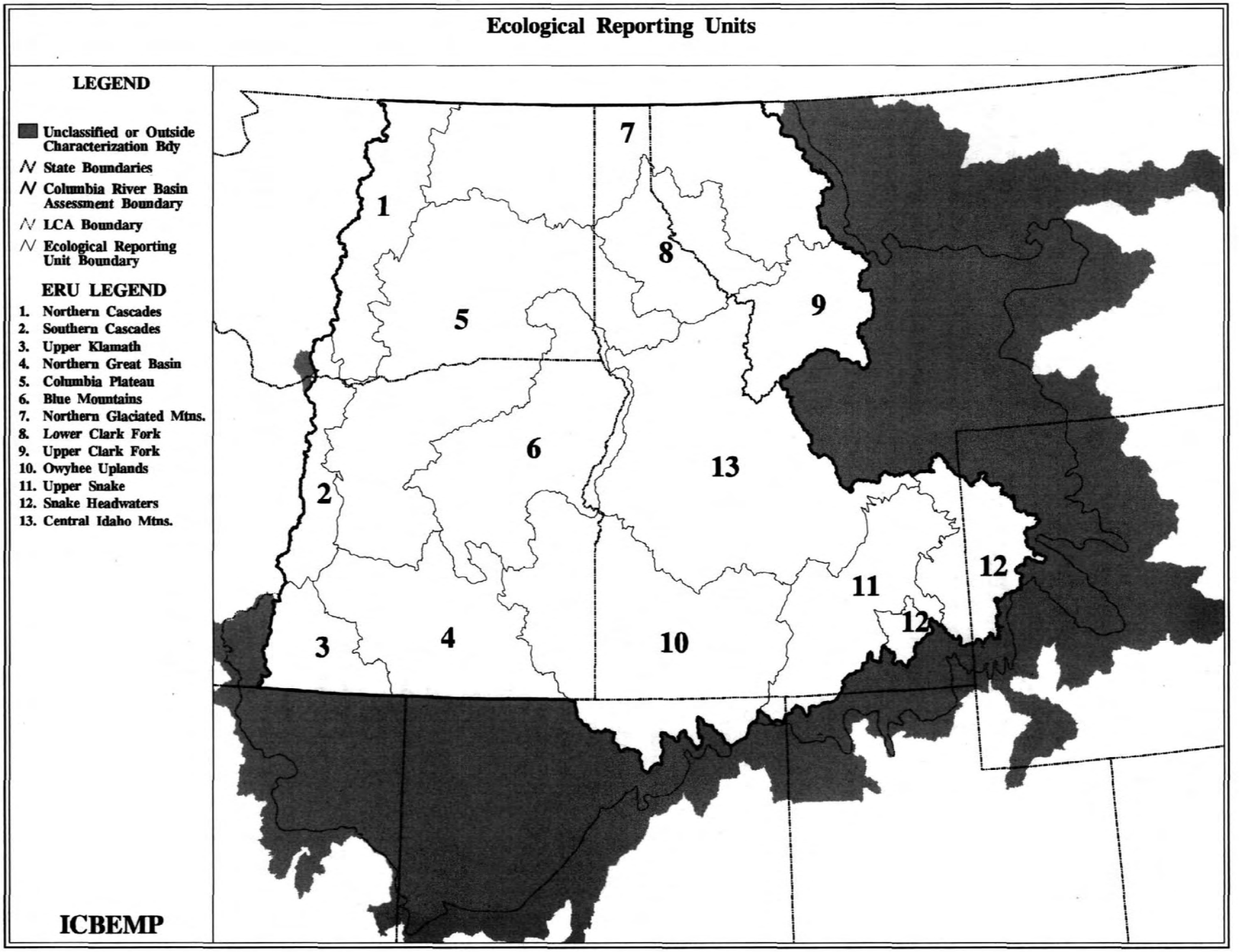
- Key statistics about characteristic subsection, lithology, potential vegetation type composition, and basic climatic and morphometric descriptions.
- Key descriptions of generalized soil characteristics and evaluation of productivity.
- Key interpretations of stream type groups, valley bottom settings, and wetland complexes.
- Key interpretations of upland erosion processes and sediment sources.
- Key interpretations of the predicted vulnerability of stream channels to disturbances, inherent channel recovery potential, and sensitivity to disturbance of the subwatersheds within each ERU.

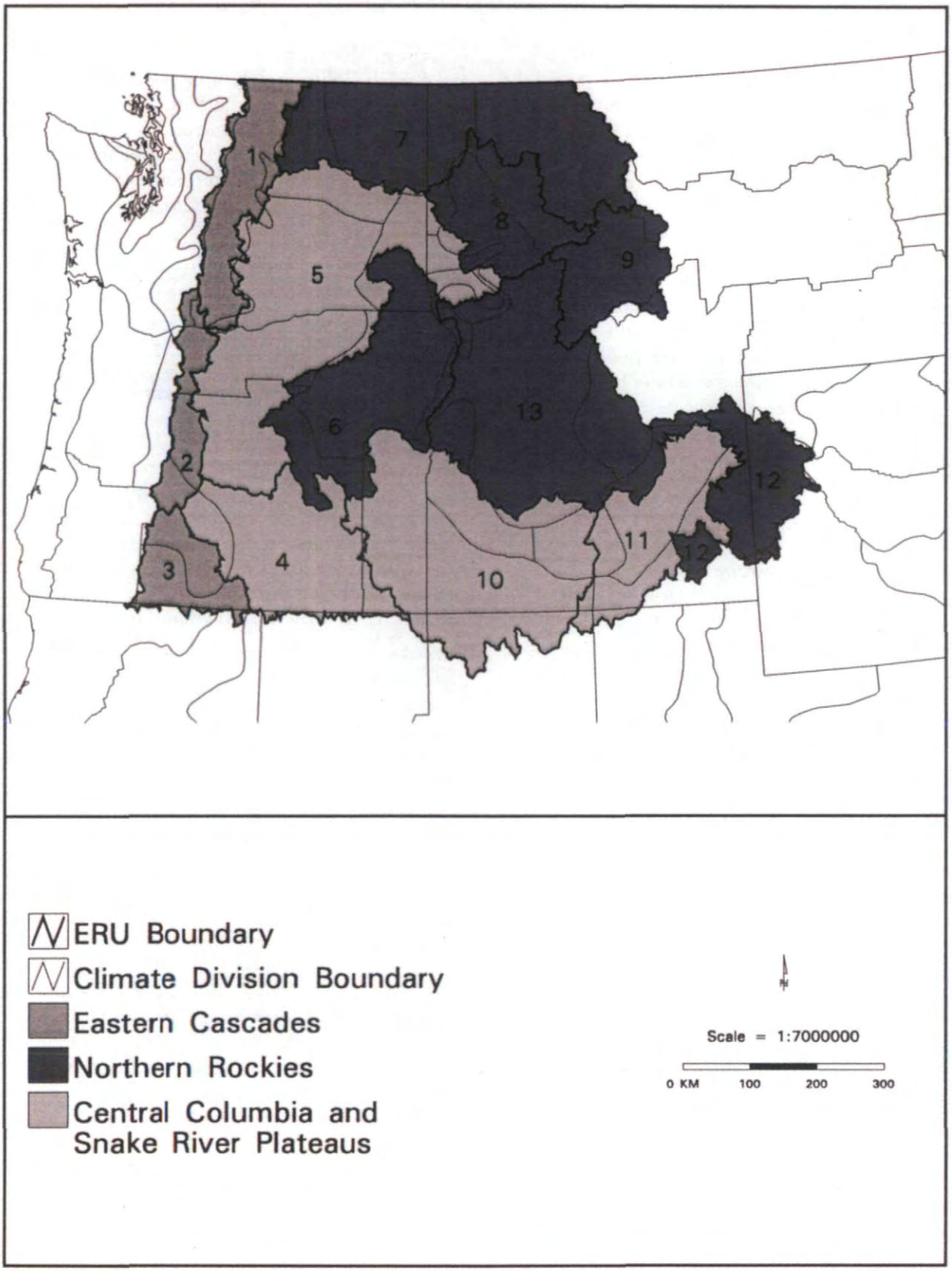
Climate Overview

The Basin is in a transition-type climate zone and is influenced by three distinct air masses:

- Moist, marine air from the west that moderates seasonal temperatures.
- Continental air from the east and south, which is dry and cold in winter and hot with convective precipitation and lightning in summer.
- Dry Arctic air from the north that brings cold air to the Basin in winter and helps cool the Basin in summer.

Map 2.32—Ecological Reporting Units.





Map 2.33—Basin's climate by three broad regions.

Eastern Cascades—The Cascade Mountains block most marine air from entering the Basin. The eastern slopes of the mountains (ERUs 1, 2, and 3) lie in a rain shadow of oncoming Pacific storms. During winter, however, when westerly winds are strongest, enough moisture spills over the crest to cause this region to remain wetter than other parts of the Basin (map 2.27). This region also receives high quantities of snowfall. Seasonal totals of snowfall typically range from about 200 centimeters in the south (ERU 3) to over 300 centimeters in the north (ERU 1), with greater amounts at higher elevations (over 2,000 cm of snowfall has been recorded at Crater Lake, Oregon). During summer, when westerly winds are weak, the rain shadow effect of the Cascades is most apparent and this region becomes the driest in the Basin (map 2.27).

Chinook winds can cause occasional warm, dry, and windy conditions that rapidly melt snow or initiate blow-down. Strong winds are also common within mountain gaps as air flow is channeled from both east and west directions. The westerly gap winds, most common in summer, are strongest as they flow into the Eastern Cascade region. The principal mountain gap is the Columbia River Gorge, just east of Portland, Oregon. Tornadoes and funnel clouds have been observed near the outflow of the gorge's westerly winds. In addition, the persistence such winds allows the gorge to be one of the nation's principal wind-surfing recreation areas. Strong southerly winds are also common, mainly during winter, on several east-west oriented ridges that protrude into the Basin from the Cascade crest.

Although this region often is under continental-type climate conditions (with cool, dry winters and hot, dry summers), marine air spilling over the mountain crests and through mountain gaps moderates both summer and winter temperatures. In addition, Arctic air often pools in the Basin and is pulled against the Cascades, causing a persistent temperature inversion to about 1,200 meters, especially in winter. Sharp contrasts in temperature occur when Arctic air is displaced by marine air; rain-on-snow flooding is common at all elevations.

Northern Rockies—The Canadian Rockies and British Columbia Mountains block most Arctic air from entering the Basin. The deep Okanogan, Columbia, and Pend Oreille valleys, however, can funnel the dry Arctic air into the Basin where it often stagnates, especially during winter when the air is cold and dense.

The Rocky Mountains on the eastern border of the Basin intercept continental air masses that rise over the mountains resulting in thunderstorm development around the edge of the Basin, especially in western Montana and southern Idaho. A thermal trough that migrates northward during spring and summer can also cause thunderstorms, mainly in central Oregon around the Blue Mountains (ERU 6). The convection causes an increase in precipitation during spring, with 24-hour accumulations often greater than 25 millimeters. Drier lightning is more common during summer and fall. Most convection and lightning occurs in the east and southeast units of this region (ERUs 9 and 12), nearest the Continental Divide.

Blow-down in this region is common. Strong down-burst winds associated with convective cells can cause blow-down, most commonly during spring. Blow-down also occurs in the north-south elongated valleys that channel strong southerly storm winds, mainly during winter. The high and contrasting topography also favors accelerated storm winds near ridgetops during winter and persistent slope winds during summer.

The northern Rockies are the coldest part of the Basin with mean winter temperatures between minus 4.2° C and minus 10.2° C. Snowfall amounts vary from about 200 centimeters to over 300 centimeters, with greater amounts at higher elevations. Although winter precipitation in the northern Rockies is less than the eastern Cascades, snowfall amounts are comparable for two reasons:

- Cold winter temperatures cause relatively low density snowfall in the northern Rockies, so snowfall amounts appear greater even though snow water equivalents may be less than the eastern Cascades.
- Colder spring and fall temperatures in the northern Rockies allow more snowfall during these two seasons than in the warmer Cascades.

Despite cold winter temperatures in the northern Rockies, occasional marine intrusions can cause sudden warming and initiate rain-on-snow floods, mainly at lower elevations and those places exposed to flow from the Columbia Gorge. In summer, the marine intrusions moderate summer high temperatures and add moisture to the convective cycle, increasing the chance that lightning is accompanied by precipitation.

Central Columbia and Snake River Plateaus—This is the driest part of the Basin (map 2.27). The Columbia Plateau and Snake River Valley, however, are susceptible to marine intrusions that can relieve summer hot spells and winter cold spells. The accompanying moisture can extinguish summer wildfires or cause winter rain-on-snow floods. Although rain-on-snow floods are rare in this region, any occurrences are more destructive and of much greater magnitude than spring floods. Typical seasonal snowfall totals range from 40 to 80 centimeters.

The upper plateaus (ERUs 4, 10, and 11) experience a moderate spring cycle of convective precipitation with lightning most common in ERU 11. Convection can be caused by the northward migration of a thermal low, especially in ERUs 4 and 5, and in the western part of ERU 10. Also, hot unstable air from the Great Salt Lake region can increase thunderstorm and lightning development over ERU 11 and eastern ERU 10.

Strongest winds in this region occur during the summer from the west at the east outflow of the Columbia Gorge (ERU 5) and during the winter from the south and west along ridgetops. Although climate in this region is marked by few extremes, long periods of stagnation occur during winter in the central Columbia Basin (ERU 5), in the Snake River Valley (ERU 10), and in high isolated basins (ERUs 4, 10, and 11). The stagnation events cause this region to be the most susceptible to air pollution concerns.

Climate trends in ERUs—Because ERUs do not exactly match the National Weather Service climate division boundaries used to calculate 30-year averages, new summaries were calculated using available COOP and HCN data within each ERU (tables 2.21, 2.22a and 2.22b). To analyze climatic trends in each ERU of the Interior Columbia River Basin, representative stations were selected that had weather records extending back more than 40 years and occurred near the mid-range of station elevations within a unit. A simple 10-year moving average of monthly mean values was used to evaluate trends and to help approximate year-to-year variability. Although historical trends in precipitation were apparent, trends in temperature were not obvious.

A notable maximum in snowfall and winter precipitation occurred in all areas during the mid-1970s. This event coincided with a stepwise change in other climate variables during 1976 (Ebbesmeyer and others 1991).

Winter precipitation since the mid-1970s decreased by 30 to 80 percent in all areas to a level comparable to historical means, except in ERUs 3, 8, 9, and 10, where the current winter precipitation trend is slightly lower than any in previous history.

Table 2.21—Dataset descriptions for climate data used in the Basin assessment.

Dataset Name	Begin Year	Basin Sites	Time Step	Duration	Measurement
HCN	1895	9	daily	annual	T, ppt
Coop	varies >1895	>300	daily	annual	T, ppt
SNOTEL	1978	45	daily	annual	T, ppt, SWE
Snow Course	1930	50	monthly	winter	H, SWE
RAWS	1985	~200	hourly	summer	T, Tf, RH, ppt, W
SAMSON	1961	10	hourly	annual	T, Td, RH, W, P, Q
RAOBS	1948	2	2/day	annual	T, Td, W, P (multiple heights)

In contrast to winter trends, all areas showed an increasing trend (30 to 80%) in summer precipitation during the last 30 years. Comparable highs in summer precipitation occurred around 1910. Since the mid-1980s, about half the Basin (ERUs 3, 6, 10, 12, and 13) has shown a 20 to 70 percent decrease in summer precipitation, but remains 40 to 80 percent above the 1960 levels. Periods of drought throughout the Basin since 1988 appear to be related to the overall decrease in winter precipitation and beginning signs of decreasing summer precipitation.

Trends in annual precipitation over the last 100 years show significant variability around the Basin (Karl and others 1996). The central Basin (Washington, northeastern Oregon, and eastern Idaho) showed 5 to 10 percent increases. Elsewhere, annual precipitation decreased 5 to 10 percent, with ERU 3 showing a 20 percent decrease. It is difficult to compare the 100-year trends with those calculated from stations within each ERU that have records of only 50 to 70 years. Also, Mock (in press) illustrated the highly seasonal nature of precipitation in the western United States. Therefore, changes in spring and autumn months that influence annual trends are not shown in the January and July records analyzed for each ERU.

Although there has been almost no change in measured winter temperatures in the Eastern Cascades, this area has had a notable increase in the percentage of winter precipitation. This increase could indicate somewhat higher snow levels with less snow accumulating at lower elevations. In the same region, a 1° to 2° Celsius decrease in the diurnal range of summer temperatures may suggest slightly increasing summer cloudiness. Other regions have less obvious changes, but overall trends appear to be toward slightly cooler summers and slightly warmer winters.

Mean temperature has increased 1° to 2° Celsius throughout the Basin over the last 100 years (Karl and others 1990). Because many of the stations used to analyze ERU trends have records since the 1930s drought era, their trends are smaller than the 100-year trends and even slightly negative.

The persistent drought throughout the Basin in the 1930s may relate to warm winter temperatures and associated high snow levels. Many areas also experienced a decrease in summer precipitation during the 1930s, adding to severe drought conditions. Periods of significant drought in a few areas of the central Basin and plateau regions during the 1950s appear driven more by warmer than normal temperatures rather than changes in precipitation.

Table 2.22a—Climate Summary for each Ecological Reporting Unit (ERU) with number of weather stations. The range of station elevations (meters) are shown. Data from available HCN and COOP weather observation stations having records of 10 years or more were used to calculate monthly mean values (°C) of maximum daily temperature [T(max)], minimum daily temperature, daily range in temperature [del T], average daily temperature [T(avg)], and monthly total values of daily precipitation [PPT] in millimeters and snowfall in centimeters. In addition, the ratio of snowfall to precipitation [%Water] is given to help show water content of snow.

Month	T(max)	T(min)	del T	T(avg)	PPT	Snowfall	%Water
ERU 01							
Number of Weather Stations:26							
Station Elevations:	Min	Max	Avg	Range			
	195	1,207	603	1,012			
1	-1.12	-8.61	7.49	-4.87	124.69	78.03	0.374
2	3.21	-5.92	9.14	-1.36	88.17	52.28	0.407
3	7.44	-3.55	10.98	1.95	69.87	36.15	0.483
4	12.44	-0.52	12.96	5.96	41.74	10.77	0.742
5	16.01	2.10	13.91	9.04	29.86	2.41	0.919
6	20.93	6.50	14.43	13.70	30.55	0.15	0.995
7	25.30	8.69	16.60	16.99	12.90	0.04	0.997
8	25.01	8.35	16.66	16.68	18.28	0.00	1.000
9	20.91	4.64	16.27	12.76	29.86	0.18	0.994
10	13.66	0.35	13.31	6.99	62.27	4.43	0.929
11	4.95	-3.18	8.12	0.87	114.12	36.14	0.683
12	0.43	-6.37	6.80	-2.97	135.49	77.14	0.431
Annual	12.43	0.21	12.22	6.31	63.15	24.81	0.746
ERU 02							
Number of Weather Stations:18							
Station Elevations:	Min	Max	Avg	Range			
	30	1,475	848	1,445			
1	2.42	-6.29	8.71	-1.95	108.68	62.77	0.422
2	5.30	-4.57	9.87	0.36	74.80	35.86	0.521
3	7.27	-3.71	10.98	1.76	61.68	26.40	0.572
4	11.10	-1.85	12.95	4.61	34.09	7.92	0.768
5	15.35	0.97	14.38	8.17	27.16	1.76	0.935
6	19.01	3.98	15.03	11.48	23.16	0.15	0.994
7	25.41	7.07	18.35	16.23	8.35	0.01	0.999
8	24.97	6.74	18.23	15.85	14.86	0.00	1.000
9	21.06	3.63	17.43	12.35	20.14	0.18	0.991
10	13.27	-0.57	13.84	6.35	44.24	2.54	0.943
11	6.98	-2.68	9.67	2.14	93.70	22.35	0.761
12	3.21	-5.06	8.27	-0.94	114.26	48.36	0.577
Annual	12.95	-0.20	13.14	6.37	52.09	17.36	0.790

Table 2.22a (continued).

Month	T(max)	T(min)	del T	T(avg)	PPT	Snowfall	%Water
ERU 03							
Number of Weather Stations:12							
Station Elevations:	Min	Max	Avg	Range			
	1,231	1,972	1,370	741			
1	2.35	-8.24	10.60	-2.95	72.60	41.69	0.426
2	4.89	-6.39	11.28	-0.75	58.34	33.73	0.422
3	7.51	-4.81	12.32	1.34	55.82	34.20	0.387
4	11.78	-2.89	14.67	4.43	32.91	14.73	0.553
5	16.42	0.25	16.18	8.31	33.02	5.85	0.823
6	20.68	3.42	17.26	12.04	26.75	1.47	0.945
7	25.67	5.89	19.79	15.78	9.42	0.07	0.993
8	25.18	5.05	20.13	15.08	13.46	0.03	0.997
9	21.55	1.85	19.70	11.66	19.03	0.71	0.963
10	15.38	-1.52	16.90	6.92	41.68	6.39	0.847
11	7.35	-4.67	12.02	1.33	69.93	25.33	0.638
12	3.11	-7.30	10.41	-2.09	84.60	46.16	0.454
Annual	13.49	-1.61	15.10	5.92	43.13	17.53	0.704
ERU 04							
Number of Weather Stations:22							
Station Elevations:	Min	Max	Avg	Range			
	1,253	1,713	1,355	460			
1	2.68	-8.32	11.00	-2.83	27.59	15.90	0.424
2	5.68	-5.96	11.64	-0.15	21.95	10.10	0.540
3	8.68	-4.31	12.99	2.17	25.30	9.35	0.630
4	13.12	-2.37	15.49	5.35	20.96	3.70	0.824
5	17.91	1.11	16.80	9.50	28.46	1.75	0.939
6	22.60	4.75	17.86	13.67	25.31	0.48	0.981
7	27.78	7.36	20.41	17.57	10.17	0.00	1.000
8	27.00	6.59	20.41	16.79	14.20	0.01	1.000
9	22.57	2.42	20.15	12.48	13.94	0.13	0.990
10	16.29	-1.48	17.77	7.37	20.20	1.53	0.924
11	7.81	-4.74	12.55	1.52	29.69	8.54	0.712
12	3.35	-7.80	11.15	-2.25	31.65	16.10	0.491
Annual	14.62	-1.06	15.68	6.77	22.45	5.63	0.788

Table 2.22a (continued).

Month	T(max)	T(min)	del T	T(avg)	PPT	Snowfall	%Water
ERU 05							
Number of Weather Stations: 87							
Station Elevations:	Min	Max	Avg	Range			
	58	1,902	566	1,844			
1	1.75	-6.37	8.12	-2.32	39.13	19.46	0.503
2	5.63	-3.85	9.48	0.89	28.60	10.10	0.647
3	10.24	-1.61	11.85	4.31	30.20	6.14	0.797
4	14.91	0.98	13.93	7.94	25.78	2.17	0.916
5	19.72	4.54	15.19	12.12	28.60	0.47	0.984
6	23.89	8.00	15.89	15.94	28.40	0.03	0.999
7	28.61	10.39	18.22	19.49	10.33	0.00	1.000
8	27.96	9.95	18.01	18.95	13.04	0.00	1.000
9	23.22	6.14	17.08	14.67	16.37	0.05	0.997
10	15.80	1.47	14.34	8.63	24.47	0.78	0.968
11	7.17	-2.18	9.35	2.49	40.05	6.93	0.827
12	2.73	-4.94	7.68	-1.12	41.69	16.15	0.613
Annual	15.14	1.88	13.26	8.50	27.22	5.19	0.854
ERU 06							
Number of Weather Stations: 34							
Station Elevations:		Min	Max	Avg	Range		
		363	1,506	959	1,143		
1	0.66	-9.03	9.69	-4.20	41.76	10.90	0.337
2	5.05	-6.54	11.59	-1.11	31.39	6.13	0.504
3	9.07	-3.82	12.89	2.61	34.71	4.33	0.683
4	13.97	-1.11	15.07	6.42	30.61	1.39	0.884
5	18.62	2.34	16.29	10.46	39.47	0.27	0.983
6	22.93	5.63	17.31	14.27	35.04	0.02	0.998
7	28.31	7.81	20.50	18.04	14.23	0.00	1.000
8	27.78	7.10	20.68	17.43	18.47	0.00	1.000
9	22.97	3.08	19.89	13.02	19.21	0.11	0.986
10	16.19	-0.86	17.05	7.65	26.23	0.41	0.960
11	7.25	-4.23	11.48	1.50	39.57	4.08	0.738
12	1.80	-7.62	9.42	-2.93	44.38	9.21	0.473
Annual	14.55	-0.60	15.16	6.93	31.26	3.07	0.795

Table 2.22a (continued).

Month	T(max)	T(min)	del T	T(avg)	PPT	Snowfall	%Water
ERU 07							
Number of Weather Stations: 52							
Station Elevations:		Min	Max	Avg	Range		
		250	1,795	796	1,545		
1	-1.57	-9.48	7.91	-5.54	57.15	45.28	0.208
2	2.27	-7.18	9.45	-2.46	41.39	24.34	0.412
3	6.87	-4.58	11.44	1.13	38.36	14.39	0.625
4	12.78	-0.94	13.72	5.92	34.17	3.30	0.903
5	18.02	2.93	15.10	10.46	45.34	0.67	0.985
6	21.91	6.35	15.56	14.12	49.73	0.08	0.998
7	25.90	7.84	18.06	16.86	26.83	0.01	1.000
8	26.13	7.70	18.42	16.90	28.80	0.01	1.000
9	19.75	3.40	16.35	11.57	31.54	0.19	0.994
10	12.27	-0.66	12.93	5.80	36.31	2.27	0.937
11	3.83	-4.09	7.93	-0.13	58.77	18.14	0.691
12	-0.56	-7.58	7.02	-4.07	60.98	41.02	0.327
Annual	12.30	-0.52	12.82	5.88	42.45	12.48	0.757
ERU 08							
Number of Weather Stations: 29							
Station Elevations:		Min	Max	Avg	Range		
		658	1,817	882	1,159		
1	-1.36	-8.88	7.52	-5.13	94.84	54.51	0.425
2	2.06	-6.88	8.94	-2.41	67.44	32.48	0.518
3	5.42	-5.28	10.69	0.07	59.80	20.71	0.654
4	9.56	-2.82	12.38	3.38	45.81	4.09	0.911
5	15.44	0.87	14.58	8.15	51.54	0.98	0.981
6	20.61	4.90	15.70	12.74	54.33	0.05	0.999
7	24.19	5.78	18.41	14.98	23.20	0.00	1.000
8	24.91	6.15	18.76	15.53	29.54	0.00	1.000
9	20.56	2.77	17.79	11.04	39.60	0.28	0.993
10	11.02	-1.53	12.54	4.73	52.34	2.99	0.943
11	2.82	-4.76	7.58	-0.98	78.69	20.07	0.745
12	-0.67	-7.33	6.65	-4.00	100.53	52.82	0.475
Annual	11.21	-1.42	12.63	4.84	58.14	15.75	0.804

Table 2.22a (continued).

Month	T(max)	T(min)	del T	T(avg)	PPT	Snowfall	%Water
ERU 09							
Number of Weather Stations: 21							
Station Elevations:		Min	Max	Avg	Range		
		1,030	1,847	1,367	817		
1	-3.55	-13.07	9.53	-8.31	25.65	27.61	-0.076
2	-0.66	-11.12	10.46	-5.90	17.49	17.95	-0.026
3	2.56	-8.66	11.22	-3.05	19.06	18.04	0.054
4	7.51	-5.16	12.67	1.16	22.41	7.63	0.659
5	11.86	-1.84	13.70	5.00	38.53	2.59	0.933
6	15.46	1.17	14.30	8.31	44.36	0.27	0.994
7	19.83	2.64	17.19	11.23	23.03	0.00	1.000
8	19.32	1.98	17.34	10.64	25.53	0.09	0.997
9	15.84	-0.57	16.41	7.61	26.41	1.48	0.944
10	10.03	-4.17	14.20	2.93	21.37	4.80	0.775
11	1.24	-8.62	9.85	-3.69	22.07	15.05	0.318
12	-2.85	-11.97	9.12	-7.43	23.74	24.86	-0.047
Annual	8.05	-4.95	13.00	1.54	25.80	10.03	0.544
ERU 10							
Number of Weather Stations: 62							
Station Elevations:		Min	Max	Avg	Range		
		652	2,146	1,124	1,494		
1	1.23	-8.81	10.03	-3.81	31.41	17.21	0.452
2	4.94	-6.21	11.15	-0.66	24.89	12.97	0.479
3	9.47	-3.57	13.04	2.93	27.09	7.93	0.707
4	14.77	-0.39	15.16	7.19	24.17	3.95	0.836
5	19.80	3.62	16.18	11.69	28.94	1.50	0.948
6	24.52	7.34	17.19	15.91	34.18	0.27	0.992
7	29.81	10.47	19.34	20.13	8.01	0.00	1.000
8	28.93	9.45	19.49	19.18	10.64	0.04	0.997
9	23.58	4.76	18.82	14.17	14.52	0.49	0.966
10	6.94	0.06	16.89	8.49	19.32	2.05	0.894
11	7.84	-4.27	12.11	1.78	30.18	6.88	0.772
12	2.18	-7.85	10.03	-2.86	30.39	12.41	0.592
Annual	15.34	0.38	14.95	7.85	23.65	5.47	0.803

Table 2.22a (continued).

Month	T(max)	T(min)	del T	T(avg)	PPT	Snowfall	%Water
ERU 11							
Number of Weather Stations: 22							
Station Elevations:		Min	Max	Avg	Range		
		1,268	1,798	1,409	530		
1	-1.88	-11.76	9.89	-6.83	23.31	20.46	0.122
2	1.42	-9.14	10.56	-3.89	19.92	14.04	0.295
3	5.96	-5.82	11.79	0.06	21.90	8.78	0.599
4	12.04	-2.08	14.12	4.95	22.32	3.66	0.836
5	17.06	2.00	15.06	9.50	32.48	1.09	0.966
6	21.74	5.54	16.19	13.64	27.44	0.02	0.999
7	26.71	8.60	18.11	17.65	13.44	0.00	1.000
8	25.96	7.51	18.45	16.74	14.67	0.00	1.000
9	20.74	3.01	17.73	11.88	16.60	0.15	0.991
10	14.24	-1.65	15.89	6.30	18.38	1.69	0.908
11	5.08	-6.19	11.27	-0.57	22.87	8.33	0.636
12	-0.46	-10.36	9.91	-5.42	23.08	18.37	0.204
Annual	12.38	-1.70	14.08	5.34	21.37	6.38	0.713
ERU 12							
Number of Weather Stations: 12							
Station Elevations:		Min	Max	Avg	Range		
		1,603	2,487	1,959	884		
1	-3.83	-16.42	12.59	-10.21	51.22	71.29	-0.392
2	-0.67	-14.50	13.83	-7.65	42.33	51.59	-0.219
3	2.89	-11.35	14.24	-4.25	40.36	46.55	-0.153
4	8.32	-6.00	14.32	1.15	40.17	23.86	0.406
5	14.31	-1.48	15.79	6.39	53.49	7.43	0.861
6	19.56	1.77	17.79	10.66	43.39	0.53	0.988
7	24.18	4.07	20.11	14.10	29.99	0.00	1.000
8	23.41	3.23	20.18	13.34	32.79	0.02	0.999
9	18.44	-0.73	19.17	8.81	38.16	2.04	0.946
10	12.05	-5.10	17.15	3.46	34.08	10.10	0.704
11	2.40	-10.25	12.65	-3.94	48.79	45.20	0.074
12	-3.18	-15.60	12.42	-9.46	50.29	66.05	-0.313
Annual	9.82	-6.03	15.85	1.87	42.09	27.06	0.408

Table 2.22a (continued).

Month	T(max)	T(min)	del T	T(avg)	PPT	Snowfall	%Water
ERU 13							
Number of Weather Stations: 51							
Station Elevations:		Min	Max	Avg	Range		
		485	2,225	1,371	1,740		
1	-1.17	-12.48	11.31	-6.87	70.07	44.12	0.370
2	2.51	-10.29	12.80	-3.90	42.09	28.03	0.334
3	6.53	-7.05	13.59	-0.27	40.85	20.79	0.491
4	11.98	-3.06	15.04	4.45	37.02	7.99	0.784
5	17.31	0.81	16.49	9.05	43.48	2.11	0.952
6	21.86	4.29	17.57	13.07	44.06	0.13	0.997
7	27.37	6.54	20.84	16.93	19.22	0.00	1.000
8	26.78	5.68	21.10	16.22	21.84	0.00	1.000
9	21.36	1.63	19.73	11.48	26.91	0.33	0.988
10	13.76	-2.85	16.61	5.45	30.35	2.87	0.906
11	4.94	-6.74	11.68	-0.92	48.71	20.53	0.578
12	-0.49	-11.31	10.82	-5.94	65.76	41.51	0.369
Annual	12.73	-2.90	15.63	4.90	40.86	14.03	0.731

Table 2.22b—Seasonal trends in daily temperature range (delT), average temperature (Tavg) and precipitation (PPT) for each Ecological Reporting Unit (ERU). Significant trends in winter precipitation after about 1975 and summer precipitation after about 1960 and 1985 also are shown.

Trend	del T	T(avg)	PPT	PPT>1960	PPT>1975	PPT>1985
ERU 01						
Approximated by data from Cle Elem, Washington (588 meters elevation and 64 years of record).						
Winter	-0.5	0	0%		-35%	
Summer	-2.5	0	+50%	+50%		+10%
ERU 02						
Approximated by data from Bend, Oregon (1,116 meters elevation and 67 years of record).						
Winter	+0.5	0	0%		-40%	
Summer	-1	-1	0%	+75%		+10%
ERU 03						
Approximated by data from Lake View, Oregon (1,457 meters elevation and 67 years of record).						
Winter	+0.5	0	0%		-40%	
Summer	-1	-1	0%	+75%		+10%

Table 2.22b (continued).

Trend	del T	T(avg)	PPT	PPT>1960	PPT>1975	PPT>1985
ERU 04						
Approximated by data from Squaw, Oregon (1,420 meters elevation and 58 years of record).						
Winter	+0.5	0	0%		-40%	
Summer	-1	-1	0%	+75%		+10%
ERU 05						
Approximated by data from Moscow, Idaho (810 meters elevation and 95 years of record).						
Winter	+0.5	0	0%		-40%	
Summer	-1	-1	0%	+75%		+10%
ERU 06						
Approximated by data from Union, Oregon (844 meters elevation and 67 years of record).						
Winter	+0.5	0	0%		-40%	
Summer	-1	-1	0%	+75%		+10%
ERU 07						
Approximated by data from Fortine, Montana (719 meters elevation and 95 years of record).						
Winter	-2	+0.5	-25%		-40%	
Summer	-2	+1	0%	+30%		N/A
ERU 08						
Approximated by data from Haugan, Montana (890 meters elevation and 43 years of record).						
Winter	-2	+2	-25%		-50%	
Summer	-2	+0.5	+40%	+40%		N/A
ERU 09						
Approximated by data from Butte, Montana (1,689 meters elevation and 95 years of record).						
Winter	0	0	-50%		-45%	
Summer			0%	+35%		0%
ERU 10						
Approximated by data from Caldwell, Idaho (722 meters elevation and 90 years of record).						
Winter			-25%		-60%	
Summer		+2	0%	+50%		-70%
ERU 11						
Approximated by data from Aberdeen, Idaho (1,344 meters elevation and 81 years of record).						
Winter			0%		-75%	
Summer			0%	+80%		+10%
ERU 12						
Approximated by data from Ashton, Idaho (1,603 meters elevation and 47 years of record).						
Winter			0%		-50%	
Summer		+1	+50%	+80%		-35%
ERU 13						
Approximated by data from McCall, Idaho (1,533 meters elevation and 65 years of record).						
Winter		+2	0%		-50%	
Summer	+2		+50%	+60%		-20%

Ecological Reporting Unit Descriptions

ERU 1: Northern Cascades

Two subsection groups dominate this ERU:

- M242-01, characterized by glaciated mountains and foothills of igneous and sedimentary rocks that have been modified by glacial and fluvial processes.
- M242-05, characterized by mountains and foothills covered by ash and pumice, frequently underlain by igneous extrusive rocks, and modified by fluvial, mass wasting, and aeolian processes.

This area has cold stony soils including some with higher amounts of organic matter. Southern Washington has some soils with thick volcanic ash, and other soils with thick dark topsoils. Due to rain shadow presence, soils on the eastslope are usually dry for a significant time during the summer. Many of these soils are influenced by volcanic ash and commonly have low bulk density, topsoils rich with organic matter, and subsoils with accumulated clay.

High Elevation Sites—This portion of the Northern Cascades has shallow to moderately deep, cold soils with low available nitrogen. These limitations produce low productivity sites. Soils are generally resilient and have low to moderate susceptibility to compaction. Natural surface erosion and mass failure hazards are high.

Mid- to Low-Elevation Sites—This portion of the Northern Cascades is highly productive. Many soils in this area have formed in deep, volcanic ash or on landflows with abundant moisture. Soils on steep slopes are shallow to moderately deep with limited moisture and nutrient content. Organic matter and moisture are the most limiting factors to productivity in this area. The soils present are generally resilient but moderately susceptible to compaction. Natural surface erosion and mass failure hazards are moderately high.

The Northern Cascades ERU has one of the lowest average elevations (approx. 1,200 m) within the Basin. The average slope is 27%, which is similar to ERUs 8 and 13. Annual precipitation is 95 cm which is similar to ERUs 2 and 8. The major potential vegetation types are cool moist (F22); cold moist (F12); and warm dry forestlands (F33), with each having constancy and average percent cover values, when present, of greater than 55 percent and 15 percent, respectively.

The dominant valley settings in the Northern Cascades are those with steeply sloping, moderately to highly confined valley bottoms (VB forms 1 and 2), and those having gentle slopes with low confinement (VB form 9), with constancy and average percent composition values greater than 55 percent and 20 percent, respectively. Rosgen A stream types, that are characterized by cascades and step-pool systems, dominate this ERU (88% constancy and 72% average percent composition when present); however, rapids-dominated B-stream types are also very common (as determined in subwatershed subsampling). Other locally important stream types that are potential sources of sediment in this ERU are braided system D-types (about 40% constancy, but having low average percent composition values).

The value for erosion, assuming existing vegetation, is in the 65th percentile. Only three other ERUs have similar median values (ERUs 5, 6, and 7). The estimated median mass wasting index is at the 81st percentile; this high potential is corroborated by the stream type group estimates. The potential for sediment to reach streams is also high with a median sediment delivery hazard of about 78 percent, the highest across all ERUs.

The median index value for stream channel sensitivity to increased flow and sediment, at a site, is the lowest of all ERUs. There are, however, numerous outliers between the 40th and 80th percentile, which indicates that other localized sensitivity levels occur. The downstream transfer effects of increases in flow and sediment are average as contrasted across all ERUs. Vegetation is relatively unimportant for maintaining the mor-

phology of the A-, B-, and D-stream types present. Overall, the potential for the estimated dominant stream types of this ERU to recover from disturbance is among the highest of all ERUs.

ERU 2: Southern Cascades

Three subsection groups dominate this ERU:

- M242-05, characterized by mountains and foothills covered by ash and pumice, frequently underlain by igneous extrusive rocks, and modified by fluvial, mass wasting, and aeolian processes.
- M242-01, characterized by glaciated mountains and foothills of igneous and sedimentary rocks that have been modified by glacial and fluvial processes.
- M342-07, characterized by foothills composed mainly of loess over basalt that has been modified by fluvial and aeolian processes.

Constancy values for these subsection groups are 74 percent, 56 percent, and 29 percent, respectively. Average percent composition of these types, when present, varies from 49 percent to 59 percent. The lithologic mosaic for this ERU is dominated by mafic volcanic flows (98% constancy, and almost 50% average composition), and calcic-alkaline volcanoclastics (61% constancy, and about 25% average composition).

Cold stony soils dominate this ERU. Due to the rain shadow presence, east slope soils are usually dry for a significant time during the summer. Many of these soils are influenced by volcanic ash, and have low bulk density, high organic matter, and subsoils with accumulated clay. The southern part of this ERU has cold soils formed in volcanic ash and pumice from Mount Mazama.

Productivity limitations of soils include cold temperatures, short growing seasons, and limited available nitrogen or other nutrients. Natural mass failure hazard is low, and natural surface erosion hazard is moderately low.

The Southern Cascades ERU has one of the highest annual precipitations (100 cm) and is also in the highest class for maximum winter temperature (along with ERUs 5 and 10).

The major potential vegetation types present are warm dry (F33); cool moist (F22); and cool, very dry forestlands (F24). Each of these forestland types have constancy values greater than 59 percent, and average compositions of greater than 20 percent.

The dominant valley bottom settings present have steep slopes with low to moderate confinement (VB 2), moderate slopes with moderate confinement (VB 5), and gentle slopes with low confinement (VB 9). Steep A-stream types, characterized by cascades and step-pool systems predominate, followed by the more stable, rapids-dominated B-stream types. There are also significant numbers of E-stream type reaches in this ERU, which are characterized by narrow, torturously meandering channels, and frequently cool, swift water. Wetlands and lakes were estimated to be present in roughly 30 percent and 50 percent, respectively, of the valley bottoms described in subsampling.

The median value for the erosion, assuming existing vegetation cover, is about the 45th percentile, which is similar to that of ERUs 8, 9, 12, and 13. The value for mass wasting is about the 81st percentile, which is similar to the Northern Cascades. The spread of the mass wasting index values in this ERU, however, is much greater, reflecting the relatively greater number of gently sloping valleys present. The sediment delivery hazard of this ERU is in the mid-range (about the 38th percentile) of all ERUs.

The median index value for stream channel sensitivity to increases in flow and sediment is low (about the 20th percentile), but the spread in this index value is large, possibly reflecting the mosaic of E-types and the unstable, entrenched F- and G-stream types present. Overall, the downstream transfer effect of increases in flow and sediment is low, but there are several high outliers. The median value for potential bank erosion is moderate (about the 38th percentile), but there is a large

spread in related index values. The importance of vegetation to maintaining the morphology of the dominant channel types of this ERU is average (about the 48th percentile). The median recovery potential is high (about the 80th percentile), reflecting the estimated high percentage of A-, B-, and C-stream types present. The spread in this index is large, however, which reflects the poorer recovery potential of the F- and G-stream types also described in subsampling.

ERU 3: Upper Klamath

Three subsection groups dominate this ERU:

- M261-02, characterized by intermontane basins, foothills, and plateaus of igneous extrusive rocks overlain by ash, pumice, and alluvium that have been modified by fluvial and volcanic processes.
- M242-02 characterized by plains of ash and pumice over volcanic rocks, mostly basalt, that have been modified by alluvial and volcanic processes.
- M261-04, characterized by mountains comprised of extrusive igneous rocks, modified by fluvial processes.

Percent constancy values for each subsection group vary between 42 percent and 47 percent, and average percent composition, when present, varies from 55 percent to 71 percent. In addition, lake sediments and playas, and alluvium are important lithologic components in some areas (60% and 42% constancy values, respectively).

The Upper Klamath ERU has cold dry soils on pumice-mantled plateaus, and mountains. Soils on pumice plateaus have light-colored surface layers and little horizonation, and can have some volcanic ash influence. Soils that occur on high plateaus and mountains generally have dark-colored organic matter-rich surface layers, with some volcanic ash. There are some wet, cool and cold soils in basins and valleys. (Some of these consist of mineral soils and others are organic soils.) There are dry warm soils on floodplains and terraces and on grass-shrublands. The soils that occur on floodplains and terraces have some dark-colored surface layers rich in organic matter and some wet soils with dense restrictive layers. Soils on grass-shrublands are generally shallow with dark-colored organic matter-rich surface layers, and subsoil accumulation of clay.

Productivity of soils in the Upper Klamath is relatively low. Major limitations to plant growth in this area include cold and dry soil conditions, and inadequate amounts of organic matter and available nitrogen. The resiliency of these soils is generally low, often making them susceptible to compaction. Natural mass failure hazard is low, and natural surface erosion hazard is moderately low.

This ERU has a high average elevation (1,560 m), and has some of the lowest relative relief and lowest average slopes (10%) of all ERUs. It has the 5th lowest annual precipitation value of the ERUs (57 cm), and is in the highest class of winter solar radiation (0.0047 joule/m^2). The major potential vegetation types of this ERU are warm dry (F34); hot moist (42); and hot, very dry forestlands (F44); each type has constancy values of 62 percent or greater. Cool, very dry forestlands (F24) are also common (42% constancy) and, where present, have high average composition (48%).

The dominant valley bottom settings of this ERU are those having gentle valley slopes and moderate to unconfined side-slopes (VB forms 8 and 9); such valleys occur in all subwatersheds, with average composition values of 17 percent to 38 percent. Steep, confined valley bottoms and moderately steep, moderately confined valleys are also common in most subwatersheds, but have lower average composition values. Steep, step-pool, A-stream types are common, and the majority of these types are estimated to be unstable channels (that is, they generally contain finer bed materials). Rapids-dominated B-stream types are also common. Compared to all ERUs, the Upper Klamath ERU has a high percentage of narrow, highly sinuous E-stream types (50% constancy

across subwatersheds with 10% average composition). This ERU also has a high percentage of channelized reaches (50% constancy), entrenched, low-gradient F-stream types (50% constancy), and a moderate percentage of entrenched, gully G-stream types.

The Upper Klamath ERU (along with ERU 4) is within the lowest class across all ERUs for estimated upland erosion, given existing vegetation. It is within the second lowest class for mass wasting hazard (median value is the 60th percentile), and has the lowest ranked sediment delivery hazard across all ERUs. This ERU ranks second highest across all ERUs in terms of the sensitivity of stream channels at-a-site to increases in flow and sediment (median value is about the 70th percentile). It is in the second lowest class (along with ERUs 7 and 12) with respect to downstream transfer effects of increased flow and sediment. Only about 30 percent of the ERUs within the Basin are ranked higher with respect to potential for bank erosion, reflecting the occurrence of sensitive E-types, and unstable F- and G-stream types present. Riparian vegetation is fairly important to maintaining existing channel morphology in this ERU (median value is about the 60th percentile). This ERU is ranked at the 40th percentile for inherent channel recovery potential, due to the slow recovery times of the unstable A-, F-, and G-stream types present.

ERU 4: Northern Great Basin

Three subsection groups dominate this ERU:

- 342-05, characterized by plateaus and foothills composed mainly of tuffs and basalts that have been modified by fluvial and aeolian processes.
- 342-04, characterized by intermontane basins and valleys composed mainly of alluvium, ash, and lacustrine materials over basalt.
- 342-06 characterized by mountains composed mainly of tuffs and basalts that have been modified by fluvial processes.

Lake sediments and playas, and alluvium are present in 75 percent and 48 percent of the subwatersheds, respectively, with average composition values of 13 percent and 20 percent, where present.

The soils generally have light-colored surface layers. The soil horizons may be the result of movement and accumulation of salts, carbonates or silicate clays, or of cementation by carbonates or silica. These are generally dry soils with cool to warm temperatures. Large areas have saline-sodic soils.

In the northern Great Basin, moisture is the principal limiting factor to plant growth. Riparian areas and higher elevation sites, however, are wetter and have the most organic matter. They are, therefore, generally the most productive. Low elevation sites with the least precipitation and areas of saline-sodic soils are the least productive settings in this ERU. Resiliency of these soils is generally low, often making them susceptible to compaction. Natural mass failure hazard is low, and the natural surface erosion hazard is moderate to high.

The Northern Great Basin ERU occurs at higher elevations (average is approximately 1,600 m), and is within the lowest class of relative relief across all ERUs. It has the lowest average slopes across all ERUs (9%), but there are numerous outliers representing localized steep slopes. It is in the lowest class of annual precipitation (comparable to ERUs 5 and 10), and is in the second highest class of winter solar radiation (0.0046 joule/m^2). The major potential vegetation type of this ERU is warm dry shrublands (S33) having a constancy value of 88 percent, and average composition of 70 percent, where present.

ERU 5: Columbia Plateau

Five subsection groups dominate this ERU:

- 342-07, characterized by foothills composed mainly of loess over basalt that has been modified by fluvial and aeolian processes.

- 342-03, characterized by plateaus and high plains of fluvial and lacustrine sediments and ash deposits created by aeolian, fluvial, and lacustrine processes.
- 331-02, characterized by intermontane basins and valleys of valley fill, alluvium, and lacustrine materials overlying volcanic and sedimentary rocks.
- 331-04, characterized by glaciated mountains of volcanic and sedimentary rocks that have been modified by colluvial, fluvial, residual, and glacial processes.
- 342-05, characterized by plateaus and foothills composed mainly of tuffs and basalts that have been modified by fluvial and aeolian processes.

Mafic volcanic flows occur on 88 percent of the subwatersheds within this ERU, with average composition values (where present) of 47 percent. Loess deposits occur on 48 percent of all subwatersheds within the ERU, with an average composition, where present, of greater than 50 percent.

Columbia Basin Section and west half of Palouse Prairie Section—The soils are mostly warm and dry. They formed in parent materials resulting from erosion and redeposition by great floods and strong winds across the relatively level lava plateau. Volcanic ash deposited in this area has been mostly eroded and mixed with other materials. Loess blankets most of the area. The central part has soils formed in silty and sandy wind-deposited materials. The northeastern part has loess hills dissected by channeled scablands. Soils on the loess hills formed in mostly deep, coarse-textured loess; some have dark topsoil; some have lime-enriched subsoil; and some have clay-enriched subsoil. Soils on the flood-scoured channeled scablands are similar to soils on the highly dissected lava benches in the western part of the Section. In the south, the soils are moist except in summer and commonly have dark, organic matter-rich topsoil; some are shallow to bedrock; some have lime and commonly have dark, organic matter-rich topsoil; some are shallow to bedrock; some have lime-enriched and clay-enriched subsoils, and some have thick dark topsoil. Volcanic ash influence is recognized in some soils.

High Lava Plain Section—The soils are generally warm and dry, varying in depth to bedrock and influence of volcanic ash. The southern part has some soils with thin dark topsoils and some with volcanic ash. Other soils have thin dark topsoil and a cemented hardpan that impedes roots, and a clay enriched subsoil, with or without volcanic ash. Shallow sandy soils also occur in this area. In other areas, most soils have thick dark topsoil and clay-enriched subsoil. Some of these soils also contain volcanic glass.

The southern portion of the Columbia Plateau has predominantly moderate to low productivity soils that support grasses, forbs, shrub communities, and juniper woodlands. The most productive soils of this area are located in riparian settings. Where soils are deep and moisture is available, productivity is commonly moderate. Shallow droughty soils, however, dominate this area with moisture as the principal limiting factor to plant growth. Surface organic matter content of these shallow soils is low, and they are generally resilient but susceptible to compaction. Natural mass failure hazard in this area is low. Although soils on slopes steeper than 40 percent are highly erodible, gentle slopes generally have moderate to low erosion hazards.

The northern portion of the Columbia Plateau ranges from scablands, with shallow droughty soils with reduced water-holding capacity and low productivity, to deep loess-influenced soils with high productivity. Loess soils are highly susceptible to wind and water erosion. Sandy glacial soils occur in some areas and are droughty, have low productivity, and moderate to high erosion hazards. The major limitation to plant growth is moisture with shallow soil depth being an additional problem to management in the scablands. Soils are generally not resilient or susceptible to compaction in this area. Although natural mass failure hazard is low, the surface erosion hazard is high.

The Columbia Plateau ERU has the lowest average elevation across all ERUs (approx. 500 m), and is within the lowest class of relative relief and lowest average slope (median slope value is about 8%, but numerous outliers indicate localized high slopes). Along with ERUs 4, 5, 10, and 11, this ERU is in the lowest annual precipitation class (40 cm). This ERU is tied with ERU 2 for the highest average value for maximum winter temperature (about 4.5° C), and is within the highest class of average August temperature (18° C). The dominant potential vegetation types of this ERU are warm dry shrublands (S33); warm, dry herbaceous lands (H33); and cool moist shrublands (S22).

The dominant valley bottom settings are highly confined with steep valley slopes (VB 1); moderately confined with moderate valley slopes (VB 5); and moderately confined with gentle slopes (VB 8). A-stream types, characterized by step-pools, are dominant, and about two-thirds of these are estimated to be unstable and thus high sources of sediment. Also common in this ERU are B-stream types (characterized by rapids), and C-stream types (that is, alluvial channels that are well-connected to their floodplain processes). This ERU has a high number of braided, D-stream types (constancy value is 62%), but their occurrence is localized. It also has a high number of unstable, entrenched F-types (34% constancy with 11% average composition), as well as a large proportion of channelized reaches (comparable in extent only to ERU 11).

The erosion index of this ERU, assuming current vegetation, is at the 70th percentile of all ERUs (which is similar to ERUs 5, 6, and 7). The mass wasting hazard index is the third lowest across all ERUs, reflecting the generally gentle slopes and low precipitation present. The sediment delivery hazard is about average (48th percentile) as contrasted across all ERUs.

The median index value for at-a-site channel sensitivity in this ERU to increases in flow and sediment is the second highest of all ERUs, but has many lower outliers. In addition, the median index value for bank erosion and downstream transfer effects is the second highest across all ERUs, reflecting the large proportion of unstable, entrenched F- and G-stream types, and braided D-stream types present. The importance of vegetation for maintaining the width to depth ratio of the dominant channels in this ERU is at the 58th percentile across all ERUs, but there is a wide spread in this index value. The recovery potential of streams in this ERU is low, which reflects the unstable A-, F-, and D-stream types present.

ERU 6: Blue Mountains

Three subsection groups dominate this ERU:

- M332-08, characterized by a heterogeneous mosaic of mountains comprised of igneous, sedimentary, and metamorphic rock that have been primarily modified by fluvial and colluvial processes, and secondarily by glaciation, frost churning, and mass wasting.
- M332-07, characterized by a heterogeneous mosaic of mountains comprised of igneous and metamorphic rocks with lesser amounts of sedimentary rocks, all of which have been modified by fluvial, colluvial, mass wasting, frost churning, and glacial processes.
- M332-02, characterized by foothills of granitics and volcanics, with some metamorphic and sedimentary inclusions, all of which have been modified by glacial, fluvial, and residual processes.

Most soils are influenced by volcanic ash from Mount Mazama. The ash mantle is relatively undisturbed on gentle north slopes under forest canopy. On southerly exposures, it has been mostly removed by erosion. Commonly the ash is redeposited and mixed with loess, colluvium, and alluvium. The high mountains have cold, usually moist soils with high amounts of volcanic ash. Some soils have dark-colored surface layers rich in organic matter and some have clay-enriched subsoils; wet meadows have soils with a high water table and an organic surface layer. The lower elevations have cool, usually moist soils with a thick ash mantle and clay-enriched subsoil.

On lower mountain slopes, soils are dry in late summer. Some soils have relatively high amounts of volcanic ash with a surface layer rich in organic matter or with a clay-enriched subsoil. Others have medium amounts of ash and a surface layer rich in organic matter. Some soils with little volcanic ash have surface layers rich in organic matter and may or may not have clay-enriched subsoils. On valley floors, soils under a grass-shrub vegetation are dry for most of the summer and have topsoils rich in organic matter.

In the Blue Mountains, the most productive soils occur at mid-elevations and have thick volcanic ash surface layers. Soils derived from glacial materials at high elevations have moderate to low productivity and are limited by nutrients and cold temperatures. Soils at low elevations and on south slopes with minimal volcanic ash have moderate to low productivity. Although soils are generally resilient in this area, they are highly susceptible to compaction. Natural mass failure hazard is low, and natural surface erosion hazard is moderate.

The Blue Mountains ERU falls within the mid-range class for most climatic and elevational data, with a few important exceptions: it is within the lowest annual precipitation class (however, outlier values reflect the orographic effect of the high peaks present). In addition, this ERU is in the second highest class across all ERUs for both winter solar radiation and average maximum winter temperature (again, there are numerous outliers reflecting localized high elevation settings). The major potential vegetation types are warm, dry forestlands (F33).

The dominant valley settings of this ERU are highly confined, with steep valley slopes (VB 1), moderately confined on moderate valley slopes (VB 5), and moderately confined on gentle valley slopes. The high-gradient, A-stream types present occur on 86 percent of all subwatersheds, with an average composition of 57 percent where present; mid-gradient B-types occur on 74 percent of all subwatersheds, with 23 percent average composition. The low-gradient streams present (C-, D-, and E-types) are estimated to have moderate distribution across all subwatersheds (for example, from about 30% to 48% constancy values). Relative to all ERUs, however, there is a high proportion of unstable, entrenched F-types (present in 30% of all subwatersheds), with an average composition of 18 percent where present.

The value for erosion, assuming existing vegetation, is about the 65th percentile, placing it in the highest erosion category along with the Northern Cascades, Columbia Plateau, Northern Glaciated Mountains, and Upper Snake ERUs. The estimated median mass wasting index is about the 60th percentile; this is corroborated by the stream type group composition. The potential hazard for sediment to be delivered to streams is at about the 50th percentile. Overall, the recovery potential of streams within this ERU is low (20th percentile), due to slow and generally poor recovery potential associated with the characteristic steep A-stream types, and entrenched, unstable F- and G-stream types.

ERU 7: Northern Glaciated Mountains

Three subsection groups dominate this ERU:

- M333-03, characterized by glaciated mountains of granitic and metasedimentary rocks, all of which have been modified by glacial and fluvial processes.
- M333-02, characterized by intermontane basins, valleys, and till plains of lacustrine, outwash, alluvium, and till.
- M333-04, characterized by mountains and breaklands of granitic and metasedimentary rocks.

This area has been modified mainly by fluvial and colluvial processes with some frost churning and alpine glaciation at high elevations. Alluvium occurs in 73 percent of all subwatersheds, with an average composition of 24 percent; open water occurs in 37 percent of all subwatersheds, with an average composition of 5 percent.

High mountains have cold moist soils with volcanic ash, dark topsoils rich in organic matter; high-mountain basin floors have soils with a water table near the surface and organic topsoils. Mid-elevations have cool, cobbly and stony soils with some volcanic ash influence and other soils with dark topsoils rich in organic matter. On valley floors and foothills along major drainages are warm dry soils that include stratified, gravelly soils, and cobbly well-drained soils with dark topsoils on terraces; floodplains have poorly drained soils. On foot slopes above the valley floor are soils formed in till and colluvium. Many of these soils have dark topsoil rich in organic matter.

Flathead Valley Section—These soils are generally cool or cold. Most soils in the mountains have light-colored surface layers. Many of these are young to weakly developed soils with some having subsoil accumulations of clay. Some soils have a thin to thick deposit of volcanic ash at the surface. The basins and valleys have two general groups of soils. One group has thick, dark topsoil, and the second group includes young to weakly developed soils with little horizonation. In general, these soils are moderately deep to deep with loamy to sandy textures, and most have been strongly influenced by volcanic ash.

Northern Rockies Section—These are generally cool to cold soils. Many are young and poorly developed with little horizonation and usually light-colored surface layers. Some have subsoil accumulations of clay. These soils are generally shallow to moderately deep, with loamy to sandy textures containing rock fragments. Some soils at higher elevations have been moderately influenced by volcanic ash deposits.

The western portion of the Northern Glaciated Mountains is dominated by soils with surface layers derived from volcanic ash. These soils are highly productive, especially where moisture and nitrogen are abundant. Some glacial scouring over this area has resulted in shallow to moderately deep, rocky soils that have lower productivity. Deep soils from lake deposits, while productive, are relatively unstable. Soil organic matter is abundant on volcanic ash soils, but low on some of the soils formed in glacial deposits. Volcanic ash soils can be compacted at all moisture levels. Soils derived from residual materials, or with thin layers of volcanic ash, are moderately productive, limited primarily by moisture and nutrients. Many soils of this area are cold and have short growing seasons. Most soils of this area are generally resilient but have high susceptibility to compaction. Natural mass failure and surface erosion hazards are high.

The central portion of the Northern Glaciated Mountains generally has a mix of continental and maritime climates. Areas with a continental climate have colder soils with high temperature extremes which causes them to be less productive. Volcanic ash caps in this area become thinner as distance from Cascade Mountain Volcanic ash sources increases. Areas of thinner ash are usually less productive than those with thicker ash caps. Soils of this area are generally resilient but highly susceptible to compaction. Natural mass failure and surface erosion hazards are high.

The eastern portion of the Northern Glaciated Mountains is dominated by a temperate continental climate and has minor amounts of volcanic ash. This combination contributes to a predominance of soils that are generally shallow to moderately deep, have low productivity and resiliency, and are susceptible to compaction. Both natural mass failure and natural surface erosion hazards are moderate to high.

This ERU is in the second highest class of relative relief (along with ERUs 8, 9, and 12) and second highest class for slope (21%) along with ERU 9. It is in the second highest class for annual precipitation (87 cm), and is in the highest class for summer precipitation (15 cm). Across all ERUs, this ERU has among the lowest maximum winter temperatures.

The major potential vegetation types of this ERU are warm dry (F33), cool moist (F22), and cool dry (F23) forestlands; and each type has constancy values of 56 percent to 76 percent.

The dominant valley bottom settings within this ERU include the following: steep confined valleys (VB 1) having 85 percent constancy across all subsampled watersheds and about 38 percent average composition. Broad, gently sloping valleys (VB 5 and 9) also occur with an 80 percent constancy and 17 percent average composition. Additionally, steeply sloping, moderate to unconfined valley bottoms (VB 2) occur with a 72 percent constancy and 16 percent average composition.

The dominant stream types observed in subsample watersheds are steep, step-pool A-stream types (expected to have cobble and gravel beds and banks); rapids-dominated B-stream types; and meandering, alluvial C-stream types with well-developed floodplains. Narrow, highly sinuous E-stream types also occur with a 50 percent constancy and 5 percent average composition. Entrenched, meandering, unstable F-stream types are also scattered throughout the ERU, having 15 percent constancy across all watersheds and 16 percent average composition, where present. Wetlands and lakes were present in the majority of subsampled watersheds (52% and 70% constancy, respectively).

The erosion potential, given current vegetation, is among the highest across all ERUs (about the 70th percentile). Median mass wasting hazard and potential delivery of sediment to streams is also high, reflecting the characteristic steep slopes and high drainage density present. The overall recovery potential following disturbance is generally good, reflecting the likely stability of the steeper stream types, and the long-term natural recovery potential of the alluvial channels.

ERU 8: Lower Clark Fork

One subsection group dominates this ERU: M333-04, characterized by mountains and breaklands of granitic and metasedimentary rocks, all of which have been modified mainly by fluvial and colluvial processes with some frost churning and alpine glaciation at higher elevations. This ERU has among the highest relative relief of all ERUs (along with ERUs 1, 7, and 13), the highest class of average slope (26%), and the highest class of annual precipitation (111 cm). It has the lowest value for winter solar radiation (0.0023 joules/m^2). The major potential vegetation types present are cool dry (F23), cool moist (F22), and warm dry forestlands (F33). Constancy values for each of these are greater than 70 percent.

Cool to cold mountain soils dominate this area and thick deposits of volcanic ash occur over most of the landscape. Most soils have light-colored surface layers, and a few have dark-colored surface layers. A few soils have subsoil accumulations of clay. These soils are generally shallow to moderately deep with loamy to sandy textures.

The Lower Clark Fork ERU is characterized by thick volcanic ash deposits that were not altered by continental ice sheet flows. Most of this section occurs at low- to mid-elevations where temperature and moisture are favorable to plant growth. The suitable climate, thick volcanic ash, and moderate to highly weathered soils with few restrictive layers contribute to very productive soils in this area. These soils are generally resilient but susceptible to compaction. Natural mass failure and surface erosion hazards are moderate to high.

Steep confined valley bottoms (VB 1) occurred in all subsampled watersheds, with an average composition of 51 percent. Moderately confined and moderate gradient valley bottoms and broad unconfined valleys also occurred in all watersheds, with about 14 percent average composition. Steep A-stream types (having probable cobble and gravel beds and banks) dominate the subsampled watersheds. Alluvial, meandering C-stream types also occurred in all subsampled watersheds, with about 18 percent average composition.

Given current vegetation patterns, upland erosion potential is estimated as moderate, relative to all other ERUs. Mass wasting potential, however, is the highest of all ERUs, reflecting the steep A-channels with gravel and cobble beds and banks. The potential for sediment to reach streams is also very high, relative to all ERUs, with most watersheds in the ERU ranking around the 90th percentile. These watersheds are fairly sensitive to

increased streamflow and sediment, both onsite (about 70th percentile), and downstream due to transfer effects (about 60th percentile). Riparian vegetation is relatively insignificant in maintaining stream channel morphology. Watersheds in this ERU show the highest sensitivity to disturbance of all ERUs.

ERU 9: Upper Clark Fork

Four subsection groups dominate this ERU:

- M332-05, characterized by glaciated mountains and gneiss with lesser amounts of volcanic and sedimentary rocks; all have been modified by glacial, periglacial, fluvial, colluvial, and mass wasting processes.
- M332-07, characterized by mountains of igneous and metamorphic rocks with lesser amounts of sedimentary rocks; all have been modified by fluvial, colluvial mass wasting processes.
- M332-08, characterized by mountains of igneous, sedimentary and metamorphic rocks; all have been modified mainly by fluvial and colluvial processes with lesser amounts of glaciation, frost churning, and mass wasting.
- M332-04, characterized by intermontane basins and valleys of alluvium, lacustrine and loess deposits; all have been modified by fluvial, mass wasting, glacial, and aeolian processes.

Alluvium is found in 86 percent of the subwatersheds with an average composition of 15 percent, where present.

Cool to cold soils are common and usually have little development and light-colored surface layers. There are significant areas of rockland and talus. Some soils in basins have dark-colored surface layers rich in organic matter, and others have light-colored surface layers that are low in organic matter. Soils with dry moisture regimes probably occur. These soils are generally shallow to moderately deep, with loamy or sandy texture containing large amounts of rock fragments. Some soils at higher elevations are moderately influenced by volcanic ash.

In the Upper Clark Fork, soil productivity is generally low; however, some soils have minor amounts of volcanic ash that make them slightly more productive. Soils in the Bitterroot Valley are deep and productive. The most limiting factors for productivity are shallow soils, large amounts of talus and rock outcrops, and low temperatures. Soils are generally less resilient and less susceptible to compaction in this area. Natural mass failure hazard is moderate, and natural surface erosion hazard is moderate to high.

This ERU has the third highest average maximum elevation (2,432 m); only ERUs 12 and 13 have higher elevations. It has the fourth highest average slope (22%), and moderate relative relief. It is approximately equal to ERUs 7, 8, and 9 for highest summer precipitation (15 cm). Along with ERUs 7, 8, and 11, this ERU has the lowest maximum winter temperatures (-0.3° C). The major potential vegetation types of this ERU are warm dry (F33), cool dry (F23), cold wet (F11), and cold moist (F12) forestlands. Percent constancy values for each major type vary from 45 percent to 94 percent.

Steep confined valley bottoms (VB 1) occur in all Upper Clark Fork subsample watersheds, comprising about 50 percent average composition. Moderate gradient, moderately confined valley bottoms (VB 5), and steep moderately confined valley bottoms (VB 2) occur in virtually all subsampled watersheds within this ERU. Where these valley types occur, they comprise 13 percent and 11 percent average composition respectively. Steep, step-pool A-stream types predominate the subsampled watersheds, and rapids-dominated B-stream types were observed with about 15 percent average composition within all subsampled watersheds. Meandering, alluvial C-stream types and narrow and highly sinuous E-stream types were observed in about one-half of the watersheds, comprising 8 percent and 6 percent of the stream types, where present. These low gradient streams likely have beds and banks composed of cobbles,

gravels, and sand. Wetlands and lakes occurred in 61 percent and 67 percent of the subsampled watersheds, respectively.

The upland erosion potential for the Upper Clark Fork ERU is at the 50th percentile, and its mass wasting hazard is at the 60th percentile. The potential for sediment delivery to streams is ranked at the 60th percentile of all ERUs. Although bank erosion potential is locally significant for C-, E-, F-, and G-stream types, overall bank erosion potential is ranked at about the 30th percentile. The inherent recovery potential of these watersheds is quite high (70th percentile).

ERU 10: Owyhee Uplands

Three subsection groups dominate this ERU:

- 342-02, characterized by plateaus and high plains of basalts and tuffs; all have been modified by fluvial and aeolian processes.
- 342-06, characterized by mountains composed mainly of tuffs and basalts; all have been modified by fluvial and aeolian processes.
- 342-03, characterized by plateaus and high plains of fluvial and lacustrine sediments and ash deposits that have been created by aeolian, fluvial, and lacustrine processes.

Alluvium is present in 68 percent of the subwatersheds with average composition of about 21 percent.

This area contains dry soils with light-colored surface layers, young soils with little or weakly developed horizonation, and soils with thick, dark-colored surface layers. The soil horizons may be the result of movement and accumulation of salts, carbonates, or silicate clays, or of cementation by carbonates or silica. Most soils are warm to cool and dry to moist. Cold soils occur at high elevations.

In the Owyhee Uplands, moisture is the principal limiting factor to plant growth. The most productive portions of this area are the riparian and wetland settings, which are much more productive than the most productive upland sites. On upland sites, higher elevation areas are usually the most productive. Soils that occur on lower elevations are often shallow to bedrock, or have hardpans that result in low productivity. Soils of this area are generally resilient but susceptible to compaction. Natural mass failure and natural surface erosion hazards are low.

The Owyhee Uplands ERU has relatively high elevation subwatersheds (average elevation is about 1,400 m) and is among the three lowest ERUs in terms of relative relief and average slope (9%), with numerous outliers that indicate the presence of localized steep slopes. Along with ERUs 4 and 5, this ERU has the lowest annual precipitation (30 cm) and has some of the lowest summer precipitation values (4 cm). It has the highest August temperature (18° C), the third highest winter temperature (-1.4° C), and is in the highest class for winter solar radiation. The major potential vegetation types present are warm dry (S33), warm very dry (S34), cool moist (S22), and cool dry (S23) shrublands. Constancy values for each of these major types vary from 35 percent to 77 percent.

Gentle slopes in moderately confined valley bottoms (VB 8) occur in all watersheds, with an average composition of 25 percent. Moderate slopes in confined to moderately confined valley bottoms were also present (VBs 4 and 5 are codominant, occurring in 96% of the subsampled watersheds and comprising about 20% average composition). Steep confined valleys occur in most watersheds, but comprise only about 15 percent of the total valley bottom settings.

Steep, step-pool, A-stream types and rapids-dominated B-stream types occur in all subsampled watersheds, but comprise only about a one-quarter of the observed stream types. Meandering, alluvial C-stream types with well-developed floodplains were observed in most watersheds (92%) and represented about 20 percent of the stream type pattern composition. Braided channels (88% constancy across watersheds with 9% average composition) and entrenched, G-stream types, as well as entrenched, meandering F-stream types

(76% constancy with 52% average composition) also occur in the subsample watersheds.

Upland erosion potential, given current vegetation, ranks at about the 60th percentile over all ERUs. Mass wasting potential is quite low, second to the Great Basin (ERU 4). Sediment delivery hazard is similarly low (about the 20th percentile), reflecting the moderate slopes, low stream dissection, and sparse rainfall. Potential bank erosion is quite high (median value 70th percentile), with vegetation moderately important in maintaining width to depth ratios. Inherent recovery potential following disturbance is among the lowest of all ERUs, reflecting the high probable occurrence of unstable, entrenched channels (that is, G- and F-stream types).

ERU 11: Upper Snake

Two subsection groups dominate this ERU:

- 342-02, characterized by plateaus and high plains of basalts and tuffs that have been modified by fluvial and aeolian processes.
- 342-06, characterized by mountains composed mainly of tuffs and basalts that have been modified by fluvial and aeolian processes.

Alluvium occurs in 84 percent of the subwatersheds, with an average composition, where present, of 37 percent.

Northwestern Basin and Range Section—The soils that occur in the drier areas have light-colored surface layers with subsoil accumulations of clay or hardpans. Large areas have saline-sodic soils.

Snake River Basalts Section—There are two major groups of soils. One group is dry with light-colored surface layers, and some have accumulations of clay in the subsoil or have hard pans. The second group occur in more moist areas and have thick dark topsoils.

This ERU is characterized by high elevations (average of approx. 1,700 m), low relief, and low average slope (10%). It is among the lowest class of annual precipitation (31 cm), and summer precipitation (6 cm), and has high winter solar radiation (0.0045 joule/m^2). This ERU has the third highest average daily August temperature (behind only ERUs 5 and 10).

Moisture is the principal limiting factor for vegetation growth in the Upper Snake ERU. Riparian areas and higher elevation sites are wetter, have the most organic matter, and are generally the most productive sites. Low elevation sites with the least precipitation and areas with saline-sodic soils are the least productive environments. Soils of this area vary in their resilience and susceptibility to compaction. Natural mass failure hazard is low and natural surface erosion hazard is moderate.

The major potential vegetation types present are warm dry (S33) and warm moist shrublands (S32); hot very dry forestlands (F44); and cool moist shrublands (S22). These types generally coincide with the eastern portion of the Northwestern Basin and Range Section (342B), and the Snake River Basalts Section (342D).

Moderately confined valley bottoms on gentle slopes predominate this ERU, comprising 29 percent of the total valley bottom composition and occurring in all subsampled watersheds. Moderately confined valley bottoms on moderate slopes are co-dominant (with 80% constancy and 20% average composition, where present). Moderate gradient, rapids-dominated B stream types occur in 93 percent of subsampled watersheds, and comprise 28 percent of the average stream type pattern composition. Steep, step-pool A stream types occur in almost 80 percent of the subsampled watersheds, with an average composition of almost 40 percent. Entrenched, gully-like G stream types also occur as a minor component (4% average composition) within a majority of watersheds in the Upper Snake (71%). Channelized and trenched streams are also common, occurring in 57 percent of subsampled watersheds and representing 7 percent average composition.

Upland erosion potential, given current vegetation patterns, ranks at about the 60th percentile, but mass wasting and potential sediment delivery to streams is low relative to other ERUs. The overall onsite sensitivity of these watersheds to increased

flow and sediment ranks at about the 50th percentile, but there is a large spread in the distribution of index values. The Upper Snake ERU is distinguished by relatively high streambank erosion potential (about the 65th percentile). Riparian vegetation is especially important for maintaining channel morphology (90th percentile) in these settings. The inherent stream channel recovery potential is quite low (about the 40th percentile).

ERU 12: Snake Headwaters

Four subsection groups dominate this ERU:

- M331-06, characterized by mountains of sedimentary and volcanic rocks; all have been modified by colluvial, fluvial, residual, glacial, and periglacial processes.
- M331-02, characterized by intermontane basins and valleys of valley fill, alluvium, and lacustrine materials overlying volcanic and sedimentary rocks.
- M331-03, characterized by glaciated mountains of volcanic and sedimentary rocks; all have been modified by colluvial, fluvial, residual glacial, and periglacial processes.
- M331-04, characterized by glaciated mountains of volcanic and sedimentary rocks; all have been modified by colluvial, fluvial, residual, and glacial processes.

Alluvium is present in 88 percent of the subwatersheds, with average composition, where present, of 19 percent.

Most soils are young to weakly developed and have very poor horizonation; others have subsoil accumulations of clay, thick dark-colored topsoils, or are organic soils. Soil temperatures range from cool to cold, and soil moisture ranges from dry to wet.

The Snake River Headwaters include some of the highest elevations in the Basin. Soil productivity is generally moderate and many soils are cold, shallow to moderately deep, rocky, or stony. Alpine areas consist mostly of rock outcrops and talus. Glaciation has produced many areas of shallow soils and rock outcrop. Soil moisture can be limiting in some areas, and most soils are moderately resilient and have low to moderate susceptibility to compaction. Natural mass failure hazard is moderate to high due to the interbedded sedimentary rocks that weather to form slip surfaces. Natural surface erosion hazard is moderate to high.

This ERU has the highest average elevations of all ERUs (approx. 2,200 m) with relative relief and averages slope (18%) in the mid-range for all ERUs. It has high winter solar radiation (0.0048 joule/m^2), a moderate level of summer precipitation, and low maximum winter temperatures. The major potential vegetation types present are cool moist shrublands (S22), cool dry forestlands (F23), warm dry forestlands (F33), and warm dry shrublands (S33). Constancy values for these types vary from 45 percent to 67 percent.

Steep, moderately confined valleys (VB form 2) dominate this ERU, followed by moderately confined valleys on moderate slopes (VB 5; 100% constancy and 17% average composition). Broad, gently sloping valleys (VB 9; 100% constancy and 15% average composition) are also present. Steep, step-pool, A-stream types occur in all subsampled watersheds. Meandering, alluvial channels with well-developed floodplains also occur in all subsampled watersheds, and represent about 18 percent of stream type composition where present. Narrow, highly sinuous, low gradient E-stream types occur in almost half of all subsampled watersheds, but are more limited in extent (that is, represent 4% average composition, where present). Braided channels also occur over small areas in a majority of watersheds (about 60%). Lakes occur in 76 percent of the subsampled watersheds, representing about 6 percent of the aquatic pattern composition.

The mass wasting index is high (the 80th percentile) for the Snake Headwaters ERU; however, the potential for sediment delivery to streams is only moderate due to low drainage densities. Maintenance of riparian vegetation is fairly important, relative to other ERUs, reflecting the occurrence of C- and E-type channels, and gully-like G-stream types.

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ERU 13: Central Idaho Mountains

Three subsection groups dominate this ERU:

- M332-07, characterized by mountains of igneous and metamorphic rocks with lesser amounts of sedimentary rocks; all have been modified by fluvial, colluvial, and mass wasting processes.
- M332-05, characterized by glaciated mountains and gneiss with lesser amounts of volcanic and sedimentary rocks; all have been modified by glacial, periglacial, fluvial, colluvial, and mass wasting processes.
- M332-01, characterized by breaklands and foothills of granitic rocks; all have been modified by fluvial, colluvial, and mass wasting processes.

The Central Idaho Mountains ERU generally coincides with the Idaho Batholith Section (M332A), the Challis Volcanics Section (M332F), and a part of the Beaverhead Mountains Section (M332E).

Idaho Batholith Section—These are mostly cool and cold soils of the mountains. Most are immature soils with few diagnostic horizons, but a few have clay-enriched subsoils. Most soils have light-colored surface layers; and some have thick, dark-colored topsoil. Some areas have soils with thick volcanic-ash surface layers. Soils are generally shallow to moderately deep, with loamy to sandy textures.

Challis Volcanics Section—Two main groups of soils occur in this section. One group has young to weakly developed soils with light-colored surface layers. The second group has more profile development and includes soils with thick dark-colored topsoils and those with clay-enriched subsoils. Most soils have cool to cold temperature regimes, and dry to wet moisture regimes.

Beaverhead Mountains Section—Soils temperatures range from cool to cold. Some soils have light-colored surface layers and possible accumulations of clay in the subsoil. Other soils have thick, dark-colored topsoil. Young, poorly developed soils occur in alluvial valleys. Mountain soils are generally shallow to moderately deep and have loamy to sandy textures with rock fragments. Valley soils are moderately deep to deep and have loamy to clayey textures.

In the northern and western portion of the Central Idaho Mountains ERU, soil productivity is generally moderate; however, some areas have shallow soils with coarse textures and low organic matter, which makes them less productive. Deep soils and volcanic ash accumulations occur in this area, however, and are commonly very productive, moderately resilient, and moderately susceptible to compaction. Natural mass failure hazard is high, and natural surface erosion hazard is moderate.

In the southcentral part of this ERU, soil productivity is generally moderate to low. This area includes some of the highest elevations in the Basin; most soils are cold, shallow to moderately deep, rocky, and stony. The alpine areas that occur consist mostly of rock outcrop and talus. Glaciation has also produced many areas of shallow soils and rock outcrop. The soils of this area are often moisture-limited, have low to moderate resiliency, and are moderately to highly susceptible to compaction. Natural mass failure hazard is moderate to high, with mass failures and rock falls common at higher elevations. Natural surface erosion hazard is moderate to high.

In the eastern portion of the Central Idaho Mountains ERU, soil productivity is generally low; however, some valley areas with deeper soils have moderate to high productivity. Soils of this area generally have low resiliency and are moderately susceptible to compaction. The natural mass failure hazard is low, and the natural surface erosion hazard is moderate to high.

The Central Idaho Mountains ERU is within the second highest elevation class (average elevation is approx. 1,900 m). It has the highest relative relief and highest class of average slopes (26%) of all ERUs. This ERU also has high winter solar radia-

tion values. The major potential vegetation types present are warm dry (F33), cool dry (F23), cold dry (F13) forestlands; and cool moist shrublands (S22).

Steep confined valleys (VB 1) dominate this ERU. Moderately confined valleys with moderate slopes (VB 5) and steep slopes (VB 2) are also common. Steep step-pools and cascade streams (Stream type-A) occur in all subsampled watersheds and comprise a high average composition when present (66%). On more moderate slopes, rapids dominated B-stream types, and localized occurrences of braided D-stream types are common (93% and 45% constancy respectively). Highly sinuous, narrow, riffle-pool streams (E-types) occur in 45 percent of all subsampled watersheds, comprising 7 percent of the average stream composition where they are present. Unstable, entrenched F-types, probably with cobble, gravel, or sand bed and banks, occur in one-third of all watersheds, with 5 percent average composition, where present.

Upland erosion potential, given current vegetation, is about average relative to all ERUs. Mass wasting potential and potential delivery of sediment to streams is quite high (both are at the 65th percentile). The overall sensitivity of these watersheds to increased sediment and streamflow is fairly low (25th percentile). There are, however, numerous watersheds containing the unstable entrenched F-stream types and gully-like G-stream types. The overall rating for potential downstream transfer effects of disturbances caused by increased streamflow and sediment is moderately high (about the 60th percentile), again reflecting unstable channels that can introduce large amounts of channel-derived sediment into the drainage network.

Hydrologic Integrity Assessment

Estimation of hydrologic integrity across the Basin was complicated by a lack of consistent finer scale data. Stream parameters such as bankfull width, depth, and gradient and streambed substrate composition were generally lacking for most watersheds. These parameters are required if site-specific quantifications of hydrologic integrity are to be made in the Basin and need to be incorporated into future integrated aquatic inventories.

Because of the lack of finer-scale stream morphometric data, a more generalized probabilistic approach was used in determining subbasin hydrologic integrity. Information concerning the resiliency of watersheds to disturbance and estimates of past management activity disturbance to watersheds were both used in determining the hydrologic integrity of subbasins. Rangeland and forested watersheds were assessed independently in this analysis to facilitate characterization of these environments separately at the subbasin level. Subwatersheds (6th-field HUCs) were assigned to a forested type if 20 percent or more of a subwatershed was comprised of forested potential vegetation environments as described earlier in this chapter on Regional Potential Vegetation Classification. Subwatersheds with at least 20 percent or more of rangeland potential vegetation were assigned to a rangeland environment type. The following is a brief description of the methods used in determining the hydrologic disturbance, resiliency, and hydrologic integrity of forest and rangeland environments by subbasin (4th-field HUCs) in this analysis.

Assessment of Hydrologic Disturbance

Impact variables that were considered to be potentially detrimental to the hydrologic integrity of a watershed and that were available continuously across all the watersheds of the Basin were identified in this analysis. These variables included: surficial mining, dams, cropland conversion, and roads.

To facilitate scaled comparisons of these impact variables across the Basin, each subwatershed was assigned to an impacted or non-impacted class for each of the four impact variables studied based on the presence of the impact variable. The percent of impacted subwatersheds within each subbasin was then calculated by impact variable type to produce a coarser-scale description of probable subbasins with impaired hydrologic function (that is, hydrologic disturbance). The four impact variable type

percent values for each subbasin (that is, mining, dams, cropland, and roads) were then converted to cumulative frequency distributions that facilitated general comparisons of relative impact differences across all 4th-field HUC subbasins (that is, each subbasin was assigned a number between 0 and 100 that reflected the percent of other subbasins having an equal or lower value for each of the four impact variables studied).

A generalized description of hydrologic disturbance was constructed for the Basin by summing all four impact variable values for each subbasin by forest and rangeland environment stratifications. This resulted in a potential score for each subbasin ranging from 0 (least impacted) to 400 (most impacted). This summary impact value for each 4th-field HUC subbasin was then converted to a cumulative frequency value that reflected overall relative hydrologic impact differences across all forest and rangeland subbasins. These cumulative frequency values were converted into three hydrologic disturbance class ratings as follows:

- Subbasins with values of 0 to 33 percent were assigned to a low hydrologic disturbance class (that is, they had the lowest overall percent impact by the four variables studied).
- Subbasins with values of 34 to 66 percent were assigned to a moderate hydrologic disturbance class.
- Subbasins with values greater than 66 percent were assigned to a high hydrologic disturbance class.

Maps were produced from these disturbance class ratings to illustrate relative hydrologic disturbance class differences between forested (map 2.34) and rangeland (map 2.35) environments by subbasin.

An assessment of probable riparian area disturbance on rangeland portions of each subbasin was also performed in this analysis. Because detailed information concerning actual riparian conditions was not available for many of the subbasins, riparian disturbance was estimated based on information concerning the sensitivity of streambanks to grazing and the sensitivity of stream channel function to the maintenance of riparian vegetation. In this approach, the resiliency of riparian areas to grazing was used to infer probable riparian area disturbance given the fact that many riparian areas in the Basin have experienced historically high grazing pressure which may still persist today. Accordingly, areas with low relative grazing resiliency were considered to potentially have high riparian disturbance while areas with relatively high grazing resiliency were considered to potentially have lower riparian disturbance. Cumulative frequency distributions were calculated for the combined streambank sensitivity and riparian vegetation sensitivity scores of each rangeland subwatershed which were then averaged by subbasin.

Stratification of these cumulative frequency values into low (0 to 33%), moderate (34 to 66%), and high (greater than 66%) disturbance classes facilitated construction of a map that displays probable relative riparian area disturbance class differences of rangelands by subbasin (map 2.36).

Assessment of Hydrologic Resiliency

The hydrologic and riparian disturbance ratings discussed above reflect relative management impact differences across subbasins. These ratings do not, however, indicate the resiliency of such watersheds to disturbance (that is, their ability to recover following impact). To better understand the potential hydrologic integrity of the watersheds and subbasins within the Basin, a variety of resiliency ratings were developed for each subwatershed and subbasin. These ratings were used in conjunction with the hydrologic impact ratings discussed above in the assessment of overall hydrologic integrity. For example, areas with high hydrologic impact and high stream and riparian vegetation sensitivity are considered to have the lowest probable hydrologic integrity across the Basin. Areas with high hydrologic impact and low stream and riparian vegetation sensitivity, however, would likely possess higher hydrologic integrity because they are better able to absorb such impacts without loss of hydrologic function.

Map 2.34—Relative hydrologic disturbance ratings of forest environments within subbasins.

Map 2.35—Relative hydrologic disturbance ratings of rangeland environments within subbasins.

Map 2.36—Relative riparian disturbance ratings of rangeland environments within subbasins.

For these reasons, hydrologic resiliency ratings should always be considered when interpreting the impacts of past management activities on hydrologic system integrity.

The following is a brief description of the hydrologic resiliency ratings considered in this analysis:

- Road Sediment Hazard: This hazard rating provides a relative description of areas where roads are likely to contribute sediment to streams following construction. Variables considered in this rating include road erosion rates as interpreted by lithologic groups and sediment delivery potential, which considers the average slope and dissection of a watershed. This variable is used in assessing potential impacts to streams following road construction.
- Hillslope Sediment Hazard: This hazard rating provides a relative description of the sediment likely to reach a stream under conditions of no vegetation or ground cover (that is, following wildfire or heavy vegetation extraction). Variables considered in this rating included bare soil erosion rates and sediment delivery potential.
- Stream Sensitivity: This sensitivity rating provides a relative description of watersheds where increased sediment or streamflow are likely to adversely affect stream hydrologic function. This rating is derived from an estimate of the probable stream types within a watershed and their sensitivity to increased sediment and flow.
- Bank Sensitivity: This sensitivity rating provides a relative description of watersheds where streambanks are likely to be adversely affected by management activities (that is, areas where streambanks are sensitive to disturbance). This rating is derived from an estimate of the probable stream types within a watershed and their inherent streambank sensitivity.
- Vegetation Sensitivity: This sensitivity rating provides a relative description of watersheds where riparian vegetation is important to the maintenance of stream function. This rating is derived from an estimate of probable stream types within a watershed and their sensitivity to altered riparian vegetation.
- Hydrologic Recovery Potential: This potential rating provides a relative description of the potential that a watershed has for recovery of hydrologic function following disturbance. This rating is derived from an estimate of probable stream types within a watershed and their potential for recovery following disturbance. This variable is displayed for forestlands on map 2.37 and for rangelands on map 2.38.

The above hydrologic resiliency ratings were calculated individually for each subwatershed and subbasin. Cumulative frequency values for these variables were also calculated for each 4th-field HUC subbasin by forest and rangeland environments. Summary statistics for these resiliency variables were calculated for six forested environment clusters (table 2.23) and six rangeland environment clusters (table 2.24) that are described later in this chapter. Methods used in the identification of the Forest and Rangeland Environment clusters are described in the Integrated Assessment (Quigley and others 1996).

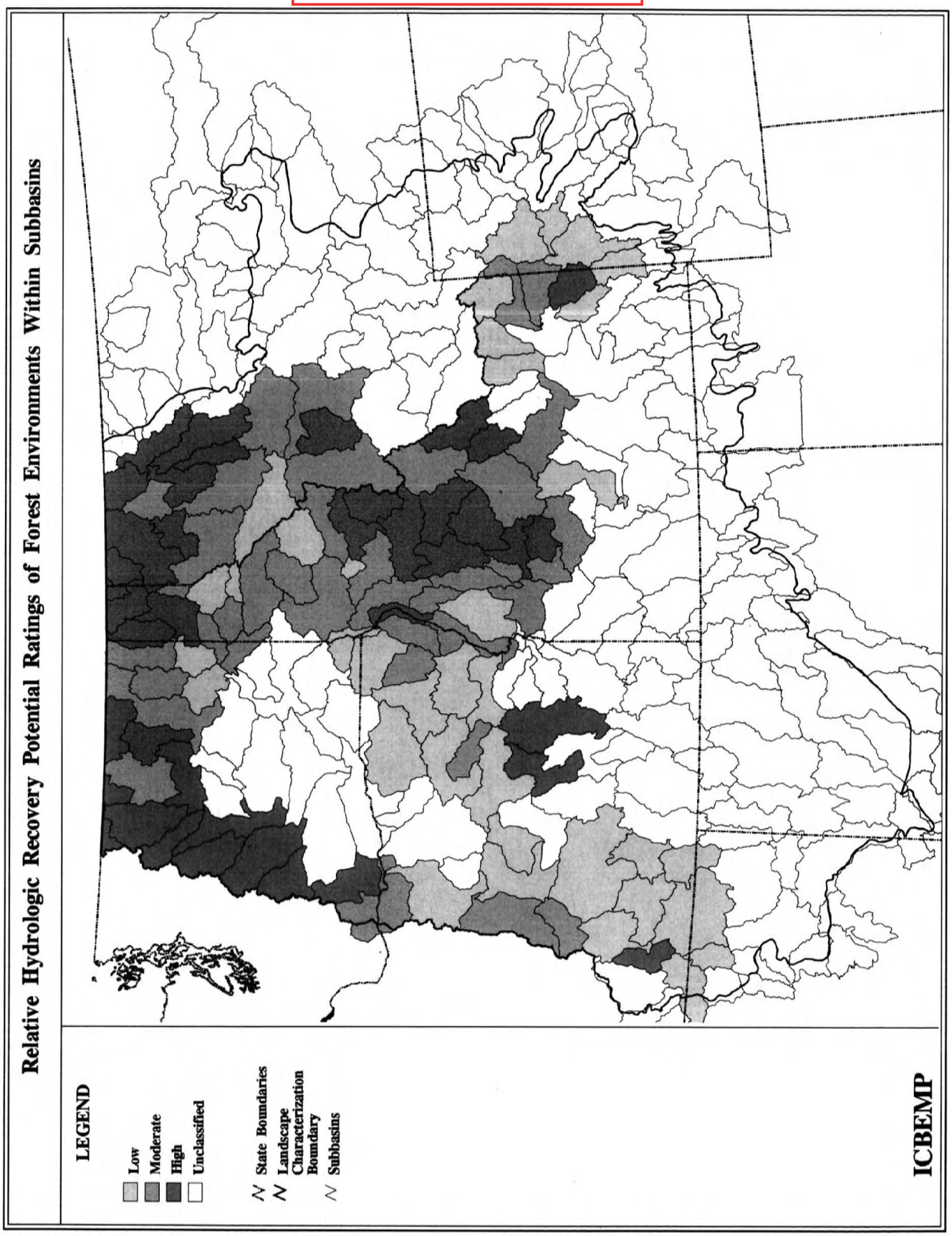
Assessment of Hydrologic and Riparian Integrity

Generalized assessments of hydrologic integrity were made for the forest and rangeland subwatersheds of each subbasin by combining average cumulative frequency values for hydrologic disturbance and hydrologic recovery potential. In this analysis, hydrologic disturbance values were subtracted from 100 to make them compatible with hydrologic recovery potential ratings in the calculation of hydrologic integrity.

Continue

Previous

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Map 2.37—Relative hydrologic recovery potential ratings of forest environments within subbasins.

Map 2.38—Relative hydrologic recovery potential ratings of rangeland environments within subbasins.

Table 2.23—Hydrologic integrity, disturbance, and resiliency rating summary statistics for six forest clusters of the Basin. (Values represent percent of subbasins with equal or lower value for a particular rating.)

		Forest Cluster					
Rating	**Value**	**1**	**2**	**3**	**4**	**5**	**6**
Hydrologic Integrity	x (min./max.)	88 (78-100)	76 (30-99)	39 (4-86)	57 (6-97)	36 (3-79)	24 (1-79)
	SD	13	18	23	22	21	18
Hydrologic Disturbance	x (min./max.)	15 (1-46)	29 (2-75)	64 (25-95)	47 (12-96)	56 (4-97)	76 (16-100)
	SD	13	20	21	23	25	21
Recovery Potential	x (min./max.)	63(3-100)	68 (2-100)	53 (1-99)	51 (1-99)	28 (1-97)	38 (1-97)
	SD	28	22	27	27	26	23
Road Sediment Hazard	x (min./max.)	66 (3-100)	58 (1-100)	48 (1-99)	48 (1-99)	34 (1-99)	53 (1-99)
	SD	27	30	27	26	27	26
Hillslope Sediment Hazard	x (min./max.)	68 (1-100)	63 (1-96)	46 (1-97)	58 (1-99)	28 (1-98)	36 (1-94)
	SD	27	22	24	27	25	22
Stream Sensitivity	x (min./max.)	50 (1-96)	26 (1-99)	43 (1-100)	58 (1-99)	66 (5-100)	56 (4-100)
	SD	31	22	28	19	31	25

(Note: x=Mean, SD=Standard Deviation)

Table 2.24—Hydrologic integrity, disturbance, and resiliency rating summary statistics for six rangeland clusters of the Basin. (Values represent percent of subbasins with equal or lower values for a particular rating.)

		Rangeland Cluster					
Rating	**Value**	**1**	**2**	**3**	**4**	**5**	**6**
Hydrologic Integrity	x (min./max)	38 (23-56)	89 (42-99)	53 (4-100)	10 (1-24)	75 (39-95)	39 (5-70)
	SD	11	15	25	7	15	19
Hydrologic Disturbance	x (min./max)	53 (26-79)	23 (1-66)	55 (1-98)	85 (67-99)	25 (4-69)	56 (11-100)
	SD	17	19	27	10	18	25
Riparian Integrity	x (min./max)	31 (1-46)	91 (62-100)	67 (14-97)	21 (2-68)	64 (24-90)	27 (1-64)
	SD	14	11	20	18	17	17
Riparian Disturbance	x (min./max)	57 (21-91)	30 (1-93)	44 (1-100)	50 (1-82)	32 (1-100)	64 (1-100)
	SD	13	30	27	17	29	29
Recovery Potential	x (min./max)	42 (1-90)	77 (34-99)	59 (1-100)	25 (1-99)	70 (2-100)	47 (1-99)
	SD	21	18	26	19	23	27
Road Sediment Hazard	x (min./max)	57 (1-97)	70 (1-100)	68 (1-99)	56 (1-99)	40 (1-100)	48 (1-100)
	SD	23	25	23	25	30	29
Hillslope Sediment Hazard	x (min./max)	62 (1-100) 24	74 (16-100)	65 (9-99)	44 (1-100)	57 (2-100)	41 (1-100)
	SD	26	24	28		28	28
Stream Sensitivity	x (min./max)	68 (15-100)	35 (2-97)	45 (1-100)	63 (3-96)	25 (1-98)	59 (1-100)
	SD	15	29	27	19	20	29
Bank Sensitivity	x (min./max)	68 (17-96)	26 (1-79)	43 (1-96)	66 (1-100)	26 (1-100)	58 (1-100)
	SD	16	24	27	19	19	29
Vegetation Sensitivity	x (min./max)	60 (21-87)	38 (1-89)	50 (1-92)	42 (1-83)	37 (1-100)	61 (1-100)
	SD	14	34	30	20	31	28

(Note: x = Mean; SD = Standard Deviation)

The combined values of the adjusted hydrologic disturbance and hydrologic recovery potential ratings for both the forest and rangeland environment settings of each subbasin were used to produce new cumulative frequency distributions of hydrologic integrity by subbasin. These scores were used to produce maps of relative hydrologic integrity differences across both forested (map 2.39) and rangeland (map 2.40) environments. Class ratings used in construction of these maps include low (0 to 33%), moderate (34 to 66%), and high (greater than 66%) classes (that is, the percent of other 4th-field HUC subbasins with equal or smaller hydrologic integrity values). Hydrologic integrity ratings were also developed in a similar manner for the forest and rangeland subbasins identified in the *Integrated Assessment* (Quigley and others 1996). These ratings, however, were based on relative differences among the 112 forest and 86 rangeland subbasins identified which resulted in different subbasin scores than those presented in maps 2.39 and 2.40 (that is, the areas used in calculating relative subbasin values were different).

The relative integrity of rangeland riparian areas was calculated in a similar manner to that used in defining general hydrologic integrity. The average relative riparian disturbance and hydrologic recovery potential ratings for each subbasin were combined in determining the probable riparian integrity value of each subbasin. Cumulative frequency distributions of these values were used to produce a map of relative riparian area integrity across the different rangeland environments of the Basin (map 2.41).

The integrity values described above assume that areas with high impact (disturbance) and low recovery potential (resiliency) will often have higher probabilities of altered hydrologic functions than other areas; consequently, in this chapter, these areas are described as possessing low integrity. Conversely, areas with low relative impact by mining, dams, roads, cropland conversion, and grazing with high recovery potentials are considered to have the highest probable hydrologic and riparian integrity. The integrity values presented in this chapter reflect probabilities of finding altered hydrologic functions within 4th-field HUC subbasins based on relative differences between subbasins. Validation of these ratings was not feasible (due primarily to the lack of appropriate finer-grain data within the Basin). Accordingly, the hydrologic integrity, disturbance, and resiliency values presented should only be used for general planning purposes and should not be used in prescriptive project design. Information presented in this section is appropriate to the description of relative differences across the Basin at the 4th-field HUC subbasin level. Application of this information to more detailed planning at the subregional or landscape levels of assessment may be inappropriate.

Forest Cluster Hydrologic Integrity Narrative Descriptions—The following is a brief description of the hydrologic integrity of the six forest clusters (map 2.42) addressed in the *Integrated Assessment.*

Forest cluster 1: Hydrologic integrity of these subbasins is the highest of any forestlands. Disturbance of hydrologic function due to past management activities is low, and the potential for streams to recover following disturbance is generally moderate to high. Steep slopes, high drainage densities, and erosive soils are commonly found on the forested lands of these subbasins. These factors contribute to high sediment hazard potential ratings for these subbasins following roading or large crown-consuming fires. Accordingly, these subbasins are considered to be sensitive to the construction of new roads, and fuel management plans should be developed to limit the risk of extensive wildfires in protecting the hydrologic integrity of these subbasins. Stream channels of these environments generally display a moderate sensitivity to increased sediment and flow.

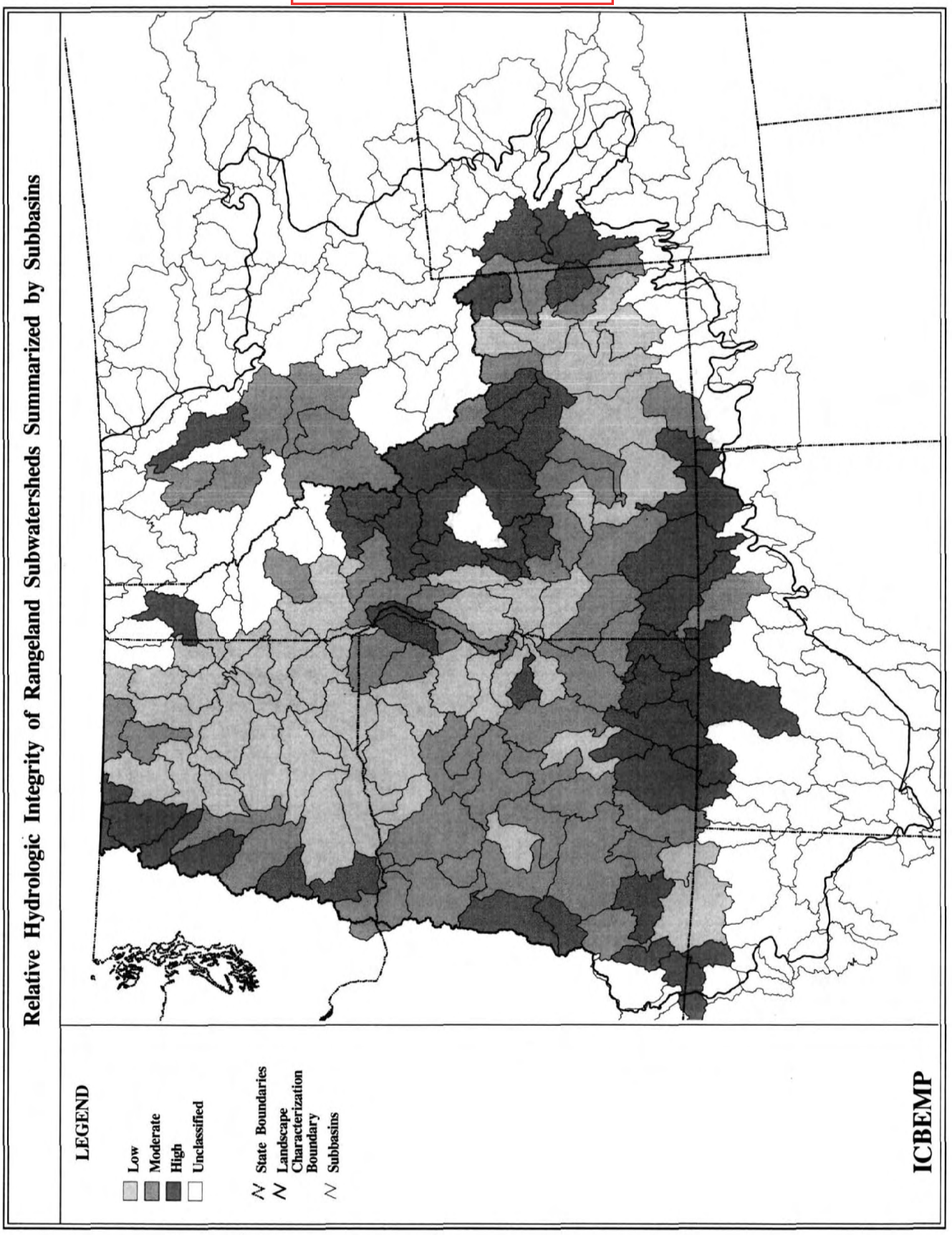
Forest cluster 2: Hydrologic integrity of the forestlands within these subbasins is relatively high. Disturbance of hydrologic function due to past management activities is generally low, and the potential for streams to recover following disturbance is commonly high. Sediment hazard potentials of these subbasins are similar to Forest Cluster 1, which is high for road construction and wildfires. Stream channels of these environments generally display a low sensitivity to increased sediment and flow.

Map 2.39—Relative hydrologic integrity ratings of forest environments within subbasins.

Continue

Previous

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Map 2.40—Relative hydrologic integrity ratings of rangeland environments within subbasins.

Map 2.41—Relative riparian integrity ratings of rangeland environments within subbasins.

Map 2.42—Forest clusters.

Forest cluster 3: Hydrologic integrity of these subbasins is low to moderate. Disturbance of hydrologic function from past management activities is moderate to high due in large part to roads, mines, and cropland conversion of lower elevation valleys. The potential for streams of these environments to recover following disturbance is moderate. Sediment hazards associated with roads and large crown-consuming fires are moderate and the sensitivity of streams to increased sediment and flow is commonly low to moderate. These subbasins present moderate limitations to management given their hydrologic resiliency; however, past management activities may have already contributed to degraded conditions in some subbasins.

Forest cluster 4: Hydrologic integrity of these subbasins is moderate. Disturbance of hydrologic function from past management activities is moderate due primarily to roads and dams. The potential for streams to recover following disturbance is also moderate. Sediment hazards associated with road construction and stand-consuming fires are moderate. Sensitivity of streams to increased sediment and flow is moderate. These forest environments present good opportunities for hydrologic integrity restoration projects.

Forest cluster 5: Hydrologic integrity of these subbasins is low to moderate. Disturbance of hydrologic function from past management activities is moderate to high, due primarily to dams and to a lesser extent roads and cropland conversion of lower elevation valleys. The potential for streams to recover following disturbance is generally low, which suggests that adverse impacts of previous activities on hydrologic function are still apparent in many subbasins of these forest areas. Due to the gentler slopes, lower dissection, and less erosive soils of these environments, sediment hazards associated with roads and large crown-consuming fires are generally low. Sensitivity of streams to increased sediment and flow, however, is high.

Forest cluster 6: Hydrologic integrity of these subbasins is the lowest of any forestlands in the Basin. Disturbance of hydrologic function from management activities is high due primarily to roads, dams, and cropland conversion of lower elevation valleys. The potential for streams to recover following disturbance is low to moderate, which suggests that adverse impacts of previous management activities on hydrologic function are still apparent in many subbasins of this forest type. Sediment hazards associated with roads are moderate to high; however, those associated with large crown fires are generally low to moderate. Sensitivity of streams to increased sediment and flow in these subbasins is generally low.

Range Cluster Hydrologic Integrity Narrative Descriptions—The following text is a brief description of the hydrologic integrity of the six rangeland clusters (map 2.43) addressed in the *Integrated Assessment* (Quigley and others 1996).

Range cluster 1: The general hydrologic integrity of these subbasins is low to moderate, and riparian environment integrity is commonly low. Disturbance of hydrologic function from past management activities is moderate, due primarily to dams and to a lesser degree roads and cropland conversion of valley bottoms. Grazing impacts to riparian areas are assumed to be moderate to high in many areas. The potential for streams to recover following disturbance is generally low to moderate within these subbasins. Sediment hazards associated with roads and wildfires are moderate to high, and the sensitivity of stream channels to increased sediment and flow is high. Sensitivity of streambanks to disturbance is high and the dependency of stream channel function to the maintenance of riparian vegetation is moderate to high. For these reasons, grazing in riparian areas can have significant impacts on the hydrologic integrity of these subbasins.

Range cluster 2: The general hydrologic integrity of these subbasins is high and the integrity of riparian environments is also high. Disturbance of hydrologic function from past management activities is low, and grazing impacts to riparian areas

Map 2.43—Range clusters.

are assumed to be generally low. The potential for streams to recover following disturbance is high within these subbasins. Sediment hazards associated with roads and wildfires tend to be some of the highest found on rangelands of the Basin; however, the sensitivity of streams to increased flow and sediment are commonly low to moderate. Sensitivity of streambanks to disturbance is low and the dependency of stream channel function to the maintenance of riparian vegetation is low to moderate. For these reasons, these subbasins support some of the most resilient riparian environments to livestock grazing.

Range cluster 3: The general hydrologic integrity of these subbasins is moderate, and the integrity of their riparian environments is moderate to high. Disturbance of hydrologic function from past management activities is moderate, due primarily to roads and mines and to a lesser degree dams and cropland conversion of valley bottoms. Grazing impacts to riparian areas are assumed to be moderate in most areas. The potential for streams to recover following disturbance is moderate within these subbasins. Sediment hazards associated with roads are high and those associated with wildfires are moderate to high. Sensitivity of streams to increased sediment and flow are generally moderate. Sensitivity of streambanks to disturbance is moderate as is the dependency of stream channel function to the maintenance of riparian vegetation.

Range cluster 4: The general hydrologic integrity of these subbasins is low as is the integrity of the riparian environments they contain. Disturbance of hydrologic function from past management activities is high, due primarily to cropland conversion of valley bottoms and to a lesser degree roads. Grazing impacts to riparian areas are assumed to be moderate where such practices exist. The potential for streams to recover following disturbance is the lowest of any rangeland setting within the Basin. Sediment hazards associated with roads are moderate, and those associated with wildfires are commonly low to moderate. Sensitivity of stream channels to increased sediment and flow is moderate to high, which suggests that the hydrologic integrity of many stream channels may still be impaired due to previous management activities within these subbasins. Sensitivity of streambanks to disturbance is high, and the dependency of stream channel function to the maintenance of riparian vegetation is moderate.

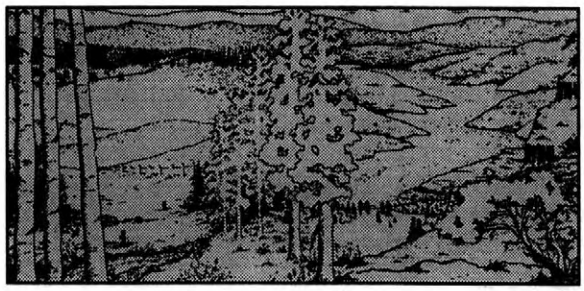
Range cluster 5: The general hydrologic integrity of these subbasins is high, and the integrity of the riparian environments they contain is commonly moderate to high. Disturbance of hydrologic function from past management activities is low, and the assumed impacts to riparian areas by grazing are low to moderate. The potential for streams to recover following disturbance tends to be high within these subbasins. Sediment hazards associated with roads are commonly low to moderate, and those associated with wildfires are moderate. Sensitivity of streams to increased sediment and flow is low to moderate. Streambank sensitivity to disturbance and the dependency of stream channel function to the maintenance of riparian vegetation are low. These subbasins commonly provide the fewest limitations to rangeland management from a hydrologic integrity perspective (that is, they are resilient and have not been heavily impacted in the past).

Range cluster 6: The general hydrologic integrity of these subbasins is low to moderate, and the integrity of their riparian environments is commonly low. Disturbance of hydrologic function from past management activities is moderate to high due to roads, dams, mines, and cropland conversion of valley bottoms. Grazing impacts to riparian areas are assumed to be moderate to high. The potential for streams to recover following disturbance is commonly low to moderate. For these reasons, past disturbances to hydrologic integrity are considered to persist in many of the subbasins within this rangeland theme. Sediment hazards associated with roads and wildfire are moderate, and stream sensitivity to increased sediment and flow is commonly moderate. Sensitivity of streambanks to disturbance and the dependency of stream channel function to the maintenance of riparian vegetation is moderate to high.

Continue

Previous

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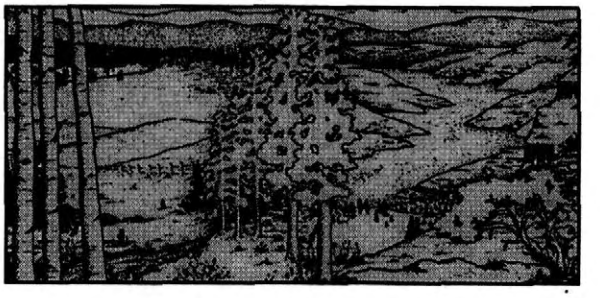
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GLOSSARY

aeolian - (a) Pertaining to the wind; especially said of such deposits as loess and dune sand, of sedimentary structures such as wind-formed ripple marks, or of erosion and deposition accomplished by the wind. (b) Said of the active phase of a dune cycle, marked by diminished vegetal control and increased dune growth.

air mass - A widespread body of air that is approximately homogeneous in its horizontal extent, particularly with reference to temperature and moisture distribution. In addition, the vertical temperature and moisture variations are approximately the same over its horizontal extent

alkalinity - The power of a solution to neutralize hydrogen ions (H+).

alluvium - A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent geologic time be a stream or other body of running water as a sorted or semi-sored sediment in the bed of the stream.

anticyclone - A closed circulation usually around a center of high atmospheric pressure. The terms anticyclone and high often are used interchangeably. Anticyclonic flow is clockwise in the northern hemisphere

biogeography - The study of the geographical distributions of organisms, their habitats (ecological biogeography) and their historical and biological factors which produce them (historical biogeography); chorology, geonemy.

biophysical - The combination of biological and shysical components in an ecosystem.

biosphere - the global ecosystem; that part of the Earth and atmosphere capable of supporting living organisms.

biotic - Living; relating to life or specific life conditions.

chinook winds - Chinook is a local name for foehn wind. Originally named for winds off the Rocky Mountains but generally applied across the western U.S.

climate - The prevailing weather or long-term manifestations of weather

climate division - Each U.S. state has been subdivided into climatic divisions. The divisional boundaries are defined mainly by drainage basins or major crops and may or may not delineate areas of climatological homogeneity.

colluvium - A general term applied to any loose, heterogeneous, and incoherent mass of soil material and/or rock fragments deposited by rainwash, sheetwash, or slow continuous downslope creep, usually collecting at the base of gentle slopes or hillsides.

continental air mass - A type of air whose characteristics are developed over a large land area and which, therefore, has the basic continental characteristic of relatively low moisture content.

convection - In meteorology, atmospheric motions that are predominantly vertical, resulting in vertical transport and mixing of atmospheric properties

Convective precipitation - Precipitation from convective clouds; generally considered to be synonymous with showers

Cooperative Observer Network (COOP) - A network of unpaid observers who maintain meteorological stations for the National Weather Service. The usual instruments of observation are maximum and minimum thermometers and a non-recording precipitaion gage.

cyclone - A closed circulation usually around a center of low atmospheric pressure. The terms cyclone and low often are used interchangeably. Also, because cyclones nearly always are accompanied by inclement (often destructive) weather, they frequently are referred to simply as storms. Cyclonic flow is counter-clockwise in the northern hemisphere.

down burst - A strong win characterized by a sudden onset and a duration on the order of minutes. Associated with the air movement around thunderstorms.

ecosystem - An area of any size with an association of physical and biological components so organized that a change in any one component will bring about a change in the other components and the operation of the whole system.

El Niño - A warm-water current that flows southward along the coast of Ecuador during the Christmas season (the name refers to the Christ child). The negative phase of an El Niño is called a La Niña.

El Niño Southern Oscillation (ENSO) - The collective link between El Niño and the Southern Oscillation that has climatic effects throughout the Pacific region and sometimes elsewhere. It occurs every five to eight years when the prevailing trade winds weaken and the equatorial countercurrent strengthens. This causes warm survace waters, normally diven westward by the wind, to form a deep layer off Indonesia and flow eastward to overly the cold waters of the Peru current.

equivalent potential temperature - The termperature that a parcel of air would be if it were brought from its inital state to a pressure level of 1,000 mb (near standard sea level), without transferring heat or mass across its boundaries. It allows analysis of air mass temperatures by minimizing the effects of changing altitude and changing water phases.

evapotranspiration - The combined processes by which water is transferred from the earth's surface to the atmosphere; evaporation of liquid or solid water plus transpiration from plants.

floodplain - lowland bordering a stream or river onto which the flow spreads at flood stage

front - The interface between tow air masses of different density. Because the termperature distribution is the most important regulator of atmospheric density, a front most often separates air masses of different temperature. Changing wind directions, moisture content, and atmospheric pressure patterns also can distinguish a front.

frontal zone - The transition zone between two air masses of differenct density.

gap winds - Winds that are channeled and usually accelerated through a gap between mountains.

geoclimatic - The combination of geologic and climatic components in an ecosystem.

greenhouse effect - The heating effect exerted by the atmosphere upon the earth by virtue of the fact that the atmosphere (mainly its water vapor) absorbs and remits infrared radiation. The shorter wavelengths of solar radiation are transmitted rather freely through the atmosphere to be absorbed at the earth's surface. The earth then remits this as long-wave (infrared) terrestrial radiation, a portion of which is absorbed by the atmosphere and again emitted -- some back downward to the earth's surface.

greenhous gas - Atmospheric gases that are nearly transparent to solar radiation but almost opaque to longwave (terrestrial) radiation. These include water vapor, carbon dioxided, tropospheric ozone, nitrous oxide, methane, chlorofluorocarbons, halocarbons, and precursors of any of these gases.

hierarchy - A general integrated system comprising two or more levels, the higher controlling to some extent the activities of the lower levels; a series of consecutively subordinate categories forming a system of classification.

Holocene - most recent geological epoch; the approximately 10,000 years since the last major continental glaciation.

humidity - Some measure of water vapor content of air. Typically measured as dew point temperature or relative humidity.

hydrography - The scientific description and analysis of the physical conditions, boundaries, flow, and related characteristics of surface waters, as ocianslakes, and rivers; the mapping of bodies of water; a book on hydrography.

intermontane - Situated between or surrounded by mountains, mountain ranges, or mountainous regions; for example the great Basin of western U.S.; between the Sierra Nevada and the Wasatch Mountains.

inversion (temperature) - A layer of air in which temperature increases with height. It is extremely stable.

jet stream - Relative strong winds concentrated within a narrow stream in the atmosphere. While this term may be applied to any such stream, regarless of direction (including vertical), it is coming more and more to mean only the quasi-horizontal jet stream of maximum winds imbedded in the mid-latiture westerlies, and concentrated at an altitude of about 10 km. Two jets are distinguished, the polar jet and subtropical jet.

lacustrine - (a) Pertaining to, produced by, or formed in a lake or lakes, such as "lacustrine sands" deposited on the bottom of a lake, or a "lacustine terrace" formed along its margin. (b) Growing in or inhabiting lakes, such as "lacustrine fauna". (c) Said of a region characterized by lakes, such as a "lacustrine desert" containing the remnants of numerous lakes that are now dry.

landscape - A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout.

loess - A widespread, homogeneous, commonly nonstratified, porous, friable, slightly coherent, usually highly calcareous, fine-grained blanket deposit (generally less than 30 m thick), consisting predominantly of silt with subordinate grain sizes ranging from clay to fine sand.

marine air mass - A type of air whose characteristics are developed over an extensive water surface and which, therefore, has the basic maritime quality of high moisture content in at least its lowere levels. Also called maritime air.

marine push - A term applied to the sudden transition between warm, dry conditions to cool, moist conditions as marine arir displaces continental air. In the Pacific Northwest a marine push often occurs after a themal low moves from the cost to the interior. While the low is near the coast, dry easterly surface winds prevail. Once inland, east of the Cascade mountains, the pressure gradients associated with the thermal low cause westerly surface winds to draw marine air in the Columbia River Basin.

meridional flow - A type of atmospheric circulation pattern in which the meridional (north and south) component of motion is unusually pronounced. The accompanying zonal component is usually weaker than normal. Meridional flow is characterized by high amplitude troughs and ridges.

mesoscale - The horizontal scale of atmospheric motion typically between 1 and 100 kilometers where vertical motions become important. Usually less than the size of a typical cyclonic strom but greater than the size of a thunderstorm.

metasediment - A sediment or sedimentary rock that shows evidence of having been subjected to metamorphism.

microrelief - (a) Local, slight irregularities of a land surface, including such features as low mounds, swales, and shallow pits, generally about a meter indiameter, and causing variations amounting to no more than 3 m. (b) Relief features that are too small to show on a topographic map, such as gullies, mounds, boulders, pinnacles, or other features less than 60 m in diameter and less than 6 m in elevation, in an area for which the topographic map has a scale of 1:50,000 or smaller and a contour interval of 3 m (10 ft) or larger.

mixing height - The height at which the atmosphere becomes stable or the height of a ground-based stable layer. An air parcel near the earth's surface can be naturally buoyant and rise vertically until it reaches a level where surrounding air is cooler than the parcel. Then it stops rising. Mixing height is the level at which air stops rising or stops vertical mixing.

normal - In meteorology, the average value of a meteorological element over any fixed period of years that is recognized as standard for the country and element concerned. In the Unitied States, the National Climatic Data Center calculates averages over 30-year periods to describe climate normals. These are recalculated every decade. The mosat recent normals at the time of this writing are for the period 1961-1990.

Pacific air mass - A marine air mass that developed over the Pacific Ocean.

Pacific North American (PNA) index - Describes the strength of the ridge-trough-ridge pattern of upper level flow over North America. Best defined during winter. Positive indices indicate a strong low centered near the Aleutian islands, a strong ridge in the eastern Pacific an western United States, and a deep trough in the eastern United States. Negative indices indicate a more zonal flow pattern with low amplitude ridges and troughs.

paleo-climate - Climate that is reconstructed from proxy data like tree rings, fossil pollen, deep sea sediments, glacier fluctuations, and ice cores. In the western U.S. this usually means any climate prior to about 1895.

palustrine - pertaining to material growing or deposited in a marsh or marsh-like environment.

periglacial - (a) Said of the processes, conditions, areas, climates, and topographic features at the immediate margins of former and exisitng glaciers and ice sheets, and influenced by the cold temperature of the ice. (b) By extension, said of an environment in which frost action is an important factor, or of phenomena induced by a periglacial climate beyond the periphery of the ice.

pit mounds - uprooting of trees creates pits and mounds that differ in several properties from soilds that have not been overturned. Pits have more litter and standing water and mounds have less than do other soils.

physiography - pertaining to geographical features of the Earth's surface [LB]

pluvial - [Clim] Said of a climate characterized by relatively high precipitation, or of the time interval during which such a climate prevailed. Formerly equated with the glacial stage of the Quaternary glacial/interglacial sequence, pluvial intervals are now regarded more as transitional, or, in low latitudes, as typical of interglacials. [Geomorph] Said of a geologic episode, change, process, deposit, or feature resulting from the action or effects of rain; such as pluvial denudation, a landslide, or gully erosion and the consequent spreading-out of the eroded material below. The term sometimes includes the fluvial action of rainwater flowing in a stream channel, especially in the channel of an ephemeral stream.

polar jet stream - A jet stream associated with the plar front. It fluctuates around 40 degrees latitude over the western U.S. during winter and areound 60 degrees latitude during summer.

potential natural vegetation - The vegetation that would exist today if man were removed from the scene and if the plant succession after his removal were telescoped into a single moment. The time compression eliminated the effects of future climatic fluctuations, while the effects of man's earlier activities are permitted to stand. The maps and description s of potential natural vegetation developed by Kuchler (1964) for the 48 conterminous States are among the most widely used.

pressure level - A level of altitude at which the atmospheric pressure is everywhere equal at a given instant.

province - An ecological unit in the ecoregion planning and analysis scale of the National Hierarchical Framework corresponding to subdivisions of a Division that conform to climatic subzones controlled mainly by continental weather patterns.

radiosonde - A balloon-borne instrument for the simultaneous measurement and transmission of meteorological data.

radiosonde observation (RAOB) - An evaluation in terms of temperature, relative humidity, and pressure aloft, of radio signals received from a balloon-borne radiosonde; the height of each mandatory and significant pressure level of the observation is computed from these data.

rain-on-snow flood - A flood caused by rain falling on an existing snowcover. Usually of greater magnitude than floods caused by pure snowmelt or by floods caused by pure rainfall. The effect is most significant when sallow snowcover exists at relatively low elevations. Deep snowcover at higher elevations can absorb rainwater.

rain shadow - A region on the lee side of a mountain or maountain range where precipitation is noticeably less than on the windward side.

ridge - In meteorology, an elongated areas of relatively high atmospheric pressure, almost always associated with and most clearly identified as an area of maximum anticyclonic curvature of wind flow.

section - An ecological unit in the subregion planning and analysis scale of the National Hierarchical Framework corresponding to subdivisions of a province having broad areas of similar geomorphic process, stratigraphy, geologic origin, drainage networks, topography, and regional climate. Such areas are often inferred by relating geologic maps to potential natural vegetation groupsings as mapped by Kuchler (1964).

significant level - In a radiosonde observation, a level (other than a mandatory level) for which values of pressure, temperature, and humidity are reported because temperature and/or moisture content data at that level are sufficiently important or unusual to warrant the attention of a forecaster, or they are required for the reasonably accurate reproduction of the radiosonde observation.

slope winds- Local diurnal winds that occur on all sloping surfaces. During the day, air rised as the ground is heated by sunshine so winds generally flow upslope. During night, air cools and sinks so winds generally flow downslope.

snow water equivallent (SWE) - The depth of water that would result from the melting of the snow pack or of a snow sample. Thus, the water equivalent of a new snowfall is the same as the amount of precipitation represented by that snowfall.

snowfall - Precipitating snow. Usually measured as depth of snow accumulating on a plate that is cleaned after each observation. Cooperative observers usually measure snowfall once each day and first-order station observers usually measure once each hour. More frequent measurements produce higher values of snowfall than less frequent measurements because snow settles and decreases volume after falling. New sensors are becomin available, which can measure the water content of snow as it is falling, that may prevent the disparities caused by variable measurement frequency.

Southern Oscillation (SO) - A fluctuation of the intertropical atmospheric circulation, in particular in the Indian and Pacific Oceans, in which air moves between the southeast Pacific subtropical high and the Indonesian equatorial low, driven by the temperature difference between the two areas. The general effect is that, when pressure is high over the eastern Pacific ocean, it tends to be low in the eastern Indian Ocean, and vice versa. The phenomenon is strongly linked to El Niño.

stable air - Air in which small disturbances do not grow; vertical motions are small. Stable air commonly causes or enhances inversions. In a dry atmosphere, if air temperatures decrease with increasing altitude at a rate less than 9.8° C per kilometer it is stable.

subregion - A scale of planning and analysis in the National Hierarchical Framework that has applicability for strategic, multi-forest, statewide, and multi-agency analysis and assessment. Subregions include Section and Subsection ecological units.

subsection - An ecological unit in the subregion planning and analysis scales of the National Hierarchical Framework corresponding to subdivisions of a Section into areas with similar surficial geology, lithology, geomorphic process, soil groups, subregional climate, and potential natural communities.

synoptic - In meteorology, the use of meteorological data obtained simultaneously over a wide area for the purpose of presenting a comprehensive and nearly instantaneous picture of the state of the atmosphere. Therefore, synoptic is synonymous to simultaneity.

synoptic weather - Weather that can be described with synoptic data, usually on the scale of a typical cyclonic storm over a period of a day or two.

thermal low (or heat low) - An area of low atmospheric pressure (a low) due to high temperatures caused by intensive heating at the earth's surface. Thermal lows are common to the continental subtropics in summer. A thermal low often develops in California's interior valley and can migrate northward into Oregon and Washington. If it stays west of the Cascades, it can cause or enhance easterly surface winds in western Oregon and Washington. If it moves from west to east of the Cascades it can create a "marine push," bringing cool marine air into the Columbia River Basin. Strong marine pushes can cause strong thunderstorms to develop over the interior valleys and into the Snake River Plain.

trough - In meteorology, an elongated area of relatively low atmospheric pressure; the opposite of a ridge.

unstable air - Air in which small disturbance can grow; vertical motions can be large. Commonly associated with thunderstorms. In a dry atmosphere, if air temperatures decrease with increasing altitude at a rate more than 9.8° C per kilometer it is unstable.

upper-air - Generally applies to the atmosphere above the 850 mb pressure level.

zonal flow (zonal circulation) - In meteorology, the flow of air along a latitude circle; the latitudinal (east or west) component of existing flow. Usually having low amplitude troughs and ridges.

APPENDIX 2A

Listing of Biophysical Environment Variable and Interpretations Attributed to Subbasins and Subwatersheds for Analysis

Field Code: ERO

Field Description: This field contains the surface erosion hazard coefficient for each hydrologic unit (4th- or 6th-field HUC). The logic and methodology outlined in U. S. Environmental Protection Agency (1980) was modified for use in broad-scale assessments. Factors used include slope, rainfall intensity, surficial geology, and vegetation cover.

Field Code: BASEERO

Field Description: This field contains the base surface erosion hazard coefficient, without the ameliorating effect of vegetation, for each hydrologic unit (4th- or 6th-field HUC). The logic and methodology outlined in U. S. Environmental Protection Agency (1980) was modified for use in broad-scale assessments. Factors used include slope, rainfall intensity, and surficial geology. (In this context BASE means surface erosion rates with no vegetation cover.)

Field Code: STE

Field Description: This field contains a measure of the physical characteristics of the landscape involved with the potential delivery of sediment to streams for each hydrologic unit (4th- or 6th-field HUC). Factors used include slope, drainage density, and surficial geology.

Field Code: SED

Field Description: This field contains the sediment delivery hazard coefficient for each hydrologic unit (4th- or 6th-field HUC). Factors used include surface erosion hazard (ERO) and sediment transport efficiency (STE).

Field Code: BASESED

Field Description: This field contains the base sediment delivery hazard coefficient, without the ameliorating effect of vegetation, for each hydrologic unit (4th- or 6th-field HUC). Factors used include the base surface erosion hazard (BASEERO) and sediment transport efficiency (STE). (In this context, BASE means surface erosion rates with no vegetation cover.)

Field Code: MASS

Field Description: This field contains the slumping (i.e., rotational slumps) hazard rating coefficient for each hydrologic unit (4th- or 6th-field HUC). The logic and methodology outlined in U. S. Environmental Protection Agency (1980) was modified for use in broad-scale assessments. Factors used include slope, soil properties, and precipitation.

Field Code: DEBRIS

Field Description: This field contains the debris avalanche (i.e., translational slump) hazard rating coefficient for each hydrologic unit (4th- or 6th-field HUC). The logic and methodology outlined in U. S. Environmental Protection Agency (1980) was modified for use in broad-scale assessments. Factors used include slope and precipitation.

Field Code: IS_FLOW

Field Description: This field contains the on-site hazard rating for changes in channel morphology resulting from increased flow and/or sediment for each hydrologic unit (4th- or 6th-field HUC). The hazard rating is for the dominant stream channel types in an area, using the stability ratings described by Rosgen (1994).

Field Code: DS_FLOW

Field Description: This field contains the on-site hazard rating for changes in channel morphology resulting from decreased flow and/or sediment for each hydrologic unit (4th- or 6th-field HUC). The hazard rating is for the dominant stream channel types in an area, using the stability ratings described by Rosgen (1994).

Field Code: BANK

Field Description: This field contains the average streambank erosion hazard rating for each hydrologic unit (4th- or 6th-field HUC). The hazard rating is for the dominant stream channel types in an area, using the stability ratings described by Rosgen (1994).

Field Code: VEG

Field Description: This field contains the average vegetation influence rating for the dominant stream channel types in each hydrologic unit (4th- or 6th-field HUC), using the stability ratings described by Rosgen (1994).

Field Code: RECOVERY

Field Description: This field contains the average stream channel recovery potential rating for the dominant stream channel types in each hydrologic unit (4th- or 6th-field HUC), using the recovery ratings described by Rosgen (1994).

Field Code: MWSI

Field Description: This field contains an index value which rates the relative sensitivity of each hydrologic unit (4th- or 6th-field). This sensitivity index is an overall rating that combines the general potential for sediment delivery with the average potential for stream channels to recover from disturbance. MWSI is a relative index that is derived using the CBASESED_B and RECOVERY fields calculated as: (CBASESED_B + [100 - RECOVERY]), where CBASESED_B is the base sediment delivery hazard/ basin cumulative frequency, which is a field containing the cumulative frequency distribution (expressed as a percentile) of the base sediment delivery hazard coefficient, without the ameliorating effect of vegetation, for each hydrologic unit (4th or 6th field). Factors used include the base surface erosion hazard (BASEERO) and sediment transport efficiency (STE). (In this context, BASE means surface erosion rates

with no vegetation cover). The cumulative frequency is relative to all HUCs within the ICRB. And where RECOVERY is the average recovery potential rating, which is a field containing the average stream channel recovery potential rating for the dominant stream channel types in each hydrologic unit (4th or 6th field), using the recovery ratings described by Rosgen (1994). The formula uses (100 - RECOVERY) to make the numerical expression of sensitivity consistent; hence a "high" recovery potential value would not cancel out a "high" base sediment delivery hazard coefficient value.

Field Code: ROADHAZ

Field Description: This field contains the relative road erosion hazard rating for each hydrologic unit (4th- or 6th-field). This rating is based on the relative erodibility of surface material as defined by lithology, calculated as: SUM (percent of each lithology *RE for each lithology).

Field Code: *MINES

Field Description: This field contains a categorical variable (Yes or No) indicating whether a 6th-field hydrologic unit has mining activity. Mining activity was derived from USGS point data and is defined as a HUC that has TYPE = placer, surface, or surf-underground and STATUS = devel. (This base layer is documented elsewhere.) This field is only in the table for 6th-field watersheds, H6INTERP.

Field Code: *CROPLAND

Field Description: This field contains a categorical variable (Yes or No) indicating whether a 6th-field hydrologic unit has substantive agricultural activity. Agricultural activity was derived from the broad-scale VEG data and is defined as a HUC that has cropland cover-type greater than or equal to 15 percent. (This base layer is documented elsewhere.) This field is only in the table for 6th-field watersheds, H6INTERP.

Field Code: *DAMS

Field Description: This field contains a categorical variable (Yes or No) indicating whether a 6th-field hydrologic unit has dams present. Dams were derived from point data from the aquatics staff. (This base layer is documented elsewhere.) This field is only in the table for 6th-field watersheds, H6INTERP.

Field Code: *ROAD_CLASS

Field Description: This field contains a categorical variable (High, Moderate, or Low) indicating the road density class of each 6th-field hydrologic unit. Road density classes were derived using the five density classes from the landscape ecology staff and collapsing them to three by combining Very Low and Low (into Low) and High and Extremely High into High. (This base layer is documented elsewhere.) This field is only in the table for 6th-field watersheds, H6INTERP.

Field Code: *RDSENSITIV

Field Description: This field contains a road sensitivity index value derived using a combination of the basinwide cumulative frequency distributions of sediment delivery hazard (CSED_B), increased flow and/or sediment hazard rating/on-site (CISFLOW_B), and the road erosion hazard (CROADHAZ_B) calculated as: (CSED_B = CISFLOW_B + CROADHAZ_B)/3. This value is then reordinated into a cumulative frequency distribution (expressed as a percentile). This field is only in the table for 6th-field watersheds, H6INTERP.

Field Code: **MASTER_LIM

Field Description: This field contains a categorical variable (Yes or No) indicating the hydrologic integrity of a 4th-field hydrologic unit that may be adversely affected by one or more factors. The factors considered include mining activity, agricultural activity, roading, and dams. The field is "Yes" if the percentage of 6th-field hydrologic units with extensive road systems in sensitive areas within a 4th-field hydrologic unit (**PCT_ROAD), or the percentage of 6th-field hydrologic units containing dams within a 4th-field hydrologic unit (**PCT_DAM), or the percentage of 6th-field hydrologic units with agricultural activity within a 4th-field hydrologic unit (**PCT_CROP), or the percentage of 6th-field hydrologic units with mining activity within a 4th- field hydrologic unit (**PCT_MINES) is equal to or greater than 15 percent. This field is only in the table for 4th-field watersheds, H4INTERP. "Yes" if (**PCT_ROAD) or (**PCT_DAM) or (**PCT_CROP) or (**PCT_MINES) is >= 15 percent.

Field Code: **HYDR_DIST

Field Description: This field contains an index value for hydrologic disturbance that was derived using factors relating to hydrologic integrity. The factors considered include mining activity, agricultural activity, roading, and dams. The index value is calculated by summing the percentage of 6th-field hydrologic units with extensive road systems in sensitive areas within a 4th-field hydrologic unit (**PCT_ROAD), and the percentage of 6th-field hydrologic units containing dams within a 4th-field hydrologic unit (**PCT_DAM), and the percentage of 6th-field hydrologic units with agricultural activity within a 4th-field hydrologic unit (**PCT_CROP) and the percentage of 6th-field hydrologic units with mining activity within a 4th-field hydrologic unit (**PCT_MINES). The sum of these percentages is then distributed into cumulative frequencies (expressed as percentiles). This field is only in the table for 4th-field watersheds, H4INTERP. HYDR_DIST = cumulative frequency distribution of (**PCT_RAOD) + (**PCT_DAM) + (**PCT_CROP) + (**PCT_MINES)

Field Code: **CHYDR_INTEG_B

Field Description: This field contains an index value that rates the relative hydrologic integrity of each 4th-field hydrologic unit. It was derived using factors that relate to both hydrologic disturbance and recovery. This integrity index is an overall rating that combines the general potential for hydrologic disturbance with the average potential for stream channels to recover from disturbance; it is derived using the CHYDR_DIST_B and CRECOVERY_B fields calculated as: (100 - CHYDR_DIST_B) + (CRECOVERY_B). Where CHYDR_DIST_B is the hydrologic disturbance index value for 4th-field hydrologic units/basin cumulative frequency, which is a field containing the cumulative frequency distribution (expressed as a percentile) of the hydrologic disturbance index for each 4th-field hydrologic unit. This index value for hydrologic disturbance was derived using factors that relate to hydrologic integrity. The factors considered include mining activity, agricultural activity, roading, and dams. The index value is calculated by summing the percentage of 6th-field hydrologic units with extensive road systems in sensitive areas within a 4th-field hydrologic unit (**PCT_ROAD), and the percentage of 6th-field hydrologic units containing dams within a 4th-field hydrologic unit (**PCT_DAM), and the percentage of 6th-field hydrologic units with agricultural activity within a 4th-field hydrologic unit (**PCT_CROP) and the percentage of 6th-field hydrologic units with mining activity within a 4th-field hydrologic unit (**PCT_MINES). The sum of these percentages is then distributed into cumulative frequencies (expressed as percentiles). The cumulative frequency is relative to all HUCs within the ICRB. CHYDR_DIST_B = cumulative frequency distribution of (**PCT_ROAD) + (**PCT_DAM) + (**PCT_CROP) + (**PCT_MINES)

And where CRECOVERY_B is the average recovery potential rating/basin cumulative frequency, which is a field that contains the cumulative frequency distribution (expressed as a percentile) of the average stream channel recovery potential rating for the dominant stream channel types, in each 4th-field hydrologic unit using the recovery ratings described by Rosgen (1994). The cumulative frequency is relative to all 4th-field HUCs within the ICRB. The formula uses (100 - CHYDR_DIST_B) to make the numerical expression of integrity consistent; hence a "high" recovery potential value would not cancel a "high" hydrologic disturbance index value. The sum of these percentiles is then redistributed into cumulative frequencies (expressed as percentiles) relative to all HUCs within the ICRB. **This field is only in the table for 4th-field watersheds, H4INTWERP.

Field Code: RIP_DIST

Field Description: This field contains an index value for riparian disturbance that was derived using factors relating to riparian condition including both streambank erosion hazard ratings and the vegetation influence rating. This disturbance index is an overall rating that combines the streambank erosion hazard rating with the average vegetation influence rating; it is derived using the BANK and BEG fields calculated as: (BANK + VEG)/2. Where BANK is the average streambank erosion hazard rating, which contains the average streambank erosion hazard rating for each hydrologic unit (4th- or 6th-field). The hazard rating is for the dominant stream channel types in an area, using the stability ratings described by Rosgen (1994). And where VEG is the average vegetation influence rating, which contains the average vegetation influence rating for the dominant stream channel types in each hydrologic unit (4th- or 6th-field), using the stability ratings described by Rosgen (1994).

Field Code: RIP_INTEG

Field Description: This field contains an index value that rates the relative riparian area integrity of each 4th- and 6th-field hydrologic unit. It was derived using factors that relate to both riparian area disturbance and recovery. This integrity index is an overall rating that combines the general potential for riparian area disturbance with the average potential for stream channels to recover from disturbance; it is derived using the RIP_DIST and RECOVERY fields calculated as: (100 - RIP_DIST) + (RECOVERY). Where RIP_DIST is the hydrologic disturbance index value for 4th-field hydrologic units, which is a field containing an index value for riparian disturbance derived using factors that relate to riparian condition including both streambank erosion hazard ratings and the vegetation influence rating. This disturbance index is an overall rating that combines the streambank erosion hazard rating with the average vegetation influence rating; it is derived using the BANK and BEG fields calculated as: (BANK + VEG)/2. Where BANK is the average streambank erosion hazard rating, which contains the average streambank erosion hazard rating for each hydrologic unit (4th- or 6th-field). The hazard rating is for the dominant stream channel types in an area, using the stability ratings described by Rosgen (1994). And where VEG is the average vegetation influence rating, which contains the average vegetation influence rating for the dominant stream channel types in each hydrologic unit (4th- or 6th-field), using the stability ratings described by Rosgen (1994).

And where RECOVERY is the average recovery potential rating, which is a field that contains the average stream channel recovery potential rating for the dominant stream channel types in each hydrologic unit (4th- or 6th-field), using the recovery ratings described by Rosgen (1994). The formula uses (100 - RIP_DIST) to make the numerical expression of integrity consistent; hence a "high" recovery potential value would not cancel out a "high" riparian area disturbance index value.

Important Notes

Cumulative frequencies, expressed as percentiles, were calculated using the standard statistical formula and definition.

Field codes prefixed with an * are only in the table for 6th code watersheds H6INTERP.

Field codes prefixed with two ** are only in the table for 4th code watersheds H4INTERP.

If TEMP_ZONE = X, the HUC is outside the boundary of this coverage, which only covers the Columbia River Basin.

Some HUCs will have zero sediment values (STE, SED, BASESED, etc.). These values are zero due to missing stream coverage for these HUCs. Some HUCs will not have hazard ratings because there is missing data for some subsection/slope phase combinations. There are a few missing values for AUG_TEMP.

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however, some errors may remain.

Common and scientific names of species.

Common name	Scientific name
Flora:	
African rue	*Peganum harmala*
Alder	*Alnus Hill*
Bitter brush	*Purshia tridentata* (Pursh) DC.
Blue-leaved penstemon	*Penstemon glaucinus*
Broad-fruit mariposa	*Calochortus nitidus*
Brome-grass	*Bromus* L.
Buck rush	*Ceanothus cuneatus* (Hook.) T. & G.
Canada thistle	*Cirsium arvense*
Cheatgrass	*Bromus tectorum* L.
Clustered lady's-slipper	*Cypripedium fasciculatum*
Common crupina	*Crupina vulgaris*
Crenulate grape-fern	*Botrychium crenulatum*
Crested wheatgrass	*Agropyron cristatum* (L.) Gaertn.
Cronquist's stickseed	*Hackelia cronquistii*
Dalmatian toadflax	*Linaria dalmatica*
Diffuse knapweed	*Centaurea diffusa*
Douglas-fir	*Pseudotsuga menziesii* (Mirbel) Franco.
Dyers woad	*Isatis tinctoria*
Grand fir	*Abies grandis* (Dougl.) Forbes
Green-tinged paintbrush	*Castilleja chlorotica*
Halogeton	*Halogeton glomeratus*
Howellia	*Howellia aquatilis*
Howell's gumweed	*Grindelia howellii*
Huckleberries	*Vaccinium* L.
Iberian starthistle	*Centaurea iberica*
Idaho fescue	*Festuca idahoensis* Elmer
Juniper	*Juniperus* L.
Kentucky bluegrass	*Poa pratensis* L.
Knapweed	*Centaurea* L.
Leafy spurge	*Euphorbia esual* L.
Lemhi penstemon	*Penstemon lemhiensis*
Lodgepole pine	*Pinus contorta* Dougl.
Long-bearded mariposa-lily	*Calochortus longebarbatus* var. *Longebarbatus*
Macfarlane's four-o'clock	*Mirabilis macfarlanei*
Malheur wire-lettuce	*Stephanomeria malheurensis*

Common name	Scientific name
Manzanita	*Arctostaphylos* Adans.
Matgrass	*Nardus stricta*
Mediterranean sage	*Salvia aethiopis*
Medusahead	*Taeniatherum caput-medusae*
Mountain hemlock	*Tsuga mertensiana* (Bong.) Carr.
Mt. Mazama collomia	*Collomia mazama*
Mulford's milk-vetch	*Astragalus mulfordiae*
Musk thistle	*Carduus nutans*
Orange hawkweed	*Hieracium aurantiacum*
Osgoodmountains milkvetch	*Astragalus yoder-williamsii*
Palouse goldenweed	*Haplopappus liatriformis*
Payson's milkvetch	*Astragalus paysonii*
Peck's mariposa-lily	*Calochortus longebarbatus* var. *Peckii*
Perennial pepperweed	*Lepidium latifolium*
Picabo milkvetch	*Astragalus oniciformis*
Ponderosa pine	*Pinus ponderosa* Dougl.
Purple loosestrife	*Lythrum salicaria*
Purple starthistle	*Centaurea calcitrapa*
Pygmy monkeyflower	*Mimulus pygmaeus*
Rush skeletonweed	*Chondrilla juncea*
Russian knapweed	*Centaurea repens*
Sagebrush	*Artemisia* L.
Saltcedar	*Tamarix ramosissima*
Scotch thistle	*Onopordum acanthium*
Spalding's campion	*Silene spaldingii*
Spiny cocklebur	*Xanthium spinosum*
Spotted knapweed	*Centaurea maculosa*
Squarrose knapweed	*Centaurea virgata*
St. Johnswort	*Hypericum perforatum*
Subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.
Suksdorf's lomatium	*Lomatium suksdorfii*
Sulfur cinquefoil	*Potentilla recta*
Syrian bean-caper	*Zygophyllum fabago*
Tansy ragwort	*Senecio jacobaea*
Thompson's clover	*Trifolium thompsonii*
Twin-spike moonwort	*Botrychium paradoxum*
Upward-lobed moonwort	*Botrychium ascendens*
Washington monkeyflower	*Mimulus washingtonensis* var. *Washingtonensis*
Washington polemonium	*Polemonium pectinatum*
Weak milk-vetch	*Astragalus solitarius*

Common name	Scientific name
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
Western juniper	*Juniperous occidentalis* Hook.
Western redcedar	*Thuja plicata* Donn.
Western white pine	*Pinus monticola* Dougl.
Wheat	*Triticum aestivum* L.
White bark pine	*Pinus albicaulis* Engelm.
White fir	*Abies concolor* (Gord. & Glend.) Lindl.
Whitetop	*Cardaria* spp.
Willow	*Salix* L.
Yellow hawkweed	*Hieracium pratense*
Yellow starthistle	*Centaurea solstitialis*
Annual, Biennial Forb:	
	Alyssum desertorum
	Amisimkia intermedia
	Blepharipappus scaber
	Clarkia pulchella
	Coldenia grandiflora
	Collinsia parviflora
	Collomia grandiflora
	Cordylanthus ramosus
	Cryptantha affinis
	Cryptantha ambigua
	Descurainia pinnata
	Descurainia richardsonii
	Draba verna
	Epilobium minutum
	Epilobium paniculatum
	Eriogonum vimineum
	Erodium cicutarium
	Euphorbia spp.
	Galium bifolium
	Gayophytum humile
	Gapophytum nuttallii
	Hemizonia pungens
	Holosteum umbellatum
	Lactuca ludoviciana
	Lagophylla ramosissima
	Layia galndulosa
	Lepidium perfoliatum

Common name	Scientific name
	Linanthus harknessi
	Lupinus microcarpus
	Madia gracilis
	madia sativa
	Microsteris gracilis
	Mimulus breweri
	Montia perfoliata
	Navarretia sp.
	Orthocarpus tenuifolius
	Phacelia linearis
	Plectritis macrocera
	Polemonium micranthum
	Polygonum majus
	Ranunculus testiculatus
	Ranunculus occidentalis
	Sanguisorba minor
	Sisymbrium altissimum
	Taraxacum ceratophorum
	Tragopogon dubius
	Verbascum thapsus
Annual Grass:	
	Agrostis interrupta
	Bromus brizaeformis
	Bromus japonicus
	Bromus mollis
	Bromus tectorum
	Festuca bromoides
	Festuca microstachys
	Festuca octoflora
	Taeniatherum asperum
Perennial Forb:	
	Achillea millefolium
	Agoseris glauca
	Agoseris grandiflora
	Allium acuminatum
	Allium douglasii
	Antennaria rosea
	Antennaria dimorpha
	Arabis hoboelii

Common name	Scientific name
	Arabis puberula
	Arabis sparsiflora
	Aster campestris
	Astragalus beckwithii
	Astragalus curvicarpus
	Astragalus filipes
	Astragalus lentiginosus
	Astragalus prushii
	Astragalus reventus
	Astragalus stenophyllus
	Balsamorhiza careyana
	Balsamorhiza sagittata
	Calochortus macrocarpus
	Castilleja applegatei
	Castilleja chromosa
	Chaenactis douglasii
	Cheilanthes gracillima
	Cirsium arvense
	Crepis acuminata
	Crepis intermedia
	Erigeron bloomeri
	Erigeron elegantulus
	Erigeron filifolius
	Erigeron linearis
	Erigeron poliospermus
	Erigeron pumilus
	Eriogonum heracleoides
	Eriogonum microthecum
	Eriogonum niveum
	Eriogonum ovalifolium
	Eriogonum sphaerocephalum
	Eriogonum strictum
	Eriogonum thymoides
	Eriogonum umbellatum
	Eriophyllum lanatum
	Fritillaria pudica
	Geum campanulatum
	Hydrophyllum capitatum
	Leptodactylon pungens
	Linum perenne

Common name	Scientific name
	Lithophragma bulbifera
	Lomatium canbyi
	Lomatium cous
	Lomatium macrocarpum
	Lomatium triternatum
	Lupinus caudatus
	Lupinus laxiflorus
	Lupinus lepidus
	Mertensia longiflora
	Microseris nutans
	Microseris troximoides
	Orobanche uniflora
	Penstemon humilis
	Penstemon gracilis
	Penstemon laetus
	Penstemon richardsoni
	Penstemon speciosus
	Petalostemon ornatum
	Phacelia hastata
	Phlox douglasii
	Phlox hoodii
	Phlox longifolia
	Potentilla glandulosa var. *intermidia*
	Ranunculus occidentalis
	Senecio canus
	Senecio integerrimus
	Sisyrinchium douglasi
	Sisyrinchium idahoense
	Stellaria americana
	Stellaria nitens
	Trifolium dubium
	Trifolium macrocephalum
	Trifolium microcephalum
	Zygadenus paniculatus
Perennial Grass:	
	Agropyron saxocpla
	Agropyron smithii
	Agropyron spicatum
	Bromus carinatus

Common name	Scientific name
	Danthonia unispicata
	Elymus cinereus
	Festuca idahoensis
	Keoleria cristata
	Oryzopsis humenoides
	Poa ampla
	Poa bulbosa
	Poa compressa
	Poa cusickii
	Poa pratensis
	Poa sandbergii
	Sitanion hystrix
	Stipa columbiana
	Stipa comata
	Stipa occidentalis
	Stipa thurberiana
Sedge:	
	Carex rossii
	Carex geyeri
	Kobresia simpliciuscula
Shrub:	
	Artemisia arbuscula
	Atremisia tridentata spp. *tridentata*
	Atremisia tridentata ssp. *wyomingensis*
	Artemisia tridentata ssp. *vaseyana*
	Artemisia rigida
	Cercocarpus ledifolius
	Chrysothamnus nauseosus
	Chrysothamnus viscidiflorus
	Grayia spinosa
	Holodiscus dumosus
	Purshia tridentata
	Ribes cereum
	Symphoricarpos oreophilus
	Tetradymia canescens
	Tetradymia glabrata

	Common name	Scientific name
Fish:		
	Bass	*Micropterus* spp.
	Bull trout	*Salvelinus confluentus*
	Brook trout	*Salvelinus fontinalis*
	Chinook salmon	*Oncorhynchus tshawytscha*
	Goose Lake sucker	*Catostomus occidentalis lacusanserinus*
	Klamath Largescale sucker	*Catostomus snyderi*
	Lahontan Cutthroat trout	*Oncorhynchus clarki henshawi*
	Lost River sucker	*Deltistes luxatus*
	Malheur sculpin	*Cottus bairdi* ssp.
	Margined sculpin	*Cottus marginatus*
	Pacific lamprey	*Lampetra tridentata*
	Pit-Klanath Brook lamprey	*Lampetra lethophaga*
	Pygmy whitefish	*Prosopium coulteri*
	Rainbow trout	*Oncorhynchus mykiss*
	Redband trout	*Oncorhynchus mykiss* ssp.
	Shorthead sculpin	*Cottus confusus*
	Shortnose sucker	*Chasmistes brevirostris*
	Slender sculpin	*Cottus tenuis*
	Sockeye salmon	*Oncorhynchus nerka*
	Steelhead	*Oncorhynchus mykiss mykiss*
	Torrent sculpin	*Cottus rhotheus*
	Walleye	*Stizostedion vitreum vitreum*
	Westslope cutthroat trout	*Oncorhynchus clarki lewisi*
	Wood River Bridgelip sucker	*Catostomus columbianus hubbsi*
	Wood River sculpin	*Cottus leiopomus*
	Yellowstone cutthroat trout	*Oncorhynchus clarki bouvieri*
Birds:		
	American kestrel	*Falco sparverius*
	American robin	*Turdus migratorius*
	Ash-throated flycatcher	*Myiarchus cinerascens*
	Bald eagle	*Haliaeetus leucocephalus*
	Band-tailed pigeon	*Columba fasciata*
	Bank swallow	*Riparia riparia*
	Barn swallow	*Hirundo rustica*
	Barred owl	*Strix varia*
	Black-backed woodpecker	*Picoides arcticus*
	Black-billed magpie	*Pica pica*
	Black-capped rosy finch	*Leucosticte arctoa*

Common name	Scientific name
Black-chinned hummingbird	*Archilochus alexandri*
Black-throated gray warbler	*Dendroica nigrescens*
Blue grouse	*Dendragapus obscurus*
Bobolink	*Dolichonyx oryzivorus*
Bohemian Waxwing	*Bombycilla garrulus*
Boreal owl	*Aegolius funereus*
Brewer's blackbird	*Euphagus cyanocephalus*
Brewer's sparrow	*Spizella breweri*
Broad-tailed hummingbird	*Selasphorus platycercus*
Burrowing owl	*Athene cunicularia*
Bushtit	*Psaltriparus minimus*
Canyon Wren	*Catherpes mexicanus*
Cedar Waxwing	*Bombycilla cedrorum*
Chestnut-backed chickadee	*Parus rufescens*
Chipping sparrow	*Spizella passerina*
Chukar	*Alectoris chukar*
Cliff swallow	*Hirundo pyrrhonota*
Columbia sharp-tailed grouse	*Tympanuchus phasianellus columbianus*
Common loon	*Gavia immer*
Common nighthawk	*Chordeiles minor*
Common poorwill	*Phalaenoptilus nuttallii*
Common raven	*Corvus corax*
Common snipe	*Gallinago gallinago*
Cooper's hawk	*Accipiter cooperii*
Downy woodpecker	*Picoides pubescens*
Dusky flycatcher	*Empidonax oberholseri*
European starling	*Sturnus vulgaris*
Ferruginous hawk	*Buteo regalis*
Flammulated owl	*Otus flammeolus*
Golden eagle	*Aquila chrysaetos*
Grasshopper sparrow	*Ammodramus savannarum*
Gray flycatcher	*Empidonax wrightii*
Gray partridge	*Perdix perdix*
Great horned owl	*Bubo virginianus*
Greater sandhill crane	*Grus canadensis tabida*
Great gray owl	*Strix nebulosa*
Green-tailed towhee	*Pipilo chlorurus*
Hammond's flycatcher	*Empidonax hammondii*
Harlequin duck	*Histrionicus histrionicus*
Horned lark	*Eremophila alpestris*

Common name	Scientific name
House finch	*Carpodacus mexicanus*
Lark bunting	*Calamospiza melanocorys*
Lark sparrow	*Chondestes grammacus*
Lazuli bunting	*Passerina amoena*
Lewis' woodpecker	*Melanerpes lewis*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Long-eared owl	*Asio otus*
Merlin	*Falco columbarius*
Mountain bluebird	*Sialia currucoides*
Mountain chickadee	*Parus gambeli*
Mountain quail	*Oreortyx pictus*
Mourning dove	*Zenaida macroura*
Northern flicker	*Colaptes auratus*
Northern goshawk	*Accipiter gentilis*
Northern pygmy-owl	*Glaucidium gnoma*
Northern rough-winged swallow	*Stelgidopteryx serripennis*
Northern shrike	*Lanius execubitor*
Northern spotted owl	*Strix occidentalis caurina*
Olive-sided flycatcher	*Contopus borealis*
Pileated woodpecker	*Dryocopus pileatus*
Pine siskin	*Carduelis pinus*
Pinyon jay	*Gymnorhinus cyanocephalus*
Prairie Falcon	*Falco mexicanus*
Pygmy nuthatch	*Sitta pygmaea*
Red-eyed vireo	*Vireo olivaceus*
Red-naped sapsucker	*Sphyrapicus nuchalis*
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoeniceus*
Ring-necked pheasant	*Phasianus colchicus*
Rock wren	*Salpinctes obsoletus*
Rough-legged hawk	*Buteo lagopus*
Rufous hummingbird	*Selasphorus rufus*
Rufous-sided towhee	*Pipilo erythrophthalmus*
Sage grouse	*Centrocercus urophasianus*
Sage sparrow	*Amphispiza belli*
Sage thrasher	*Oreoscoptes montanus*
Sharp-shinned hawk	*Accipiter striatus*
Short-eared owl	*Asio flammeus*
Southern red-backed vole	*Clethrionomys gapperi*

Common name	Scientific name
Spotted sandpiper	*Actitis macularia*
Steller's Jay	*Cyanocitta stelleri*
Swainson's hawk	*Buteo swainsoni*
Three-toed woodpecker	*Picoides tridactylus*
Townsend's solitaire	*Madestes townsendi*
Townsend's Warbler	*Dendroica townsendi*
Tree swallow	*Tachycineta bicolor*
Turkey vulture	*Cathartes aura*
Upland sandpiper	*Bartramia longicauda*
Vaux's swift	*Chaetura vauxi*
Veery	*Catharus fuscescens*
Vesper sparrow	*Pooecetes gramineus*
Violet-green swallow	*Tachycineta thalassina*
Western bluebird	*Sialia mexicana*
Western meadowlark	*Sturnella neglecta*
Western red-backed vole	*Clethrionomys californicus*
Western screech owl	*Otus kennicottii*
Western snowy plover	*Charadrius alexandrinus nivosus*
Western tanager	*Piranga ludoviciana*
White-breasted nuthatch	*Sitta carolinensis*
White-headed woodpecker	*Picoides albolarvatus*
White-winged crossbill	*Loxia leucoptera*
Wild turkey	*Meleagris gallopavo*
Willet	*Catoptrophorus semipalmatus*
Williamson's sapsucker	*Sphyrapicus thyroideus*
Willow flycatcher	*Empidonax traillii*
Wilson's warbler	*Wilsonia pusilla*
Winter wren	*Troglodytes troglodytes*
Wood duck	*Aix sponsa*
Woodpecker	*Picoides* spp.
Yellow-billed cuckoo	*Coccyzus americanus*
Yellow-breasted chat	*Icteria virens*
Yellow-rumped Warbler	*Dendroica coronata*
Yellow warbler	*Dendroica petechia*
Mammals:	
American badger	*Taxidea taxus*
American marten	*Martes americana*
Black bear	*Ursus americanus*
Black-tailed jackrabbit	*Lepus californicus*
Bobcat	*Lynx rufus*

Common name	Scientific name
Bushy-tailed woodrat	*Neotoma cinerea*
California bighorn sheep	*Ovis canadensis californiana*
Chipmunk	*Tamias* spp.
Common porcupine	*Erethizon dorsatum*
Coyote	*Canis latrans*
Deer mouse	*Peromyscus maniculatus*
Domestic horse (Feral)	*Equus caballus*
Elk	*Cervus elaphus*
Fisher	*Martes pennanti*
Fringed myotis	*Myotis thysanodes*
Golden-mantled ground squirrel	*Spermophilus lateralis*
Gray wolf	*Canis lupus*
Great basin pocket mouse	*Perognathus parvus*
Grizzly bear	*Ursus arctos*
Hoary bat	*Lasiurus cinereus*
Least chipmunk	*Tamias minimus*
Little brown myotis	*Myotis lucifugus*
Long-eared myotis	*Myotis evotis*
Long-legged myotis	*Myotis volans*
Long-tailed weasel	*Mustela frenata*
Lynx	*Lynx lynx*
Moose	*Alces alces*
Mountain lion	*Felis concolor*
Mountain (or bighorn) sheep	*Ovis canadensis*
Mule or black-tailed deer	*Odocoileus hemionus*
Northern flying squirrel	*Glaucomys sabrinus*
Northern grasshopper mouse	*Onychomys leucogaster*
Ord's kangaroo rat	*Dipodomys ordii*
Pale western big-eared bat	*Plecotus townsendii pallescens*
Pallid bat	*Antrozous pallidus*
Pinon mouse	*Peromyscus truei*
Pronghorn antelope	*Antilocapra americana*
Pygmy rabbit	*Brachylagus idahoensis*
Rocky Mountain elk	*Cervus elaphus nelsonii*
Rocky Mountain gray wolf	*Canis lupis irremotus*
Silver-haired bat	*Lasionycteris noctivagans*
Spotted bat	*Euderma maculatum*
Squirrel	*Ammospermophilus* spp.
Townsend's big-eared bat	*Plecotus townsendii*
Townsend's ground squirrel	*Spermophilus townsendii*

Common name	Scientific name
Washington ground squirrel	*Spermophilus washingtoni*
Western small-footed myotis	*Myotis ciliolabrum*
White tail deer	*Odocoileus virginianus*
White-tailed jack rabbit	*Lepus townsendii*
Wolverine	*Gulo gulo*
Woodland caribou	*Rangifer tarandus caribou*
Yellow-pine chipmunk	*Tamias amoenus*
Yuma Myotis	*Myotis yumanensis*
Amphibians and Reptiles:	
Coeur d'Alene salamander	*Plethodon idahoensis*
Common garter snake	*Thamnophis sirtalis*
Desert horned lizard	*Phrynosoma platyrhinos*
Gopher snake	*Pituophis melanoleucus*
Longnose leopard lizard	*Gambelia wislizenii*
Long-toed salamander	*Ambystoma macrodactylum*
Mojave black-collared lizard	*Crotaphytus bicinctores*
Night snake	*Hypsiglena torquata*
Northern leopard frog	*Rana pipiens*
Pacific treefrog	*Pseudacris regilla*
Painted turtle	*Chrysemys picta*
Racer	*Coluber constrictor*
Rubber boa	*Charina bottae*
Sagebrush lizard	*Sceloporus graciosus*
Sharp-tailed snake	*Contia tenuis*
Short-horned lizard	*Phrynosoma douglassii*
Side-blotched lizard	*Uta stansburiana*
Southern alligator lizard	*Elgaria multicarinatas*
Spotted frog species A	*Rana pretiosa* sp. A
Spotted frog species B	*Rana pretiosa* sp. B
Striped whipsnake	*Masticophis taeniatus*
Tailed frog	*Ascaphus truei*
Western fence lizard	*Sceloporus occidentalis*
Western pond turtle	*Clemmys marmorata*
Western rattlesnake	*Crotalus viridis*
Western skink	*Eumeces skiltonianus*
Western toad	*Bufo boreas*
Woodhouse's toad	*Bufo woodhousii*

List of Acronyms

ASQ	Allowable Sale Quantity
AUM	Animal Unit Month
BEA	Bureau of Economic Analysis
BLM	Bureau of Land Management
BMPs	Best Management Practices
BTUs	British Thermal Units
CFR	Code of Federal Regulations
CRBSUM	Columbia River Basin Succession Model
EIS	Environmental Impact Statement
EEIS	Eastside EIS Planning/Management Area
EPA	Environmental Protection Agency
ERU	Ecological Reporting Units
ESI	Existing Scenic Integrity
FACA	Federal Advisory Committe Act
FEMAT	Forest Ecosystem Management Assessment Team
FIRE	BEA designation, Finance, Insurance and Real Estate industries
FS	Forest Service
FSH	Forest Service Handbook
GIS	Geographic Information System
GPM	General Planning Model
GSP	Gross State Product
HUCs	Hydrologic Unit Codes
LWD	Large Woody Debris
ICBEMP	Interior Columbia Basin Ecosystem Management Project
ICRB	Interior Columbia River Basin
INFISH	Inland Native Fish Strategy
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWFP	Northwest Forest Plan
PACFISH	Pacific Anadromous Fish Strategy
PILT	Payments in Lieu of Taxes
RAC	Resource Advisory Committee
RHCA	Riparian Habitat Conservation Area
RMA	Riparian Management Area
ROS	Recreation Opportunity Spectrum
PVG	Potential Vegetation Group
PVT	Potential Vegetation Type
RVD	Recreation Visitor Day
SER	Species-Environment Relations (database)
SIC	Standard Industrial Code
SIT	Science Integration Team
TES	Threatened and Endangered Species
UCRB	Upper Columbia River Basin EIS Planning/Management Area
USDA	United States Department of Agriculture
USDI	United States Department of Interior
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Metric Conversion

Mile (mi)=1.61 Kilometers (km)

Kilometer (km)=.62 Miles (mi)

Square Kilometers (km^2)=.39 Square Miles (mi^2)

Centimeter (cm)=.3937 Inches (in)

Meter (m)=3.28 Feet (ft)

Hectare (ha)=10,000 Square Meters (m^2)

Hectare (ha)=2.47 Acres (ac)

Acre (ac)=43,560 Square Feet (ft^2)

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This paper provides detailed information about current conditions and trends for the biophysical and social systems within the basin. Social and economic conditions within the assessment area differ considerably depending to a great extent on population, diversity of employment opportunities, and changing demographics. This information can be used by land managers to develop broad management goals and priorities and provides the context for decisions specific to smaller geographic areas.

Keywords: Columbia basin, biophysical systems, social systems, ecosystem.

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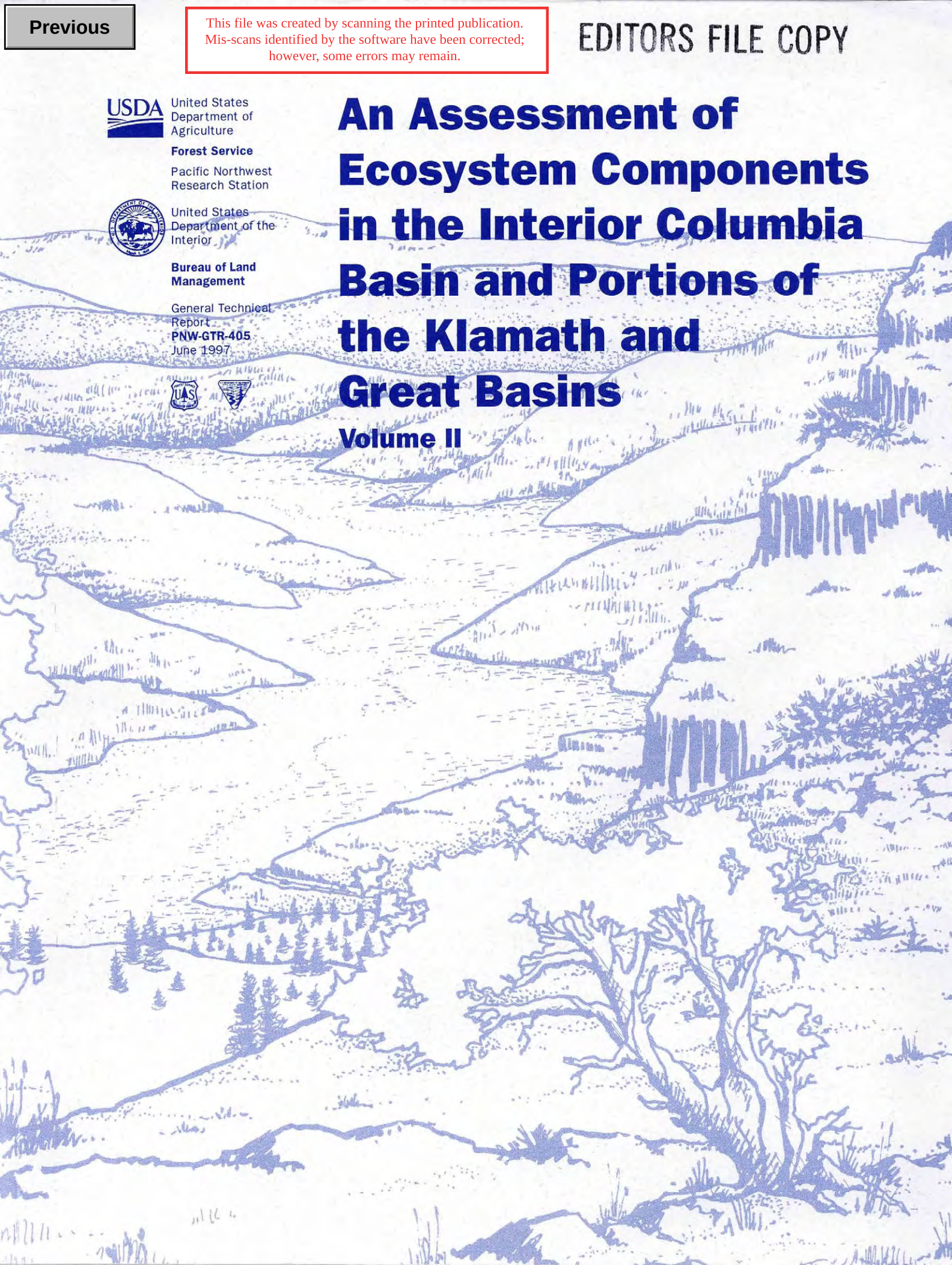
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Volume II



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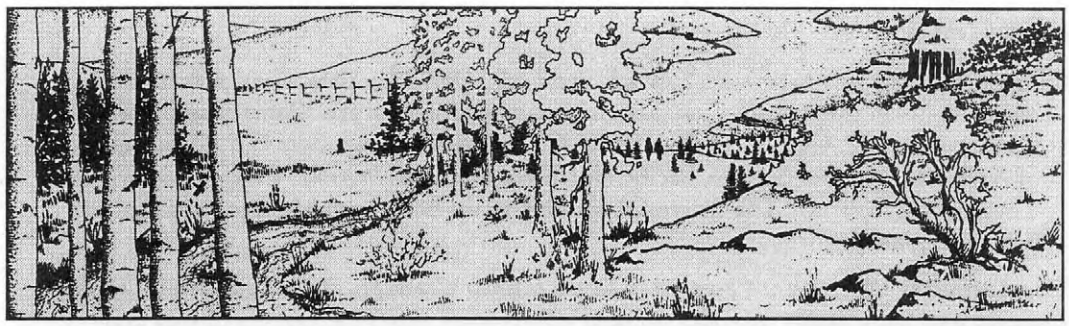
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An Assessment of Ecosystem Components in the Interior Columbia Basin

And Portions of the Klamath and Great Basins: Volume II

Thomas M. Quigley
Sylvia J. Arbelbide
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Volume II contains pages 337 through 1,055

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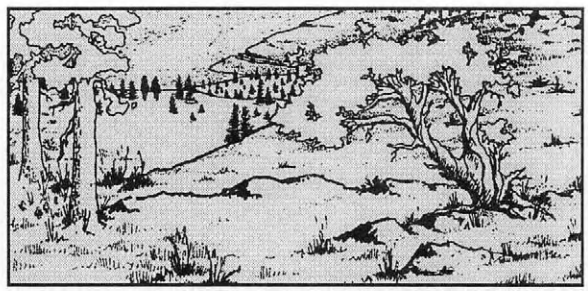
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Abstract

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The *Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins* provides detailed information about current conditions and trends for the biophysical and social systems within the Basin. This information can be used by land managers to develop broad land management goals and priorities and provides the context for decisions specific to smaller geographic areas. The Assessment area covers about 8 percent of the U.S. land area, 24 percent of the Nation's National Forest System lands, 10 percent of the Nation's BLM-administered lands, and contains about 1.2 percent of the Nation's population. This results in a population density that is less than one-sixth of the U.S. average. The area has experienced recent, rapid population growth and generally has a robust, diverse economy. As compared to historic conditions, the terrestrial, aquatic, forest, and rangeland systems have undergone dramatic changes. Forested landscapes are more susceptible to fire, insect, and disease than under historic conditions. Rangelands are highly susceptible to noxious weed invasion. The disturbance regimes that operate on forest and rangeland have changed substantially, with lethal fires dominating many areas where non-lethal fires were the norm historically. Terrestrial habitats that have experienced the greatest decline include the native grassland, native shrubland, and old forest structures. There are areas within the Assessment area that have higher diversity than others. Aquatic systems are now more fragmented and isolated than historically and the introduction of non-native fish species has complicated current status of native fishes. Core habitat and population centers do remain as building blocks for restoration. Social and economic conditions within the Assessment area vary considerably, depending to a great extent on population, diversity of employment opportunities, and changing demographics. Those counties with the higher population densities and greater diversity of employment opportunities are generally more resilient to economic downturns. This Assessment provides a rich information base, including over 170 mapped themes with associated models and databases, from which future decisions can benefit.

Keywords: Columbia basin, biophysical systems, social systems, ecosystem.



VOLUME CONTENTS

VOLUME I

Chapter 1 - Introduction

- **Executive Summary-Biophysical Environments**
- **Executive Summary-Landscape Dynamics**
- **Executive Summary-Broadscale Assessment of Aquatic Species and Habitats**
- **Executive Summary-Terrestrial Ecology**
- **Executive Summary-Economic Assessment**
- **Executive Summary-Social Assessment**
- **Executive Summary-Information System Development and Documentation**

Chapter 2 - Biophysical Environments of the Basin

VOLUME II

Chapter 3 - Landscape Dynamics of the Basin

VOLUME III

Chapter 4 - Broadscale Assessment of Aquatic Species and Habitats

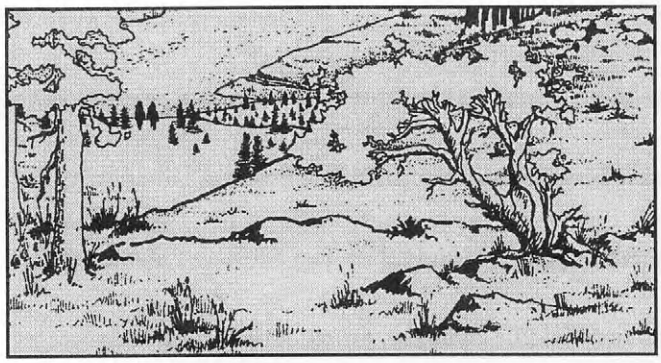
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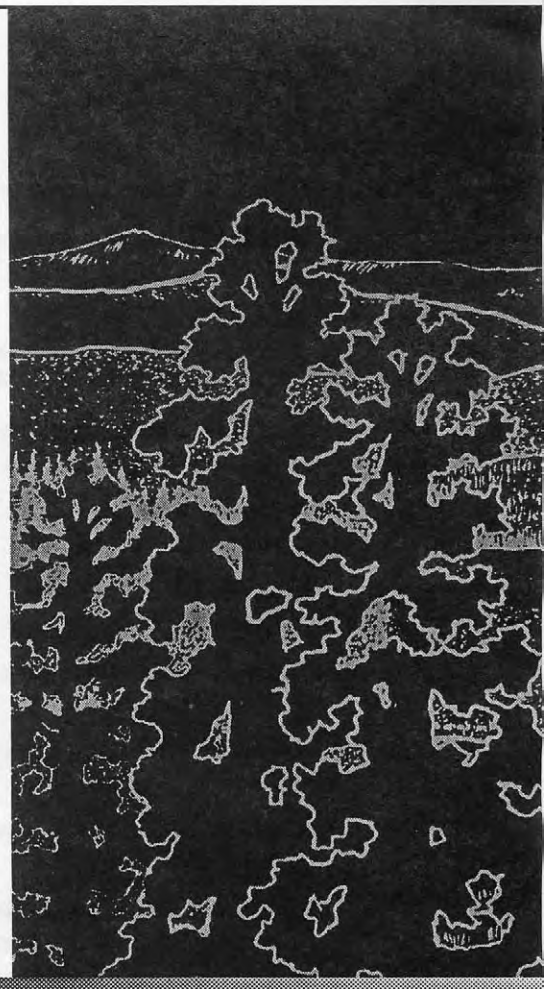
VOLUME IV

Chapter 6 - Economic Assessment of the Basin

Chapter 7 - Social Assessment of the Basin

Chapter 8 - Information System Development and Documentation





CHAPTER 3

Landscape Dynamics of the Basin



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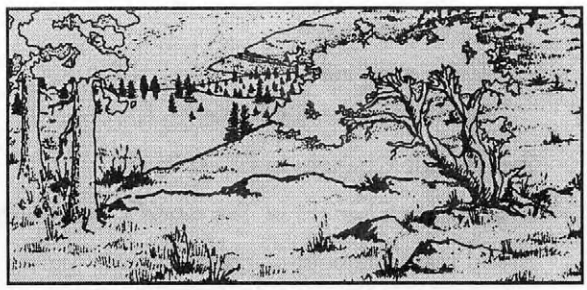
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TABLE OF CONTENTS



Introduction 363

Key Ecosystem Processes and Functions 365

Ecological equilibrium in the native system 368

Human ecological activities 371

Ecological disequilibrium 372

Assessment of Key Ecosystem Processes and Functions 373

Scale 373

Biophysical template 374

Historical range of variability (HRV) 373

Succession and disturbance regimes 376

Landscape patterns 378

Biogeochemical processes 389

Proper Functioning Landscapes 389

Conceptual Models of Natural Resource Management 392

Ecological model 392

Independent model 393

Scenarios of management 394

Overview of Methods 395

Characterization of Multi-scale Landscape Relationships 395

Broad-scale Trends 398

Biophysical Template 399

Succession and Disturbance Processes 401

Biogeochemical Processes 404

Net primary productivity index 405

Carbon stress index 405
Water stress index 406
Nutrient availability index 407
Broad-scale Changes in Cover Types 407
Broad-scale Changes in Terrestrial Community Types 410
Broad-scale Changes of Physiognomic Types 410
Broad-scale Subbasin Vegetation Departures 411
Broad-scale Changes of Vegetation Patterns 411
Physiognomic group patterns 412
Terrestrial community group patterns 413
Forest and Rangeland Integrity 413
Forest Integrity Index 415
Rangeland Integrity Index 418
Regional and Landscape Similarities of Historical and Current Vegetation Conditions, and Succession/Disturbance Regimes 420
General Landscape Patterns 420
Rangeland Ecology and Grazing Management 433
Factors related to rangeland health, and broad-scale vegetation changes on rangelands and riparian areas 433
Susceptibility of rangeland health to management-induced disturbance stresses 437
Modeling Dynamics of HRV and Management Prescriptions 441
Proper Functioning Landscape Systems 445
Overview of Results 449
Biophysical Template 449
General Patterns of Succession and Disturbance Regimes 460
Biogeochemical Processes 465
Relationships to succession/disturbance regimes 468
Biogeochemical assessment limitations 470
Summary 470
Regional Trends of Succession/Disturbance Regimes 471
Trends in Regional and Ecological Reporting Unit System Dynamics 479
The Basin 479
Woodland PVG 480

Dry Forest PVG 481
Moist Forest PVG 488
Cold Forest PVG 492
Dry Grass PVG 496
Dry Shrub PVG 500
Cool Shrub PVG 504
Riparian Shrub PVG 507
Riparian Woodland PVG 508
Alpine PVG 511
Water PVG 511
Rock PVG 511
Agricultural PVG 511
Urban PVG 512
Road PVG 512
Comparison of biogeochemical processes and succession/disturbance regimes 512
Ecological Reporting Units 517
Blue Mountains ERU 517
Central Idaho Mountains ERU 554
Columbia Plateau ERU 568
Lower Clark Fork ERU 581
Northern Cascades ERU 592
Northern Glaciated Mountains ERU 602
Northern Great Basin ERU 610
Owyhee Uplands ERU 620
Snake Headwaters ERU 624
Southern Cascades ERU 635
Upper Clark Fork ERU 643
Upper Klamath ERU 655
Upper Snake ERU 662
Regional relationships of biogeochemical processes and succession/disturbance regimes 667
Regional and Ecological Reporting Unit Cover Type Trends 673
The Basin 673

Blue Mountains ERU 674
Central Idaho Mountains ERU 674
Columbia Plateau ERU 674
Lower Clark Fork ERU 679
Northern Cascades ERU 679
Northern Glaciated Mountains ERU 684
Northern Great Basin ERU 684
Owyhee Uplands ERU 685
Snake Headwaters ERU 685
Southern Cascades ERU 690
Upper Clark Fork ERU 690
Upper Klamath ERU 690
Upper Snake ERU 691
Cover type discussion 691
Regional and Ecological Reporting Unit Terrestrial Community Trends 699
The Basin 699
Blue Mountains ERU 701
Central Idaho Mountains ERU 702
Columbia Plateau ERU 706
Lower Clark Fork ERU 707
Northern Cascades ERU 711
Northern Glaciated Mountains ERU 714
Northern Great Basin ERU 714
Owyhee Uplands ERU 718
Snake Headwaters ERU 720
Southern Cascades ERU 722
Upper Clark Fork ERU 723
Upper Klamath ERU 726
Upper Snake ERU 730
Terrestrial communities discussion 732
Regional and Ecological Reporting Unit Broad-Scale Landscape Trends 735

Regional Broad-Scale Landscape Departure 735
Early-seral Lower Montane Forest 735
Mid-seral Lower Montane Forest 736
Late-seral Lower Montane Forest 739
Early-seral Montane Forest 740
Mid-seral Montane Forest 740
Late-seral Montane Forest 740
Early-seral Subalpine Forest 741
Mid-seral Subalpine Forest 746
Late-seral Subalpine Forest 746
Upland Herbland 749
Upland Shrubland 749
Upland Woodland 753
Terrestrial community group departure discussion 753
Ecological Reporting Unit Broad-Scale Landscape Mosaics 756
Blue Mountains ERU 756
Central Idaho Mountains ERU 756
Columbia Plateau ERU 756
Lower Clark Fork ERU 757
Northern Cascades ERU 757
Northern Glaciated Mountains ERU 757
Northern Great Basin ERU 757
Owyhee Uplands ERU 757
Snake Headwaters ERU 757
Southern Cascades ERU 758
Upper Clark Fork ERU 758
Upper Klamath ERU 759
Upper Snake ERU 759
Summary of Regional Broad-Scale Landscape Trends 759
Broad-scale vegetation patterns discussion 761
Rangeland Ecology and Grazing Management 763
Causal agents in landscape conditions and trends on rangelands and riparian areas 763
Herbivory by large herbivores 763

Livestock grazing in riparian areas 767
Western juniper expansion 773
Exotic plants-noxious weeds 783
Cheatgrass 797
Microbiotic crusts: A rangeland landscape element of concern 801
Ecological roles 802
Response to disturbances 804
Susceptibility of rangeland health to management-induced disturbance stresses 805
Defining rangeland health 805
Soil property indicators 807
Climate indicators 807
Spatial extent of susceptibility 809
Regional Trends in Landscape Dynamics 815
General Landscape Patterns 815
Forest Landscape Patterns 816
Rangeland Landscape Pattern 820
Forest/Rangeland Landscape Pattern 824
Trends of Fine-scale Forest Conditions 824
Forest and Rangeland Integrity 833
Regional and Landscape Similarities of Historical and Current Vegetation Conditions 834
Response of Modeling Scenarios 846
Trends and Ecology of Wildland Fire 855
Air Quality and Effects 873
Biophysical Template and Air Quality 873
Radionuclides 874
Toxic Air Contaminants 874
Particles 874
Effects of Air Pollution on Aquatic and Terrestrial Systems 874
Visibility 876
Wild and Prescribed Fire Smoke 876
Interrelationships with Global Climate Change 876

Effects of Management Scenarios 877
Summary 879
Broad-scale Changes of Biophysical Templates 880
Broad-scale Changes of Succession/Disturbance Regimes 883
Broad-scale Changes of Biogeochemical Relationships 883
Potential Vegetation Groups (PVGs) 884
Woodland PVG 884
Dry Forest PVG 884
Moist Forest PVG 884
Cold Forest PVG 884
Dry Grass PVG 885
Dry Shrub PVG 885
Cool Shrub PVG 885
Riparian Shrub PVG 885
Riparian Woodland PVG 886
Alpine PVG 886
Road PVG 886
Regional and Landscape Conditions of Ecological Reporting Units 886
Blue Mountains ERU 886
Central Idaho Mountains ERU 887
Columbia Plateau ERU 888
Lower Clark Fork ERU 889
Northern Cascades ERU 890
Northern Glaciated Mountains ERU 891
Northern Great Basin ERU 892
Owyhee Uplands ERU 893
Snake Headwaters ERU 894
Southern Cascades ERU 895
Upper Clark Fork ERU 895
Upper Klamath ERU 896
Upper Snake ERU 897
Regional Cover Type Trends 898
Regional Trends of Terrestrial Communities 898
Landscape Trends of Terrestrial Community Groups 899

Early-seral Lower Montane Forest 899
Mid-seral Lower Montane Forest 899
Late-seral Lower Montane Forest 899
Early-seral Montane Forest 899
Mid-seral Montane Forest 899
Late-seral Montane Forest 899
Early-seral Subalpine Forest 899
Mid-seral Subalpine Forest 900
Late-seral Subalpine Forest 900
Upland Herbland 900
Upland Shrubland 900
Upland Woodland 900
Forest and Rangeland Integrity 900
Regional and Landscape Vegetation Patterns 901
Trends and Ecology of Wildland Fire 901
Trends of Mid-scale Conditions 902
Mid-Scale Changes of Physiognomic Types 903
Mid-Scale Cover Types 903
Trends of mid-scale forest and rangeland structural classes 904
Forest vulnerability to insect and pathogen disturbance 905
Potential smoke production and fire behavior 906
Trends in General Landscape Patterns 906
Proper Functioning Landscape Systems 907
Landscape Health 918
Conclusions 919
Acknowledgments 927
References 931
Glossary 961
Appendix 3A 969
Appendix 3B 971
Appendix 3C 976
Appendix 3D 981
Appendix 3E 983

Appendix 3F 987
Appendix 3G 1007
Appendix 3H 1009
Appendix 3I 1027
Appendix 3J 1029
Appendix 3K 1036
Appendix 3L 1038
Appendix 3M 1041
Appendix 3N 1053

LIST OF TABLES

Table 3.1 Comparison of geographic area stratifications of the Basin. 375
Table 3.2 Areal distribution of broad-scale (coarse) landform types on lands administered by the BLM and FS. 388
Table 3.3 Applications of human technology and their effects on ecological systems. 391
Table 3.4 Total percentages by management region, land ownership group, and management class. 396
Table 3.5 Comparison of broad-scale and mid-scale current vegetation and potential vegetation classes. 400
Table 3.6 Succession and disturbance regimes developed for broad-scale assessment. 402
Table 3.7 Cover type and terrestrial community departure classes. 409
Table 3.8 Physiognomic groups used to assess coarse landscape patterns of subwatersheds within the Basin. 412
Table 3.9 Aggregation of 24 terrestrial community types into 12 terrestrial community groups for analysis of broad-scale changes in vegetation patterns. 414
Table 3.10 Landscape metrics used to assess broad-scale vegetation patterns. 415
Table 3.11 Forest integrity of subbasins within the Basin. 419
Table 3.12 Rangeland integrity of subbasins within the Basin. 419
Table 3.13 Exotic plant species found within the Basin that show a widespread county distribution or a somewhat restricted distribution. 435
Table 3.14 Disturbance groups and associated disturbance categories used for analyzing disturbance trends. 443
Table 3.15 Management prescription sets for Historic Range of Variability (HRV) and scenario modeling. 444
Table 3.16 Management prescriptions sorted by conservation, restoration, and production emphasis. 445

Table 3.17	Potential vegetation groups (PVGs) and potential vegetation types (PVTs) in the Basin; relative change in dominant potential vegetation species from the historical to the current period.	456
Table 3.18	Historical and current distribution of broad-scale PVGs by elevation class and ownership class.	458
Table 3.19	Road area estimates by land ownership group in the Basin.	458
Table 3.20	Relationships of landforms, succession/disturbance regimes, and vegetation structures within forest landscape mosaics.	461
Table 3.21	Relationships of landforms, succession/disturbance regimes, and vegetation structures within rangeland (non-forest) landscape mosaics.	463
Table 3.22	Relationships of landforms, succession/disturbance regimes, and vegetation structures within forest/rangeland landscape mosaics.	464
Table 3.23	Change between historical and current period biogeochemical indices, by PVG.	465
Table 3.24	Relationships among biogeochemical processes, succession/ disturbance regimes, and the landscape mosaic.	469
Table 3.25	Basin distribution of succession/disturbance regimes for historical and current periods, and 100-year projection for management scenarios.	472
Table 3.26	Regional distribution of succession/disturbance regimes for historical and current periods, and 100-year projection for management scenarios.	474
Table 3.27	Potential net forest insect and disease by scenario for the Basin.	476
Table 3.28	Percent of forested PVGs within the Basin affected by direct forest disturbance, by decade and by scenario.	477
Table 3.29	Soil disturbance percent change from the current period for the historical period and the scenarios.	478
Table 3.30	Percentage of area of current and historical period physiognomic types in the woodland PVG, by land ownership group.	482
Table 3.31	Similarities of current and historical compositions of succession/ disturbance regimes, fire regimes, and physiognomic types within PVGs.	483
Table 3.32	Percentage of area of current and historical period physiognomic types in the dry forest PVG, by land ownership group.	485
Table 3.33	Percentage of area of current and historical period physiognomic types in the dry forest PVG for shade-intolerance and shade-tolerance, by land ownership group.	486
Table 3.34	Percentage of area of current and historical period physiognomic types in the moist forest PVG for shade-intolerance and shade-tolerance, by land ownership group.	489
Table 3.35	Percentage of area of current and historical period physiognomic types in the moist forest PVG, by land ownership group.	491
Table 3.36	Percentage of area of current and historical period physiognomic types in the cold forest PVG, by land ownership group.	494

Table 3.37	Percentage of area of current and historical period physiognomic types in the cold forest PVG for shade-intolerance and shade-tolerance, by land ownership group.	495
Table 3.38	Selected precipitation data for climate divisions in the Basin, 1895–1994.	498
Table 3.39	Percentage of area of current and historical period physiognomic types in the dry grass PVG, by land ownership group.	499
Table 3.40	Percentage of area of current and historical period physiognomic types in the dry shrub PVG, by land ownership group.	503
Table 3.41	Percentage of area of current and historical period physiognomic types in the cool shrub PVG, by land ownership group.	506
Table 3.42	Percentage of area of current and historical period physiognomic types in the riparian shrub PVG, by land ownership group.	508
Table 3.43	Percentage of area of current and historical period physiognomic types in the riparian woodland PVG, by land ownership group.	510
Table 3.44	Historical trends of relativized biogeochemical characteristics of PVGs and relationships with succession/disturbance regimes.	513
Table 3.45	Current PVGs, by Ecological Reporting Unit (ERU) and land ownership group.	518
Table 3.46	Percent of each ERU, by land ownership category, with high, moderate, and moderate-low susceptibility of rangeland health to management-induced disturbance stresses, as indicated by climate and soil property indicators.	521
Table 3.47	Percent of each ERU, in the context of all land ownerships and percent of BLM/FS land ownerships in each ERU, contained within the categories of high, moderate, low, and non-susceptibility to invasion, for five problematic exotic plants within the Basin.	536
Table 3.48	Historical and current PVGs for the Blue Mountains ERU.	547
Table 3.49	Current and historical physiognomic types for the dry grass PVG for Blue Mountains ERU.	578
Table 3.50	Current and historical physiognomic types for the dry shrub PVG for Blue Mountains ERU.	579
Table 3.51	Current and historical period physiognomic types for the cool shrub PVG for Blue Mountains ERU.	550
Table 3.52	Current and historical period physiognomic types for the dry forest PVG for Blue Mountains ERU.	551
Table 3.53	Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Blue Mountains ERU.	552
Table 3.54	Current and historical period physiognomic types for the moist forest PVG for Blue Mountains ERU.	554
Table 3.55	Current and historical period moist forest PVG Shade Intolerance/ Shade Tolerance for Blue Mountains ERU.	555

Table 3.56	Historical and current period PVGs for the Central Idaho Mountains ERU.	561
Table 3.57	Current and historical period physiognomic types for the dry grass PVG for Central Idaho Mountains ERU.	562
Table 3.58	Current and historical period physiognomic types for the dry shrub PVG for Central Idaho Mountains ERU.	563
Table 3.59	Current and historical period physiognomic types for the cool shrub PVG for Central Idaho Mountains ERU.	564
Table 3.60	Current and historical period physiognomic types for the dry forest PVG for Central Idaho Mountains ERU.	565
Table 3.61	Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Central Idaho Mountains ERU.	566
Table 3.62	Current and historical period physiognomic types for the moist forest PVG for Central Idaho Mountains ERU.	568
Table 3.63	Current and historical period moist forest PVG Shade Intolerance/ Shade Tolerance for Central Idaho Mountains ERU.	569
Table 3.64	Current and historical period physiognomic types for the cold forest PVG for Central Idaho Mountains ERU.	570
Table 3.65	Current and historical period cold forest potential PVG Shade Intolerance/Shade Tolerance for Central Idaho Mountains ERU.	571
Table 3.66	Historical and current period PVGs for the Columbia Plateau ERU.	578
Table 3.67	Current and historical period physiognomic types for the dry grass PVG for Columbia Plateau ERU.	580
Table 3.68	Current and historical period physiognomic types for the dry shrub PVG for Columbia Plateau ERU.	581
Table 3.69	Current and historical period physiognomic types for the cool shrub PVG for Columbia Plateau ERU.	582
Table 3.70	Current and historical period physiognomic types for the dry forest PVG for Columbia Plateau ERU.	583
Table 3.71	Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Columbia Plateau ERU.	584
Table 3.72	Historical and current period PVGs for the Lower Clark Fork ERU.	587
Table 3.73	Current and historical period physiognomic types for the dry forest PVG for Lower Clark Fork ERU.	588
Table 3.74	Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Lower Clark Fork ERU.	589
Table 3.75	Current and historical period physiognomic types for the moist forest PVG for Lower Clark Fork ERU.	590
Table 3.76	Current and historical period moist forest PVG Shade Intolerance/ Shade Tolerance for Lower Clark Fork ERU.	591
Table 3.77	Historical and current period PVGs for the Northern Cascades ERU.	594

Table 3.78 Current and historical period physiognomic types for the dry forest PVG for Northern Cascades ERU. 595
Table 3.79 Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Northern Cascades ERU. 596
Table 3.80 Current and historical period physiognomic types for the moist forest PVG for Northern Cascades ERU. 598
Table 3.81 Current and historical period moist forest PVG Shade Intolerance/ Shade Tolerance for Northern Cascades ERU. 599
Table 3.82 Current and historical period physiognomic types for the cold forest PVG for Northern Cascades ERU. 600
Table 3.83 Current and historical period cold forest PVG Shade Intolerance/ Shade Tolerance for Northern Cascades ERU. 601
Table 3.84 Historical and current period PVGs for the Northern Glaciated Mountains ERU. 604
Table 3.85 Current and historical period physiognomic types for the dry forest PVG for Northern Glaciated Mountains ERU. 606
Table 3.86 Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Northern Glaciated Mountains ERU. 607
Table 3.87 Current and historical period physiognomic types for the moist forest PVG for Northern Glaciated Mountains ERU. 608
Table 3.88 Current and historical period moist forest PVG Shade Intolerance/ Shade Tolerance for Northern Glaciated Mountains ERU. 609
Table 3.89 Historical and current period PVGs for the Northern Great Basin ERU. 617
Table 3.90 Current and historical period physiognomic types for the dry shrub PVG for Northern Great Basin ERU. 618
Table 3.91 Current and historical period physiognomic types for the dry forest PVG for Northern Great Basin ERU. 618
Table 3.92 Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Northern Great Basin ERU. 619
Table 3.93 Historical and current period PVGs for the Owyhee Uplands ERU. 622
Table 3.94 Current and historical period physiognomic types for the dry shrub PVG for Owyhee Uplands ERU. 623
Table 3.95 Current and historical period physiognomic types for the cool shrub PVG for Owyhee Uplands ERU. 625
Table 3.96 Historical and current period PVGs for the Snake Headwaters ERU. 626
Table 3.97 Current and historical period physiognomic types for the dry shrub PVG for Snake Headwaters ERU. 629
Table 3.98 Current and historical period physiognomic types for the riparian woodland PVG for Snake Headwaters ERU. 630

Table 3.99 Current and historical period physiognomic types for the dry forest PVG for Snake Headwaters ERU. 631
Table 3.100 Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Snake Headwaters ERU. 632
Table 3.101 Current and historical period physiognomic types for the cold forest PVG for Snake Headwaters ERU. 633
Table 3.102 Current and historical period cold forest PVG Shade Intolerance/ Shade Tolerance for Snake Headwaters ERU. 634
Table 3.103 Historical and current period PVGs for the Southern Cascades ERU. 637
Table 3.104 Current and historical period physiognomic types for dry forest PVG for Southern Cascades ERU. 639
Table 3.105 Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Southern Cascades ERU. 640
Table 3.106 Current and historical period physiognomic types for the moist forest PVG for Southern Cascades ERU. 641
Table 3.107 Current and historical period moist forest PVG Shade Intolerance/ Shade Tolerance for Southern Cascades ERU. 642
Table 3.108 Current and historical period physiognomic types for the cold forest PVG for Southern Cascades ERU. 644
Table 3.109 Current and historical period cold forest PVG Shade Intolerance/ Shade Tolerance for Southern Cascades ERU. 645
Table 3.110 Historical and current period PVGs for the Upper Clark Fork ERU. 647
Table 3.111 Current and historical period physiognomic types for the dry forest PVG for Upper Clark Fork ERU. 648
Table 3.112 Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Upper Clark Fork ERU. 649
Table 3.113 Current and historical period physiognomic types for the moist forest PVG for Upper Clark Fork ERU. 651
Table 3.114 Current and historical period moist forest PVG Shade Intolerance/ Shade Tolerance for Upper Clark Fork ERU. 652
Table 3.115 Current and historical period physiognomic types for the cold forest PVG for Upper Clark Fork ERU. 653
Table 3.116 Current and historical period cold forest PVG Shade Intolerance/ Shade Tolerance for Upper Clark Fork ERU. 654
Table 3.117 Historical and current period PVGs for the Upper Klamath ERU. 657
Table 3.118 Current and historical period physiognomic types for the dry forest PVG for Upper Klamath ERU. 659
Table 3.119 Current and historical period dry forest PVG Shade Intolerance/ Shade Tolerance for Upper Klamath ERU. 660
Table 3.120 Current and historical period physiognomic types for the moist forest PVG for Upper Klamath ERU. 661

Table 3.121 Current and historical period moist forest PVG Shade Intolerance/ Shade Tolerance for Upper Klamath ERU. 662
Table 3.122 Historical and current period PVGs for the Upper Snake ERU. 665
Table 3.123 Current and historical period physiognomic types for the dry shrub PVG for Upper Snake ERU. 667
Table 3.124 Relative values for biogeochemical characteristics of ERUs and relationships with succession/disturbance regimes. 668
Table 3.125 Summary of broad-scale cover type trends within the Basin. 675
Table 3.126 Summary of broad-scale cover type trends within the Blue Mountains ERU. 676
Table 3.127 Summary of broad-scale cover type trends within the Central Idaho Mountains ERU. 677
Table 3.128 Summary of broad-scale cover type trends within the Columbia Plateau ERU. 678
Table 3.129 Summary of broad-scale cover type trends within the Lower Clark Fork ERU. 682
Table 3.130 Summary of broad-scale cover type trends within the Northern Cascades ERU. 683
Table 3.131 Summary of broad-scale cover type trends within the Northern Glaciated Mountains ERU. 686
Table 3.132 Summary of broad-scale cover type trends within the Northern Great Basin ERU. 687
Table 3.133 Summary of broad-scale cover type trends within the Owyhee Uplands ERU. 688
Table 3.134 Summary of broad-scale cover type trends within the Snake Headwaters ERU. 689
Table 3.135 Summary of broad-scale cover type trends within the Southern Cascades ERU. 692
Table 3.136 Summary of broad-scale cover type trends within the Upper Clark Fork ERU. 693
Table 3.137 Summary of broad-scale cover type trends within the Upper Klamath ERU. 694
Table 3.138 Summary of broad-scale cover type trends within the Upper Snake ERU. 695
Table 3.139 Changes of broad-scale terrestrial communities between historical and current periods within the Basin. 700
Table 3.140 Dominant transitions of terrestrial communities within the Basin. 701
Table 3.141 Changes of broad-scale terrestrial communities between historical and current periods within the Blue Mountains ERU. 703
Table 3.142 Dominant transitions of terrestrial communities within the Blue Mountains ERU. 704

Table 3.143 Changes of broad-scale terrestrial communities between historical and current periods within the Central Idaho Mountains ERU. 705
Table 3.144 Dominant transitions of terrestrial communities within the Central Idaho Mountains ERU. 707
Table 3.145 Changes of broad-scale terrestrial communities between historical and current periods within the Columbia Plateau ERU. 708
Table 3.146 Dominant transitions of terrestrial communities within the Columbia Plateau ERU. 709
Table 3.147 Changes of broad-scale terrestrial communities between historical and current periods within the Lower Clark Fork ERU. 710
Table 3.148 Dominant transitions of terrestrial communities within the Lower Clark Fork ERU. 711
Table 3.149 Changes of broad-scale terrestrial communities between historical and current periods within the Northern Cascades ERU. 712
Table 3.150 Dominant transitions of terrestrial communities within the Northern Cascades ERU. 713
Table 3.151 Changes of broad-scale terrestrial communities between historical and current periods within the Northern Glaciated Mountains ERU. 715
Table 3.152 Dominant transitions of terrestrial communities within the Northern Glaciated Mountains ERU. 716
Table 3.153 Changes of broad-scale terrestrial communities between historical and current periods within the Northern Great Basin ERU. 717
Table 3.154 Dominant transitions of terrestrial communities within the Northern Great Basin ERU. 718
Table 3.155 Changes of broad-scale terrestrial communities between historical and current periods within the Owyhee Uplands ERU. 719
Table 3.156 Dominant transitions of terrestrial communities within the Owyhee Uplands ERU. 720
Table 3.157 Changes of broad-scale terrestrial communities between historical and current periods within the Snake Headwaters ERU. 721
Table 3.158 Dominant transitions of terrestrial communities within the Snake Headwaters ERU. 723
Table 3.159 Changes of broad-scale terrestrial communities between historical and current periods within the Southern Cascades ERU. 724
Table 3.160 Dominant transitions of terrestrial communities within the Southern Cascades ERU. 725
Table 3.161 Changes of broad-scale terrestrial communities between historical and current periods within the Upper Clark Fork ERU. 727
Table 3.162 Dominant transitions of terrestrial communities within the Upper Clark Fork ERU. 728
Table 3.163 Changes of broad-scale terrestrial communities between historical and current periods within the Upper Klamath ERU. 729

Table 3.164 Dominant transitions of terrestrial communities within the Upper Klamath ERU. 730
Table 3.165 Changes of broad-scale terrestrial communities between historical and current periods within the Upper Snake ERU. 731
Table 3.166 Dominant transitions of terrestrial communities within the Upper Snake ERU. 732
Table 3.167 Summary of subbasin frequency distribution by current terrestrial community group departures. 736
Table 3.168 Fragmentation indices of terrestrial community groups occurring within subbasins at a level within their median historical ranges; summation of Departure Class 3. 739
Table 3.169 Fragmentation indices of terrestrial community groups occurring within subbasins at a level within or above their median historical ranges; summation of Departure Classes 3, 4, and 5. 741
Table 3.170 Summary of broad-scale physiognomic group pattern changes within ERUs. 758
Table 3.171 Broad-Scale trends of regional vegetation patterns within the Landscape Characterization Area. 760
Table 3.172 Historical and current landscape metrics of regional vegetation patterns within the Landscape Characterization Area. 761
Table 3.173 Generalized relationships between grazing strategy, stream system characteristics, and riparian area variables (shrubs, herbs, and banks). 774
Table 3.174 Index of cover type susceptibility to invasion by 25 exotic plant species. 788
Table 3.175 Areal extent of landscape (subbasin level) pattern types, by land ownership group. 816
Table 3.176 Subbasin (4th field hydrologic unit codes) landscape patterns and their respective landscape classes on BLM/FS-administered lands. 817
Table 3.177 Comparative analysis for density of live trees for all size classes, density for size classes ≥ pole-size trees, basal area, snag density, fuel loading, and litter/duff depth, by two management regimes and by two disturbance types. 825
Table 3.178 Dominant characteristics of seral stages, by PVG and management history/class. 830
Table 3.179 Forest departure and integrity indices. 835
Table 3.180 Rangeland departure and integrity indices. 839
Table 3.181 Regional and subbasin landscape similarity to native, other, traditional reserve, and traditional commodity patterns, for all land ownerships. 842
Table 3.182 Regional and subbasin landscape similarity to native, other, traditional reserve, and traditional commodity landscape patterns, for BLM/FS land ownerships. 842
Table 3.183 Regional and subbasin landscape similarity to native, other, traditional reserve, and traditional commodity landscape patterns, for BLM/FS land ownerships by management region. 842

Table 3.184 Subbasin landscape similarity to native, other, traditional reserve, and traditional commodity landscape patterns, for BLM/FS land ownerships by type of landscape mosaic. 843
Table 3.185 Subbasin landscape similarity to native, other, traditional reserve, and traditional commodity landscape patterns, for BLM/FS land ownerships by subbasin group. 844
Table 3.186 Regional similarity of the average historical composition of physiognomic type groups and the current; and average future composition by management scenario. 845
Table 3.187 General decade levels of wildlife on BLM/FS-administered lands in the Basin. 845
Table 3.188 Fire regime severity and frequency classes within the Basin. 857
Table 3.189 Fire regime severity and frequency classes by management region for BLM/FS-administered lands within the Basin. 858
Table 3.190 Fire regime severity and frequency classes by subbasin group for BLM/FS-administered lands within the Basin. 859
Table 3.191 Current fire occurrence risks for the Basin, by land ownership group. 862
Table 3.192 Current fire occurrence risks in the Basin, by management region and land ownership group. 863
Table 3.193 Current fire occurrence risks in the Basin, by subbasin group and land ownership group. 864
Table 3.194 Historical and projected future (100-year) trends of potential forest crown fires in the Basin. 867
Table 3.195 Biophysical characteristics that influence wildfire behavior and effect risk, by ERU. 869
Table 3.196 Historical and projected future (100-year) trends of potential net wildfire in the Basin. 870
Table 3.197 Current and projected future net fire cost within the Basin. 870
Table 3.198 Historical and projected future (100-year) trends of potential net smoke within the Basin. 871
Table 3.199 Historical and projected future (100-year) trends of potential net wildfire within rangeland PVGs. 871
Table 3.200 Historical and projected future (100-year) trends of potential net wildfire on forest PVGs. 872
Table 3.201 Historical and projected future (100-year) trends of potential net surface and mixed wildfire. 872
Table 3.202 Fire regime severity and frequency classes within the Basin. 902
Table 3.203 Basin ranking of management scenarios for ability to achieve proper functioning landscape systems (PFS). 910
Table 3.204 Trends in response to management scenarios for landscape patterns for BLM/FS-admnistered lands in the Basin. 911

Table 3.205 Succession/disturbance regime percent similarity to historical for the Basin land ownership groups, by PVG. 912
Table 3.206 Succession/disturbance regimes percent similarity to historical for management region, by PVG. 913

LIST OF FIGURES

Figure 3.1 Pre-historical (native or HRV) relationships of key processes at different scales. 366
Figure 3.2 Pre-historical (native or HRV) ecological equilibrium in relation to biophysical conditions, key processes, and disturbance. 369
Figure 3.3 Relative changes in temperature, woody fuels, herbland, sediment, and water flow over time. 370
Figure 3.4 Effects of current period in relation to disequilibrium of key ecological systems. 372
Figure 3.5 Current period relationships of key ecological systems at different scales. 373
Figure 3.6 Relationship of succession/disturbance regimes to the biophysical template, and the effects of alteration in the biophysical template. 387
Figure 3.7 Proper functioning landscapes and re-establishment of equilibrium processes. 390
Figure 3.8 Contextual opportunity and risk management with a hierarchical landscape framework. 392
Figure 3.9 Independent element management without a hierarchical landscape framework. 393
Figure 3.10 Relationship between current areal extent of cover types and terrestrial community types, and their respective median historical ranges. 409
Figure 3.11 Relationship of forest landscape patterns, management regime, landform, vegetation structure, and succession/disturbance regime in areas dominated by forest potential vegetation groups (PVGs). 421
Figure 3.12 Relationship of rangeland landscape patterns, management regime, landform, vegetation structure, and succession/disturbance regime in areas dominated by rangeland PVGs. 424
Figure 3.13 Relationship of forest-rangeland landscape patterns, management regime, landform, vegetation structure, and succession/disturbance regime in areas dominated by forest and rangeland PVGs. 427
Figure 3.14 Average number of exotic plant species to which PVGs in the Basin are of high susceptibility to invasion. 459
Figure 3.15 Climax model for vegetation succession. 765
Figure 3.16 State-and-Transition Model for sagebrush grass ecosystem. 766
Figure 3.17 Theoretical conceptualization of rangeland health and its association with biophysical and management-induced stresses. 807

Figure 3.18 Response of scenarios for disturbance area within wilderness-like lands in the cold forest PVG of the Rocky Mountains generalized subbasin group. 847
Figure 3.19 Response of scenarios for physiognomic types within wilderness-like lands in the cold forest PVG of the Rocky Mountains generalized subbasin group. 847
Figure 3.20 Response of scenarios for disturbance area within wilderness-like lands in the moist forest PVG of the Rocky Mountains generalized subbasin group. 848
Figure 3.21 Response of scenarios for physiognomic types within wilderness-like lands in the moist forest PVG of the Rocky Mountains generalized subbasin group. 848
Figure 3.22 Response of scenarios for disturbance area within wilderness-like lands in the dry shrub PVG of the Intermountain generalized subbasin group. 850
Figure 3.23 Response of scenarios for physiognomic types within wilderness-like lands in the dry shrub PVG of the Intermountain generalized subbasin group. 850
Figure 3.24 Response of scenarios for disturbance area within non-wilderness lands in the dry forest PVG of the Cascade Mountains generalized subbasin group. 851
Figure 3.25 Response of scenarios for physiognomic types within non-wilderness lands in the dry forest PVG of the Cascade Mountains generalized subbasin group. 851
Figure 3.26 Response of scenarios for disturbance area within non-wilderness lands in the moist forest PVG of the Rocky Mountains generalized subbasin group. 853
Figure 3.27 Response of scenarios for physiognomic types within non-wilderness lands in the moist forest PVG of the Rocky Mountains generalized subbasin group. 853
Figure 3.28 Response of scenarios for disturbance area within non-wilderness lands in the dry shrub PVG of the Intermountain generalized subbasin group. 854
Figure 3.29 Response of scenarios for physiognomic types within non-wilderness lands in the dry shrub PVG of the Intermountain generalized subbasin group. 854
Figure 3.30 A comparison of historical (circa 1800–1900) and current (circa 1990) selected landscape elements. 881

LIST OF MAPS

Map 3.1	Landscape characterization area for the Basin with ecoregion sections.	376
Map 3.2	Assessment area of the Interior Columbia Basin and portions of the Klamath and Great Basins (the Basin), Forest Service- and BLM-administered lands.	377
Map 3.3	Ecological Reporting Units (ERUs) of the Basin.	378
Map 3.4	Landscape subbasin groups of the Basin.	379
Map 3.5	Subwatersheds (6th field hydrologic unit codes) of the Basin.	380
Map 3.6	Subbasins (4th field hydrologic unit codes) of the Basin.	381
Map 3.7	Management classes for the Basin.	397
Map 3.8	Forest integrity ratings of subbasins.	416
Map 3.9	Rangeland integrity ratings of subbasins.	417
Map 3.10	Broadscale landforms of the Basin.	430
Map 3.11	Historical period (circa 1850-1900) potential vegetation groups (PVGs).	440
Map 3.12	Current period PVGs.	451
Map 3.13	Historical period dominant physiognomic types.	452
Map 3.14	Current period dominant physiognomic types.	453
Map 3.15	Terrestrial communities during the early historical period.	454
Map 3.16	Terrestrial communities during the current period.	455
Map 3.17	Topographic map of the Basin.	520
Map 3.18	Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to wind.	526
Map 3.19	Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with potential for soil to shrink or swell from drying or wetting, and soil erodibility to wind.	527
Map 3.20	Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with potential for soil to shrink or swell from drying or wetting.	528
Map 3.21	Headwater and downstream general landforms.	529
Map 3.22	Changes in fire regime severity class from the historical to the current period.	532
Map 3.23	Changes in fire regime frequency class from the historical to the current period.	533
Map 3.24	Annual average precipitation in the Basin, showing areas (typically rangelands) that receive various increments of precipitation less than 12 inches (<305 mm) and areas that receive greater than 12 inches (>305 mm).	534

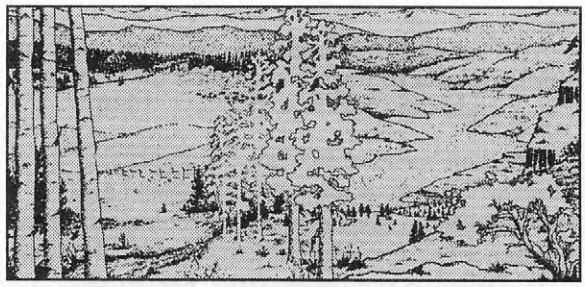
Map 3.25 The extent of grazing allotments on most public (BLM/FS, State, and other Federal lands) lands in the Basin. 535
Map 3.26 Susceptibility status of the Basin to invasion by cheatgrass, an exotic annual grass. 539
Map 3.27 Susceptibility status of the Basin to invasion by yellow starthistle, an exotic annual forb. 540
Map 3.28 Current road density classes summarized by subwatershed. 541
Map 3.29 Potentially degraded watersheds in the Basin. 542
Map 3.30 Land ownership patterns within the Basin, by subwatershed. 543
Map 3.31 Wildfire occurrence/intensity risk on BLM- and Forest Service-administered lands. 544
Map 3.32 High potential fuels, crown fire, and insect and disease mortalities, dry forest PVG. 545
Map 3.33 Rural population/wildland interface fire risk areas on Forest Service- and BLM-administered lands. 546
Map 3.34 Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil salinity and soil erodibility to wind. 557
Map 3.35 Susceptibility status of the Basin to invasion by spotted knapweed, an exotic biennial-perennial forb. 558
Map 3.36 Susceptibility status of the Basin to invasion by leafy spurge, an exotic perennial forb. 559
Map 3.37 Susceptibility status of the Basin to invasion by diffuse knapweed, an exotic annual or occasional perennial forb. 574
Map 3.38 Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to water and wind. 575
Map 3.39 Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to water. 576
Map 3.40 Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to water and wind, and salinity. 577
Map 3.41 Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to water, and salinity. 612
Map 3.42 Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil salinity. 613
Map 3.43 Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil salinity and potential for soil to shrink or swell from drying or wetting. 614

Map 3.44 Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil salinity and soil sodicity. 666
Map 3.45 Historical distribution of western juniper in the Basin. 680
Map 3.46 Current distribution of western juniper in the Basin. 681
Map 3.47 Broadscale habitat departure of the early-seral lower montane forest terrestrial community group. 737
Map 3.48 Broadscale habitat departure of the mid-seral lower montane forest terrestrial community group. 738
Map 3.49 Broadscale habitat departure of the late-seral lower montane forest terrestrial community group. 742
Map 3.50 Broadscale habitat departure of the early-seral montane forest terrestrial community group. 743
Map 3.51 Broadscale habitat departure of the mid-seral montane forest terrestrial community group. 744
Map 3.52 Broadscale habitat departure of the late-seral montane forest terrestrial community group. 745
Map 3.53 Broadscale habitat departure of the early-seral subalpine forest terrestrial community group. 747
Map 3.54 Broadscale habitat departure of the mid-seral subalpine forest terrestrial community group. 748
Map 3.55 Broadscale habitat departure of the late-seral subalpine forest terrestrial community group. 750
Map 3.56 Broadscale habitat departure of the upland herbland terrestrial community group. 751
Map 3.57 Broadscale habitat departure of the upland shrubland terrestrial community group. 752
Map 3.58 Broadscale habitat departure of the upland woodland terrestrial community group. 754
Map 3.59 Potential vegetation types (PVTs) that have the greatest potential for microbiotic crust development expected within the Basin. 803
Map 3.60 Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil salinity and sodicity, potential for soil to shrink or swell from drying or wetting, and soil erodibility to wind. 812
Map 3.61 Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to water and wind, and potential for soil to shrink or swell from drying or wetting. 813

Continue

Previous

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INTRODUCTION

Landscape ecology was defined by Forman and Godron (1986) as the study of the structure, function, and change in a heterogeneous land area comprising interacting ecosystems. In North America, the science of landscape ecology has developed rapidly since the 1970s. The recent proliferation of landscape ecology literature and its associated application in resource management and land-use planning has been fueled in part by the complexity of multi-scale issues related to achieving public objectives for sustaining resource production and the biological diversity (or biodiversity) of native[1] systems. These issues have required the rapid implementation of relatively new and non-traditional ecosystem management principles, assessment techniques, and management prescriptions at landscape levels, in both public and private natural resource management (Bourgeron and others 1994, Box 1995, Everett and others 1994a, Haynes and others 1996, Jaindl and others 1996, Jensen and Everett 1994, Kennedy and Quigley 1994, National Research Council 1994, Quigley and others 1996).

A pervasive polarization of society has developed concerning land management that allows resource production while conserving biodiversity. Many of these polarized views are not supported by scientific foundation, but reside in the beliefs and values of people. Traditional commodity practices that mitigate for ecological concerns have generally not sustained either native biodiversity or the productive capacity of commodities. Consequently, many people who place a high value on the sustainability of biodiversity believe that relatively large proportions of wildlands should be managed as reserves, in which the influences of human activities are minimized. These differing viewpoints reflect natural resource management techniques that developed in North America, although they were based on European land-management philosophies.

Traditional commodity, reserve, and multiple-use management originated in Europe at a time when much of the landscape had already been substantially altered and was generally dominated by species that had adapted to human disturbances. Consequently, when these concepts were applied to North America, which had a very different environment and complex of species, there were concurrent deleterious effects on land capability and native biodiversity. An historical account of how the philosophies of resource development affected forest, rangeland, and fire in North America was thoroughly discussed by Langston (1995), Manning (1995), and Pyne (1995). The implications and forecast of the potential outcomes of this European-based approach to land

[1] As defined in this chapter, native means plants or animals that are indigenous to a given place; growing, living, or produced originally in a given place. More specifically, when native is used to describe a system or regime, we are specifically referring to the "pre-Euro-American settlement" system which is synonymous with the historical range of variability (HRV) regime. Our historical data refers to information recorded during the early decades of Euro-American settlement of the Basin (circa 1850s).

management, as well as the argument for an ecological management alternative, were discussed in a philosophical context in the 1860s by Marsh (1907) and in the 1940s by Leopold (1949).

Information has increased concerning emerging problems relative to forest and rangeland health and the need for consideration of ecological structure, function, and process (Covington and others 1994, DellaSala and others 1995, Everett and others 1994b, Jaindl and Quigley 1996, Kolb and others 1994, Mutch and others 1993, National Research Council 1994, Sampson and Adams 1994). Many articles are available concerning the assessment and analysis of ecological conditions (Diaz and Apostol 1992, Hessburg 1993, Jensen and Bourgeron 1994, Morelan and others 1994, Shlisky 1994, U.S. Department of Agriculture 1992).

In the western United States, the application of traditional land-management philosophy appears to have been detrimental to long-term sustainability as evidenced by the reduction of native biodiversity, accelerated rates of soil erosion, and an increasing trend in area burned by wildfire (Ehrlich 1988, Harvey and others 1994a, Johnson and others 1994, Megahan 1991, Raup 1988, Wilson 1988). In general, prior to human-caused disturbances, major changes in native biodiversity were a result of substantial shifts in climate or geology. However, human influences have substantially affected ecological processes and biodiversity, and they will likely continue to do so in the future.

Agee (1993) displayed the areal extent of wildfires in Pacific Northwest forests from 1916 through 1992. He concluded that the recent increasing trend of forests disturbed by wildfires was correlated to the advancement of fire suppression technology and fuel accumulations. For example, in the early 1900s, fire intervals were generally synchronized with fuel accumulations. With the advent of improved technology for fire detection, prevention, and suppression in the 1930s, the areal extent of wildfires generally declined through the 1960s. However, with steadily increasing fuel accumulations, number of ignitions, and fire size and intensity, wildfires have overcome the human energy available for fire suppression. The area burned by wildfires steadily increased between the 1970s and 1990s, and at present, is approaching or exceeding levels experienced in the early 1900s, when fire suppression resources were relatively low.

The effects of excessive livestock grazing pressure were evident on rangelands as early as the 1890s (Griffiths 1902). Forage consumption by livestock had altered fire regimes. Livestock had also impacted hydrologic systems by increasing soil erosion, increasing sediment delivery to streams, and affecting the function of riparian communities.

This chapter addresses the following questions concerning the ecological state of landscapes within the Basin:[2]

- What are the status and trends of landscape processes and functions within the Basin? What are the causal agents responsible for the detected trends?
- How will current and future landscape disturbance regimes affect landscape patterns and biophysical potentials? What are the probable trends of disturbance regimes in response to various landscape management futures?
- What are the historical[3] and probable future trends of landscape elements important to commodity and amenity resource flows under various landscape management strategies?
- What are the probable trends of biophysical functions and processes for various landscape

[2] The Basin is defined as those portions of the Columbia River basin inside the United States east of the crest of the Cascades and those portions of the Klamath River basin and the Great Basin in Oregon.

[3] As defined in this chapter, historical refers to the "post-Euro-American settlement" time period; early historical refers specifically to the 1800s, while recent historical refers to the 1900s. This is not synonymous with historical range of variability (HRV) which refers to the "pre-Euro-American settlement" or "native" regime (see footnote 1).

management futures? What will be the opportunities, tradeoffs, and consequences of various landscape management futures for long-term productivity, nutrient and carbon cycling, and biogeochemical processes?

The objective of the landscape assessment is to display an understanding of the spatial and temporal dynamics of landscape patterns, and their relation to social, economic, terrestrial, and aquatic systems. In order to assess biodiversity, ecological integrity was evaluated. That is, we assessed the ability of landscapes to renew themselves while taking into account their paleoecological, historical, current, and future biophysical potentials. This assessment of the Basin was based on the principles and methods outlined by Allen and Hoekstra (1992), Forman (1995), Forman and Godron (1986), King (1990), and Turner and Gardner (1990). Many of the methods published by Hessburg (1993), Jensen and Bourgeron (1994), Keane (1987), and Keane and others (1989, 1990a, 1990b, 1990c) were also incorporated. In addition, many methods were created through an iterative process as the assessment was conducted (see Keane and others 1996a).

Key Ecosystem Processes and Functions

Key ecosystem processes are those that control or limit the potentials for biotic productivity, resilience to disturbance, and biological diversity. These processes are studied by ecosystem ecologists in the guise of the circulation, transformation, and accumulation of energy and matter through the biotic and abiotic systems (Cockburn 1991, Ulanowicz 1992, Waring and Schlesinger 1985). Flows in matter such as carbon and nutrients, organisms, populations, communities, and ecosystems are driven by the input of solar energy. All ecosystem processes are spatially and temporally dynamic, equating to the flows of energy, matter, genetic information, communities, and populations. The key processes developed through geologic and evolutionary time at relatively specific landscape scales (fig. 3.1).

The key processes that we focused our attention on included (1) energy flows, (2) the hydrologic cycle, (3) the carbon and nutrient cycles, (4) ecosystem food webs, and (5) evolution (Allen and Hoekstra 1992, Barbour and others 1980, Brown and Gibson 1983, Cockburn 1991, Ehrlich 1986, Forman and Godron 1986, Jenny 1980, Kimmins 1987, Naveh and Lieberman 1994, Running 1990, Thornbury 1969, Trewartha and Horn 1980, Waring and Schlesinger 1985). The evolutionary status of organisms constrains the development of biophysical conditions (Cockburn 1991, Jenny 1980, Ulanowicz 1992). In turn, biophysical conditions constrain evolutionary processes. Consequently, key ecological processes and functions are tightly woven and interdependent, and their changes accrue slowly but predictably. In contrast, when humans disrupt the interrelationships, change may occur rapidly or in opposition to ecological cause-and-effect relationships. In response, the systems become largely unpredictable.

The following discussion provides a description of these key processes as they developed through geologic and evolutionary time without substantial influence from humans, that is, without human intervention which alters ecological cause and effect, or changes the scales of effects. Understanding the development of the key processes in this manner provides the context necessary for understanding the mechanisms responsible for observed or predicted relationships between the biological and physical components of landscapes.

Although energy flows operate at virtually every scale, they are best quantified at the global scale. Energy inputs are driven by the relationship between solar radiation and the biosphere, and then distributed across continents and oceans (fig. 3.1). All ecological processes are driven by energy flows. For example, the distribution of energy is reflected in climatic variables including precipitation, temperature, and wind. These variables in turn regulate the hydrologic and carbon-nutrient cycles, which subsequently affect ecosystem food webs. Food webs are spatially and temporally explicit networks of producers, consumers, and

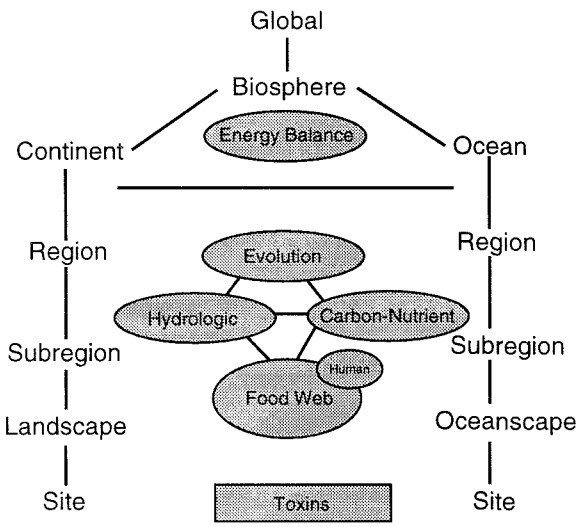


Figure 3.1—Pre-historical (native or HRV) relationships of key processes at different scales.

decomposers linked by trophic interactions and disturbance processes (Allen and Hoekstra 1992; Ulanowicz 1992). Fire, a secondary energy process, is strongly correlated with the carbon-nutrient cycles and the hydrologic cycle. Fire frequency, extent, and severity are controlled to a large degree by the availability of carbon, as well as the moisture regime. Energy flows are also influenced by geologic (volcanics, plate tectonics, and meteor impacts), geomorphologic (landform development), climatic (global temperature change), and anthropogenic processes (combustion of fossil fuels).

Although the hydrologic cycle operates within the entire global system, the variability of hydrologic systems can be effectively stratified at the subregional scale (fig. 3.1). The hydrologic cycle involves the movement of water and its associated energy, nutrients, and other matter through the biosphere, hydrosphere (ocean circulation), and cryosphere (snow and ice cover). In simplistic terms, water evaporates from aquatic environments (predominantly the oceans), precipitates onto terrestrial environments, enters fluvial systems through surface and subsurface flows, then returns to the oceans via stream discharge. Again, solar radiation drives the hydrologic cycle. The hydrologic cycle functions as a direct linkage between terrestrial and aquatic systems. On land this involves a cycle of precipitation, transpiration from floral communities, evaporation, and water flow over or through the soil to rivers and streams. In oceans this involves a cycle of precipitation, water flow from rivers and streams, and evaporation. Rivers and streams provide direct connections from the land to the ocean. River and stream flows are generally limited by precipitation and transpiration. Erosion and material transport are controlled by climate, weather, vegetation cover, topography, parent material, soil structure, and disturbance events.

Riparian systems (that is, areas adjacent to water) strongly affect the cycle of water by ameliorating water temperature and providing storage. These systems fill with water during spring snowmelt and from spring, summer, or fall rain storms, thus influencing runoff and flood events. Water stored in riparian soils is slowly released into streams and lakes during the summer drought season, thus supplementing stream flow, photosynthesis, and transpiration throughout the summer and fall. Groundwater from upland sites can also supplement flows into springs and streams during droughts.

Carbon and nutrients also cycle through the biosphere, but because these cycles are closely associated with the hydrologic cycle, their variability can also be effectively stratified at subregional scales (fig. 3.1). Dominant processes of the carbon-nutrient cycles include photosynthesis and nutrient uptake by producers, respiration by consumers, and decomposition by decomposers. Fire is also an important process that hastens the release of carbon and nutrients from plants into the soil and atmosphere. Photosynthesis, the process in which carbon is fixed from carbon dioxide in the atmosphere, is controlled by solar radiation, temperature, precipitation, and evolutionary adaptations of green plants. Productivity of the biotic communities is directly influenced by

carbon-nutrient cycles. In turn, the recovery from or resilience of communities to disturbance is largely a result of site productivity, as well as evolutionary adaptations of the biotic community to disturbance processes and patterns. Decomposition rates are controlled by temperature and precipitation; rates are faster in warm and moist environments than in cold and dry environments.

Fire and herbivory disturbance processes are indirectly linked to the carbon-nutrient cycle. More productive environments have more biomass available as fuel for fires and as food for herbivores. Nutritious foods are also commonly more available on productive sites. In addition, in that nutritious plants also tend to be palatable, they commonly attract the attention of herbivores. Evolutionary processes promote plants that conserve nutrients in nutrient-limited systems.

In simplistic terms, ecosystem food webs indicate the relationships among food production, consumption, and decomposition (Allen and Hoekstra 1992), and demonstrate the relationship between species and ecosystems. Although ultimately controlled by energy flows, food webs are more directly influenced by climate, and the hydrologic and carbon-nutrient cycles. Ecosystem food webs developed as a result of co-evolution processes among the biota of an explicit and relatively small geographic area. The variability among ecosystem food webs is effectively stratified at the subregional scale (fig. 3.1). Humans evolved within these food webs, their associated energy flows, and ecosystem cycles (Fagan 1989). Predator-prey relationships (including plant-herbivore associations) developed as a result of evolutionary processes that selected against genotypes and phenotypes that were less fit for particular environmental conditions (including disturbance processes). The responses of predator-prey relationships are highly variable because of prey response to disturbance, environment, disease, and predation, and predator response to the prey base, disturbance, and environment.

In its broadest context, evolutionary processes involve the origin and maintenance of biological diversity, both within lineages (that is, adaptation by natural selection and genetic drift), and among lineages (that is, speciation, extinction, and biogeographic colonization)(Cockburn 1991; Ulanowicz 1992). Thus, evolution involves the cumulative change in the characteristics and genetic information of organisms, populations, and species. Because evolutionary dynamics are constrained by ecosystem processes, evolutionary processes are highly correlated with the biophysical environment, including disturbance regimes and competitive strategies at the regional and subregional scales (fig. 3.1). The loss of genetic information and extinction of species usually occurs as a result of climatic changes or altered disturbance regimes and their collective effects on suitable habitats, or by a change in competition within or between species. The primeval extinction of species typically occurred as a result of infrequent, catastrophic volcanic and solar events, or due to the cumulative change in bioedaphic and climatic conditions that occurred at a rate faster than a species could adapt.

Adaptation is a process of evolutionary modification over long time periods that results in improved survival and reproductive efficiency. These adaptations occur across the full range of specialist and generalist species that are best suited to an environment and its disturbance regimes. Populations and species are typically capable of migrating within a particular set of life zones at a regional scale, in response to weather fluctuations, changing climate, loss of habitat, and catastrophic geomorphologic events.

Landscapes develop and change through geologic and evolutionary time. The climate changes largely as a result of solar cycles and conditions of the biosphere, particularly the hydrosphere (ocean circulation) and cryosphere (snow and ice cover). Biosphere conditions can either (1) increase global absorption of solar energy due to an increase of atmospheric carbon dioxide, or (2) increase global albedo (reflectivity) due to deforestation, agricultural development, and/or excessive grazing

(Kimmins 1987, Waring and Schlesinger 1985). Hydrologic systems may change as a result of climatic, geomorphologic, biotic, and edaphic processes. Landforms change over time in response to geomorphologic processes that are controlled by the hydrologic system, climate, and geologic conditions. Soils change over time in response to fluctuations of climatic, geomorphologic, hydrologic, and biotic processes. Biotic communities, and subsequently ecosystem food webs can change as a result of any, or all, of the above-mentioned changes. Landscapes and regions change over time in response to the combined and interacting fluctuations of energy flows, biotic communities, and climatic, geomorphologic, and hydrologic processes.

Classifying ecological systems in ways that integrate the key ecosystem processes could facilitate an understanding of the mechanisms behind dynamic landscapes. For example, with respect to biotic communities, a classification involving potential vegetation types or indicator species could express aquatic, riparian, or terrestrial upland capabilities. In addition, a landform or soil classification system that is correlated with potential vegetation types, and a hydrologic classification system that is correlated with potential aquatic communities could help to integrate the primary ecosystem processes and predict responses to varying disturbance regimes.

Ecological Equilibrium in the Native System

In the native system, the key ecosystem processes discussed in the foregoing section were in dynamic equilibrium. We do not consider conditions of ecological equilibrium to be static or stable, but rather to maintain similar relationships between inputs and outputs of biotic and abiotic energy and materials. These relationships conserved energy and generally maintained carbon, nutrients, water, and subsequently foods (for producers, consumers, and decomposers) within their ecological scales of spatial and temporal change. Furthermore, genetic information, and consequently, biological diversity were also conserved.

A system in ecological equilibrium has cyclic successional patterns or multiple stable states, and associated responses to disturbance (Allen and Hoekstra 1992, Naveh and Lieberman 1994, Rosgen 1996, Tausch and others 1993). As shown in figure 3.2, native system equilibrium is analogous to a balance or scale in which the fulcrum is representative of biotic potential (terrestrial and aquatic), and the platform corresponds to geologic parent material; the parent material, in turn, is shaped by geomorphologic processes, which are overlain by soil formed through pedogenic processes. The sphere surrounding our hypothetical scale in figure 3.2 is affected by climatic processes. The carbon-nutrient and hydrologic cycles are generally in balance, due in part to mediation from the biotic community (Cockburn 1991; Ulanowicz 1992). Disturbances caused by climatic, geomorphologic, biotic, and fire processes may shift the balance point, but the response would be largely predictable. For example, if soils developed a deeper profile, their water-holding capacity would likely increase. The productivity of vegetation may subsequently increase, thereby increasing transpiration rates and decreasing soil moisture. Furthermore, using this example, fire-return intervals would probably increase, as would fire severity.

The relationships between the carbon-nutrient and hydrologic cycles and the responses to disturbance, determine the composition and structure of terrestrial and aquatic communities at any given time. In other words, states of terrestrial and aquatic communities occur as a shifting mosaic across space and through time, due to the disturbance responses and subsequent changes in their biotic and abiotic environments. Secondary disturbances (such as drought, wind, fire, floods, predation, and herbivory) cause shifts in the balance point, but again, the responses are largely predictable.

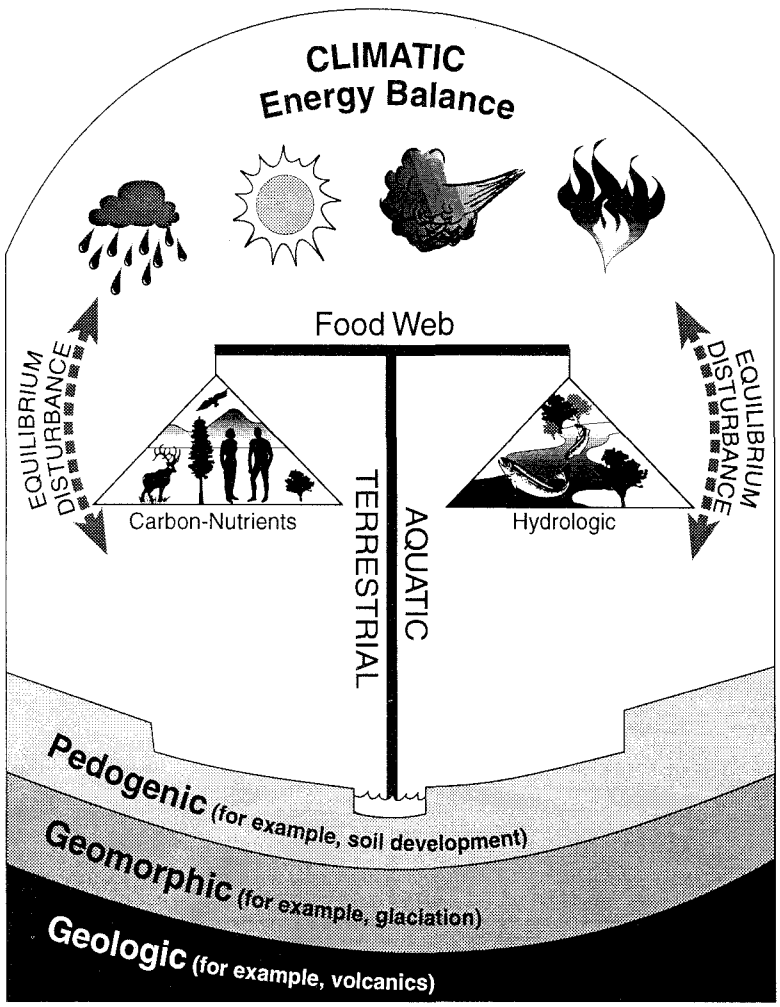


Figure 3.2—Schematic of pre-historical (native or HRV) ecological equilibrium in relation to biophysical conditions, key processes, and disturbance.

Energy, hydrologic, carbon-nutrient, and trophic systems, and subsequently evolutionary systems, cycle within explicit spatial and temporal scales. Typically, changes of the native system equilibrium were due to frequent, small magnitude fluxes of energy or material inputs and outputs that occurred throughout a long temporal period. Or, changes resulted from infrequent, large magnitude fluxes that occurred within more localized areas. Regardless of the spatial and temporal scales in which the primary processes varied, the systems remained balanced, and responses were predictable. These tightly woven processes and responses were a result of eons of evolutionary adaptations of the biotic communities, which mediated ecosystem functions (Cockburn 1991; Ulanowicz 1992). Disturbances capable of altering the relationships among the key processes typically occurred very slowly (such as climate change, glaciation, or other geomorphologic processes) which allowed for the migration and natural selection of genetic information contained within species. For example, a slow-warming climatic period would likely cause glacial recession. Flora and fauna that were adapted to cooler climates would migrate toward higher latitudes and elevations. Species adapted to warmer climates would also shift their ranges to higher latitudes and elevations. However, changes also occurred rather rapidly as a result of catastrophic geomorphological events (for example, volcanic events, meteor impacts, flooding by glacial lakes, or landslides and mudslides resulting in new landforms). Depending upon the spatial extent of these more rapid changes, some biotic entities were capable of adjusting and others were not. Catastrophic events would commonly initiate primary successional processes, and could cause a shift of the ecological equilibrium. Even so, the interrelationship of the key processes would not change substantially and the ecosystem would remain in a similar state of dynamic equilibrium.

Changes in biotic processes and potentials are strongly affected by the migration of populations and species. Migration of more competitive species into new environments occurred throughout

geologic time, but at relatively slow rates. This allowed indigenous species the opportunity to develop competitive adaptations or emigrate to new areas with less intense competition. In addition, slow migrations of species did not usually allow migrants the opportunity to isolate themselves from their parasites and pathogens. On the other hand, rapid migration across long distances (movement common to many of the species currently considered as exotic pests) may have allowed the migrants to become isolated from their controlling agents (that is, sympatric competitors, predators, parasites, and pathogens). In addition, many exotics considered pests within the New World are commonly better adapted to anthropogenic disturbances. Their competitive advantage relative to the indigenous species of the New World was a consequence of their evolution within areas under the long-term influence of human disturbances. Thus, not only are many of the New World exotics better adapted to human disturbances, but many are isolated from their natural controlling agents.

The last 1.6 million years, known as the Quaternary Period, have been dominated by continental and mountain glaciation, and cold climates with short interglacial warming periods. Catastrophic volcanic and glacial flood events were relatively common during this period. Many species that adapted to the conditions of the Quaternary Period are presently within the Basin. The migrations and evolutionary developments of biota in the Basin occurred during varying periods of climatic warming and cooling. On average, these fluctuations occurred within 8 to 10 degrees Celsius of current minimum and maximum temperatures within the Basin (fig. 3.3; Hann and others 1997, Mehringer 1996, Tausch and others 1993, Webb and Bartlein 1992). Ecosystem attributes such as biotic communities, aquatic sediments, and stream flows (fig. 3.3) responded to the climatic changes in a similar rhythm. In the northern portions of the Basin, the fluctuating climate corresponded with periods of expanding or receding continental and mountain glaciation. In the southern portions of the Basin, the extent of cold grasslands and cold forests increased during colder periods, whereas the extent of semi-desert shrublands and drier forests increased regionally during the warmer periods. During colder periods, geomorphologic processes were dominated by glacial scouring, whereas fluvial erosion and deposition were important land-forming processes during the warmer periods.

Although the climate fluctuated between colder and warmer periods, colder climates prevailed throughout most of the Quaternary Period.

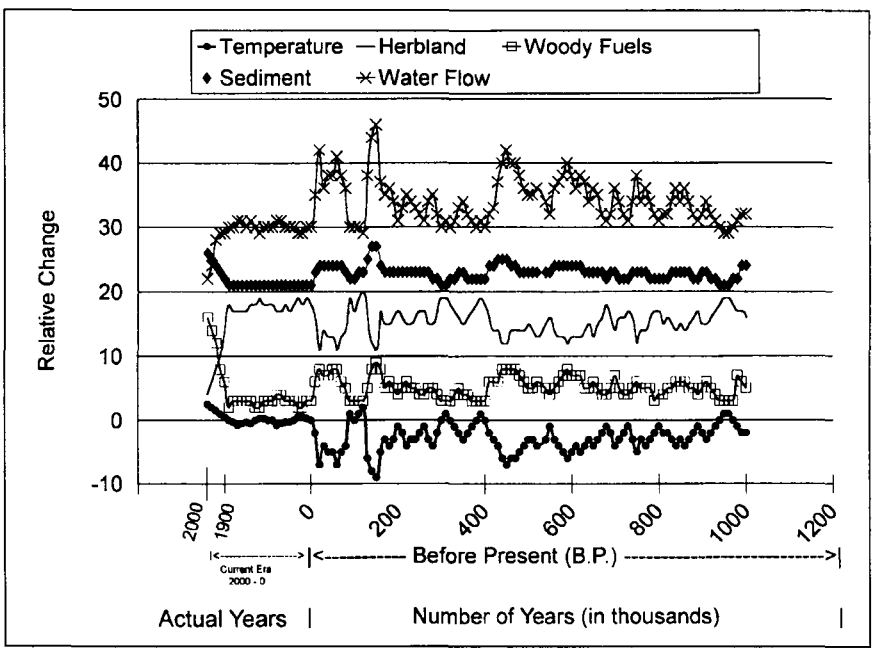


Figure 3.3—Relative changes in temperature, woody fuels, herbland, sediment, and water flow over time [adapted from Tausch and others (1993)].

Consequently, evolutionary processes (especially adaptation by natural selection) evident during the Quaternary period, were driven by cooler temperature regimes and the associated types and quantity of precipitation (Bennett 1990, Gould 1991, Tausch and others 1993). Interglacial warm periods appeared to have been too short and too divergent to substantially affect evolutionary processes. Thus, the extant genotypes in the Basin that are favored by warmer climates, likely developed during warmer temperature regimes prevalent during the Tertiary period (prior to the Quaternary period).

During the shorter interglacial warming periods, the primary strategy for species and population survival was the migration of cooler climate-adapted species and populations to northerly latitudes, higher elevations, and cooler microsites. Consequently, their ranges became more fragmented, and possibly isolated to mountaintop settings. Species and populations that had adapted to warmer conditions were capable of expanding their ranges into more northern latitudes and higher elevations. Their ranges became less fragmented. Species better adapted to fire-prone ecosystems were also able to expand their ranges and increase their population densities during the interglacial warming periods.

Extinction of species and populations adapted to cooler temperature regimes occurred during interglacial periods when migration strategies were not adequate to offset changes in interspecific competition and predation, more frequent and severe fire disturbance, loss of habitat, and stresses stemming from increased temperatures. For instance, many species of mega-fauna in the Western Hemisphere were lost by 10,000 to 4,000 years ago (Geist 1989, Gould 1991, Grayson 1993, Kurten and Anderson 1980, Lewin 1987). These extinctions appeared to have occurred in response to climatic warming and subsequent drought; reduced availability of productive cold, dry grassland communities; and possibly due to hunting by the relatively recent migrants from Asia — humans.

Human Ecological Activities

Although humans had sustained fairly wide-ranging migratory patterns over the course of their evolution, their direct and indirect influence on ecosystems processes primarily extended only to a subregional scale (fig. 3.1). Similarly, in the absence of human energy, the variability of hydrologic, carbon-nutrient, food web, and evolutionary processes could be effectively stratified at the subregional scale. Ecosystem toxins were buffered, relatively immobile, and inert during this primeval period. Regional boundaries, and to a lesser degree subregional boundaries, were relatively distinct. In particular there was a marked boundary between continental and maritime regions. Most systems conserved nutrients, food, materials, and energy within relatively closed cycles. These systems moved materials relatively slowly, and accepted and expelled energy at relatively equal rates. Events occurred that would shift equilibrium, but they were usually very infrequent and only affected sites or landscapes within a subregion.

As the global human population increased and their technologies (such as agricultural, mechanical, and chemical) developed (providing food, shelter, clothing, transportation, and recreation), the dynamic ecological equilibrium shifted to disequilibrium (fig. 3.4). As a result of these changes, human-induced processes became a significant influence on biotic and abiotic systems (Naveh and Lieberman 1994; fig. 3.5). Anthropogenic activities increased the permeability of regional and subregional boundaries. Oceans and continents were no longer effective barriers to migration and colonization. Distinct hydrologic and carbon-nutrient processes were no longer constrained mostly to subregional scales. Energy flows, hydrologic cycles, carbon-nutrient cycles, ecosystem food webs, and evolutionary processes changed to the extent that the dynamic balance, resiliency, and predictability of many systems declined. The development of human technologies also increased the mobilization and reactivity of toxins throughout the biosphere (Allen and Hoekstra 1992). As a result of these changes

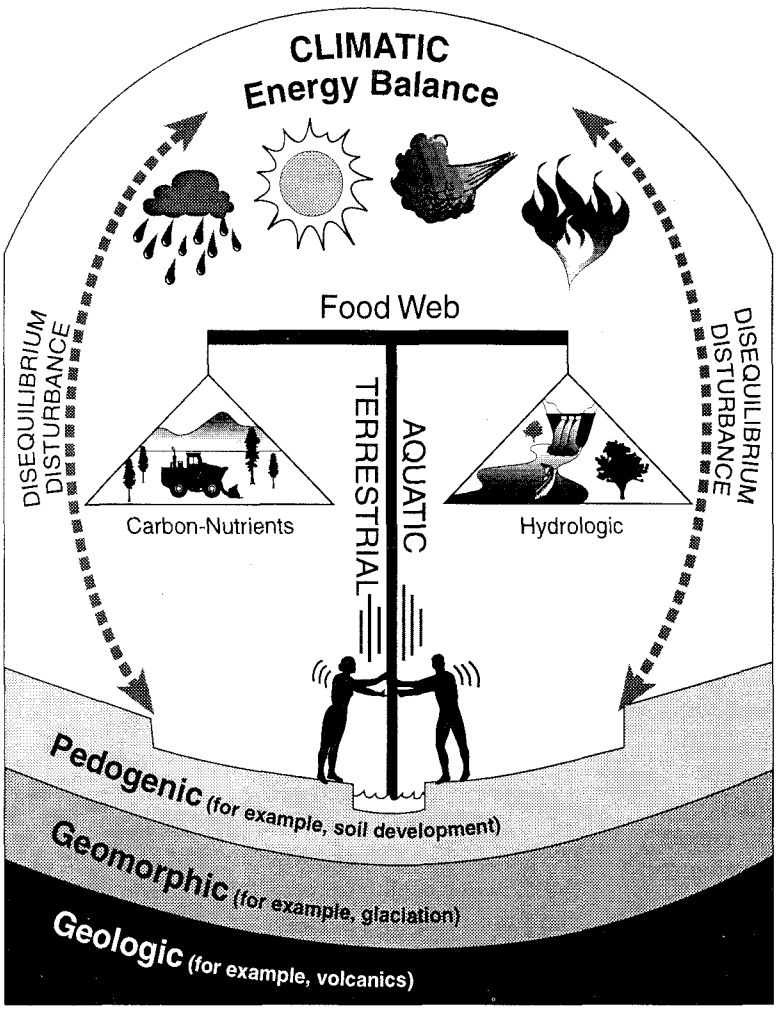


Figure 3.4—Schematic of effects of current period in relation to disequilibrium of key ecological systems.

brought about by human population growth and technological developments, long-standing ecological cause-and-effect interrelationships between different species and their environment were disrupted. Over time, species and landscape patterns that had evolved complex adaptations within well developed biophysical environments became simplified. This simplification occurred because only generalist species and poorly developed biophysical environments can be sustained in the face of chaotic cause-and-effect relationships.

Ecological Disequilibrium

Ecological disequilibrium has unequal relationships of inputs and outputs, and thus, does not have predictable cyclic successional patterns or stable states and associated responses to disturbance. Many of the relationships that are apparent during periods of ecological equilibrium are no longer apparent during periods of disequilibrium. For example, during ecological equilibrium when average temperatures are high, the relative availability of woody fuels in forest settings is low because fire frequency is relatively high. Furthermore, because fire severity would also be low, the system would be relatively resilient. After fire disturbance, vegetation would quickly return to pre-disturbance conditions, thereby recovering pre-disturbance energy flows, carbon-nutrient cycles, hydrologic cycles, and ecosystem food webs. Similarly, when average temperatures are low the availability of woody fuels in forest settings would be relatively high because of moist conditions and as a result fire frequency would be rather low. Even though fire severity would likely be high because of more fuel, the recovery rates would be relatively fast because productivity would also be high given the moister conditions. Thus, in the foregoing example, regardless of the climatic conditions, ecosystem resiliency would be high. However, these relationships are not as apparent during periods of disequilibrium. Using the above example, fire frequencies might be low even during warmer climatic regimes as a result of fire exclusion and traditional forestry and grazing practices that remove fine fuels. Recovery of vegetation to pre-disturbance conditions would be prolonged because of lower productivity in a drier regime, higher fuel loading, and increased fire severity. Consequently, the ecosystem would likely be less resilient.

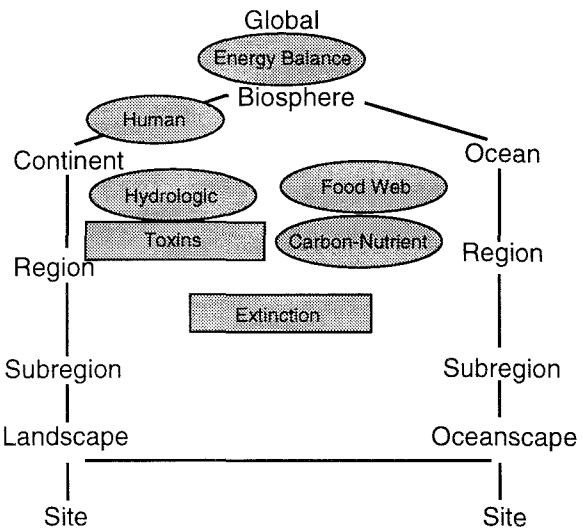


Figure 3.5—Current period relationships of key ecological systems at different scales.

Because of their aridity and certain soil properties, both of which limit plant establishment and growth, rangeland environments are extremely sensitive to stresses that disrupt their equilibrium. Inherently, many rangeland systems are less resilient than most forest systems. Consequently, recovery of rangeland vegetation to pre-disturbance conditions is inherently slow. Furthermore, the magnitude of stress necessary to shift rangeland states into disequilibrium is much smaller than that required to shift forest systems into disequilibrium. Virtually any system occurring at the extreme of its environmental gradient has high inherent natural stress and is predisposed to ecological disequilibrium.

Assessment of Key Ecosystem Processes and Functions

The following subsections on scale, biophysical template, historical range of variability (HRV),[4] succession and disturbance regimes, landscape patterns, and biogeophysical processes describe the concepts about the dominant ecological processes and functions relative to the landscape of the Basin used in our assessment.

Scale

As defined by Turner and Gardner (1990) for use in landscape ecology, scale is the spatial or temporal dimension of an object or process, characterized by both grain and extent. In landscape ecology, there are three spatial scales: region, landscape, and landscape element (Forman 1995, Forman and Godron 1986). "Regions" reflect the broadest scale (that is, have the largest geographic extent) and comprise a coarse-grained pattern of connected landscapes with contrasting boundaries that have a similar macroclimate and sphere of human activity and interest (Forman 1995). A "landscape" is a spatially heterogeneous area with repeating patterns of elements and associated disturbance regimes with similar climate and geomorphology (Forman and Godron 1986, Turner and Gardner 1990). A "landscape element" is the basic individual, population, habitat, patch, or corridor created by abiotic, biotic, or human activities. The aggregation of similar landscape elements is referred to as a "land unit." Zonneveld (1989) described land units as areas that are homogeneous relative to the scale of mapping and to the features being mapped (for example soil types, plant communities, landforms, and cover types).

The landscape assessment was considered broad in scale because it included a large regional area (Forman 1995, Turner and Gardner 1990). Continuous coarse-grained data, and mid- and fine-grained sampled data were evaluated to answer the primary questions of the assessment that involved broad-, mid-, and fine-scale landscape composition and structure. The project framework provided an overview of the uses and applications of various planning scales (Haynes and others 1996).

Our ability to address multi-scaled issues required a multi-scaled, hierarchical approach. Similarly, our ability to perceive change was dependent upon the scale of analysis. Since the issues brought forth

[4] As defined in this chapter, historical range of variability or HRV refers to the "pre-Euro-American settlement" or "native" regime. It is not synonymous with the historic or historical time period which we define as occurring in the "post-Euro-American settlement" time period.

during this assessment process were multi-scaled, the resolution of our analyses also had to vary from coarse to fine, depending on the element of concern. For example, samples at the subwatershed (6th field hydrologic unit codes or HUCs) and plot levels were used to characterize mid- and fine-scale attributes, respectively. The trends of mid- and fine-scale attributes were then statistically extrapolated and correlated with continuous broad-scale data (King 1990). The mid-scale analysis (Hessburg and others 1996a) and plot data was also used to validate and help interpret broad-scale trends of mid- and fine-scale elements. Furthermore, the mid-scale assessment considered the context of the broad-scale information as well as the trends of the fine-scale data. Our hierarchical approach provided a basis for understanding the spatial and temporal dynamics of regions, landscapes, and landscape elements.

We used three regional levels of analyses to assess ecosystem dynamics. The largest region used for the analysis was the "landscape characterization area" (LCA). The LCA was developed using Bailey's (1995) ecoregion maps to the "section" level, as refined by Nesser and Ford (1995)(map 3.1). Generally, the LCA included all sections that occurred in whole or in part within the Basin. However, the western boundary of the LCA was delineated by the watershed divide along the Cascade crest. This gave us a complete regional context for the Basin. The second level of regional analysis was the Basin (see Columbia River Basin Assessment Area on map 3.2). This area included Oregon and Washington, east of the Cascade crest, and the portions of Idaho, Montana, Wyoming, Utah, and Nevada that occurred within the Columbia River basin. These delineations were primarily oriented toward public land-management planning boundaries (see Chapter 1 of this document for further discussion). Most of the results were also summarized using the 13 Ecological Reporting Units (ERUs)(map 3.3) that were primarily aggregates of subbasins (4th field HUCs) having similar broad-scale vegetation, landform, and geomorphologic patterns. However, in some instances, the ERU delineations required splitting subbasins (that is, using subwatershed boundaries) because the subbasins contained major differences in landforms and vegetation. Due to the fact that similar types of broad-scale geographic features were found in several ERUs, the ERUs were collapsed into six areas with regional differences in landforms and climate, called "subbasin groups." At the broad scale, the subbasin groups adequately stratified the geographic differences of biophysical environments and provided a more simplified grouping system (map 3.4; table 3.1).

We used subwatersheds (6th field HUCs)(map 3.5) and subbasins (4th field HUCs)(map 3.6) as two levels of the landscape scale (see Biophysical, Chapter 2 of this document for a description of hydrologic unit codes). Subwatersheds ranged from less than 1,000 to more than 85,000 hectares and contained a repeating pattern of vegetation and similar climate, landforms, disturbance regimes, and land-use patterns. Subbasins, a coarser landscape delineation, were aggregations of subwatersheds and ranged in size from approximately 500,000 to 1,000,000 hectares. At a coarser scale, subbasins also contained a repeating pattern of vegetation and similar climate, landforms, disturbance regimes, and land-use patterns.

With respect to resolution or grain, 1-square-kilometer pixels were used to characterize landscape elements [for example, potential vegetation types (PVTs), cover types, and structural stages] for broad-scale analyses. For finer-scale information, Hessburg and others (1996a) used 4-hectare polygons to characterize mid-scale landscape patterns, and Hann and others (1997) used 375 square-meter macroplots to assess vegetation composition and structure, fuel loading, and soil cover.

Biophysical Template

In this chapter, the basis for the definition of biophysical template comes from the work of Jenny (1958) and Major (1951). They developed similar concepts of primary variables that produce the soils and vegetation of various landscapes. The biophysical template can be visualized as the

Table 3.1—Comparison of geographic area stratifications of the Basin.[1]

Generalized Subbasin Group	Subbasin Group	Ecological Reporting Unit
Cascade Mountains	Northern Cascade Mountains	Northern Cascades
	Southern Cascades and Blue Mountains	Blue Mountains
		Southern Cascades
		Upper Klamath
Intermountain	Columbia Plateau	Columbia Plateau
	Intermountain Basin	Northern Great Basin
		Owyhee Uplands
		Upper Snake
Rocky Mountains	Northern Rocky Mountains	Northern Glaciated Mountains
		Lower Clark Fork
	Central Rocky Mountains	Central Idaho Mountains
		Snake Headwaters Upper
		Upper Clark Fork

[1] There is not an exact area correlation between Ecological Reporting Units (ERUs) and subbasin groups. The relationship is for the general area. ERU boundaries split some of the subbasin boundaries. There is, however, a direct correlation between the subbasin groups and the generalized subbasin groups.

biological, physical, and disturbance characteristics of an environment over a period of relatively stable climate. The biophysical template provided a foundation for interpreting complex spatial and temporal landscape relationships such as disturbance regimes and vegetation succession, composition, and structure.

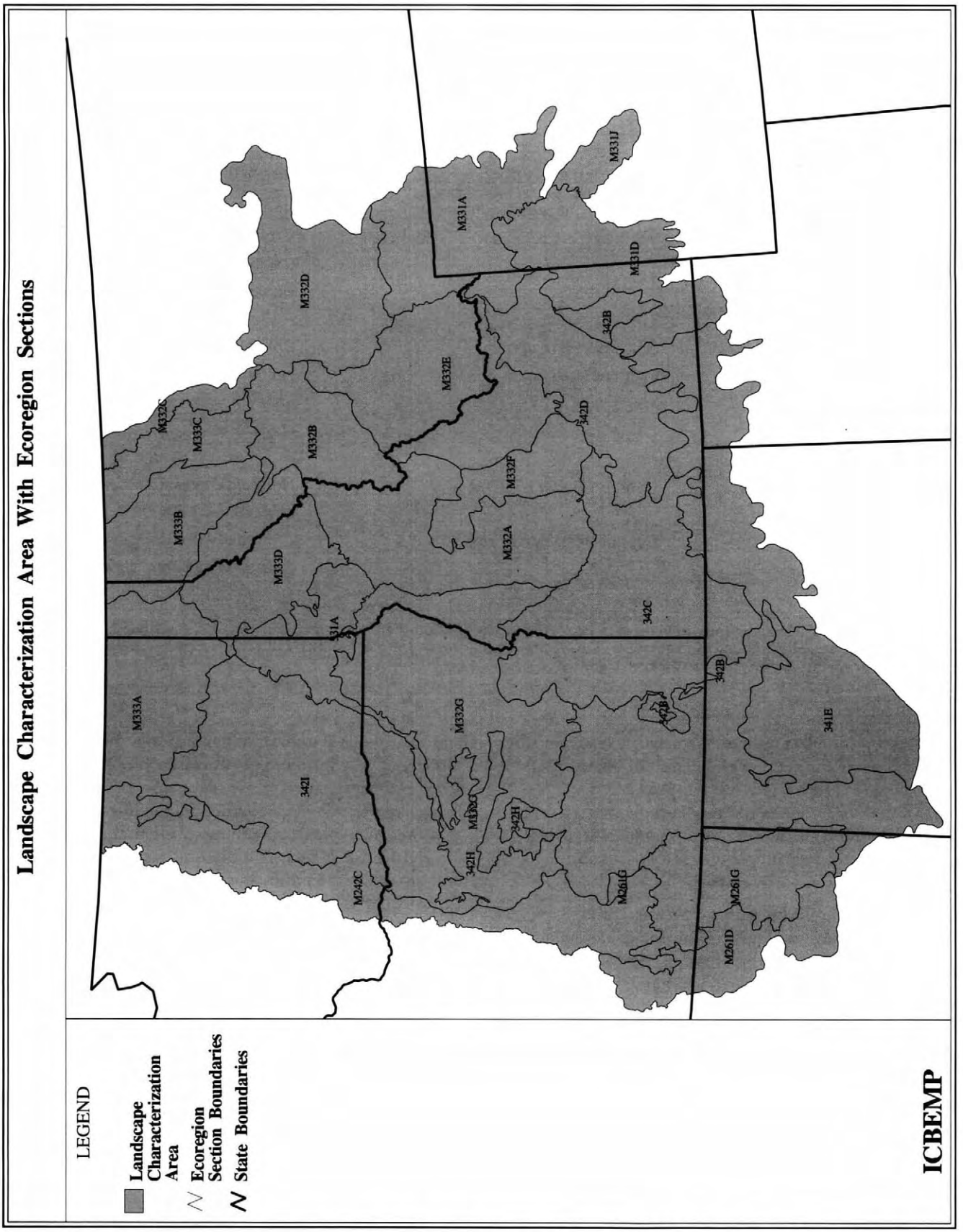
The biophysical template develops through the evolution and migration of native biota as they interact with disturbances, geomorphologic processes, geologic parent material, topography, and changing climates. This interaction further develops into interdependent combinations of biotic communities, soil, and hydrologic systems. The biophysical template is the current expression of the collective adaptations of species to competition, disturbances, and the physical environment. It is also the current expression of the soils, landform, and hydrologic system development in response to biotic and geomorphologic processes. Biophysical templates have characteristic succession and disturbance regimes that are governed by the interactions between biotic and abiotic components. The interrelationships among biota, soil, succession and disturbance regimes, and hydrologic systems developed over evolutionary and geologic periods.

Biogeochemical processes involve the productive capacity and chemical relationships of the living and nonliving system components considered as a whole (Barbour and others 1987). These processes are often unique to a biophysical template and are described in terms of accumulation, transfer, transformation, and recycling of chemical components that are associated with biological and physical energy flows (Waring and Schlesinger 1985).

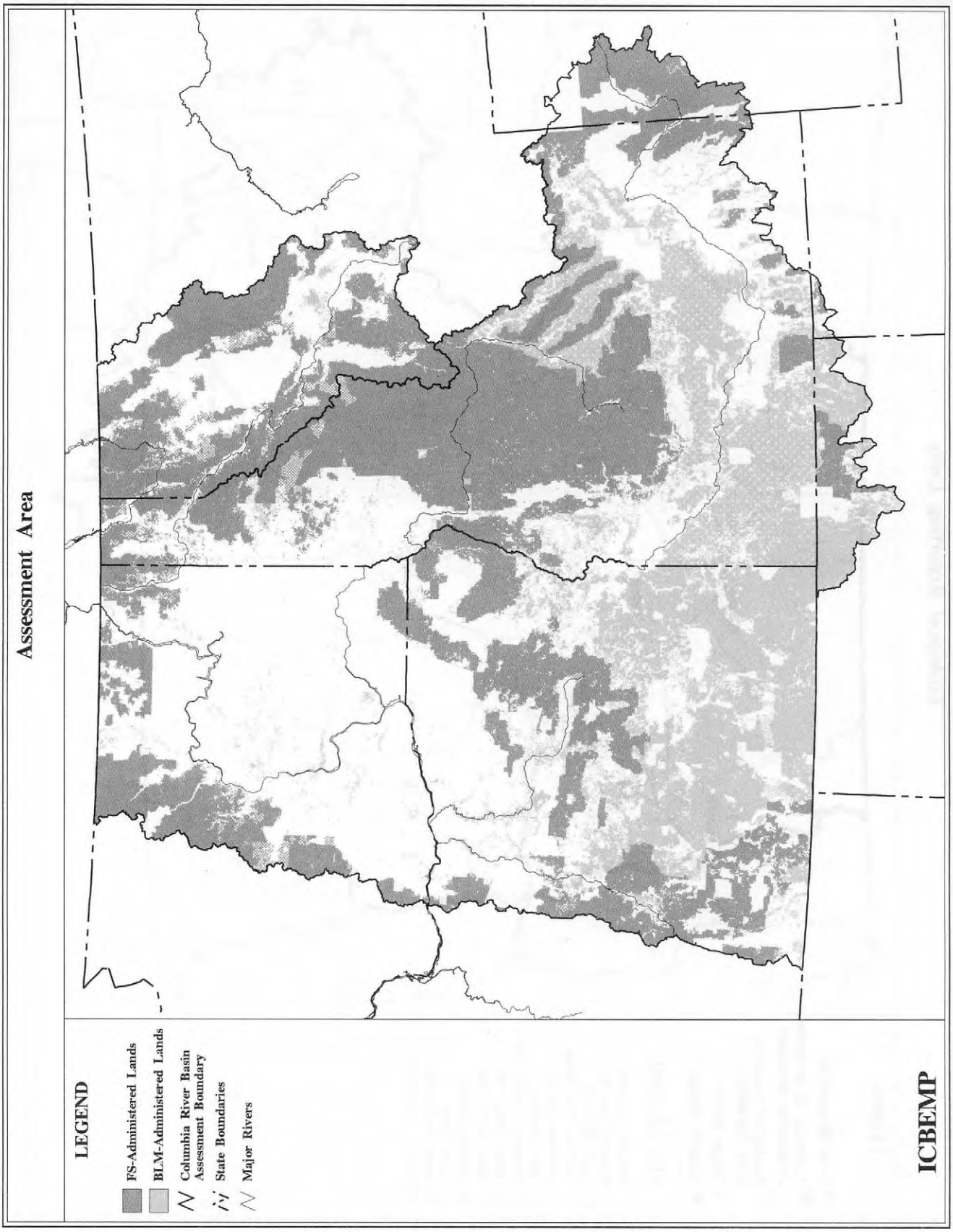
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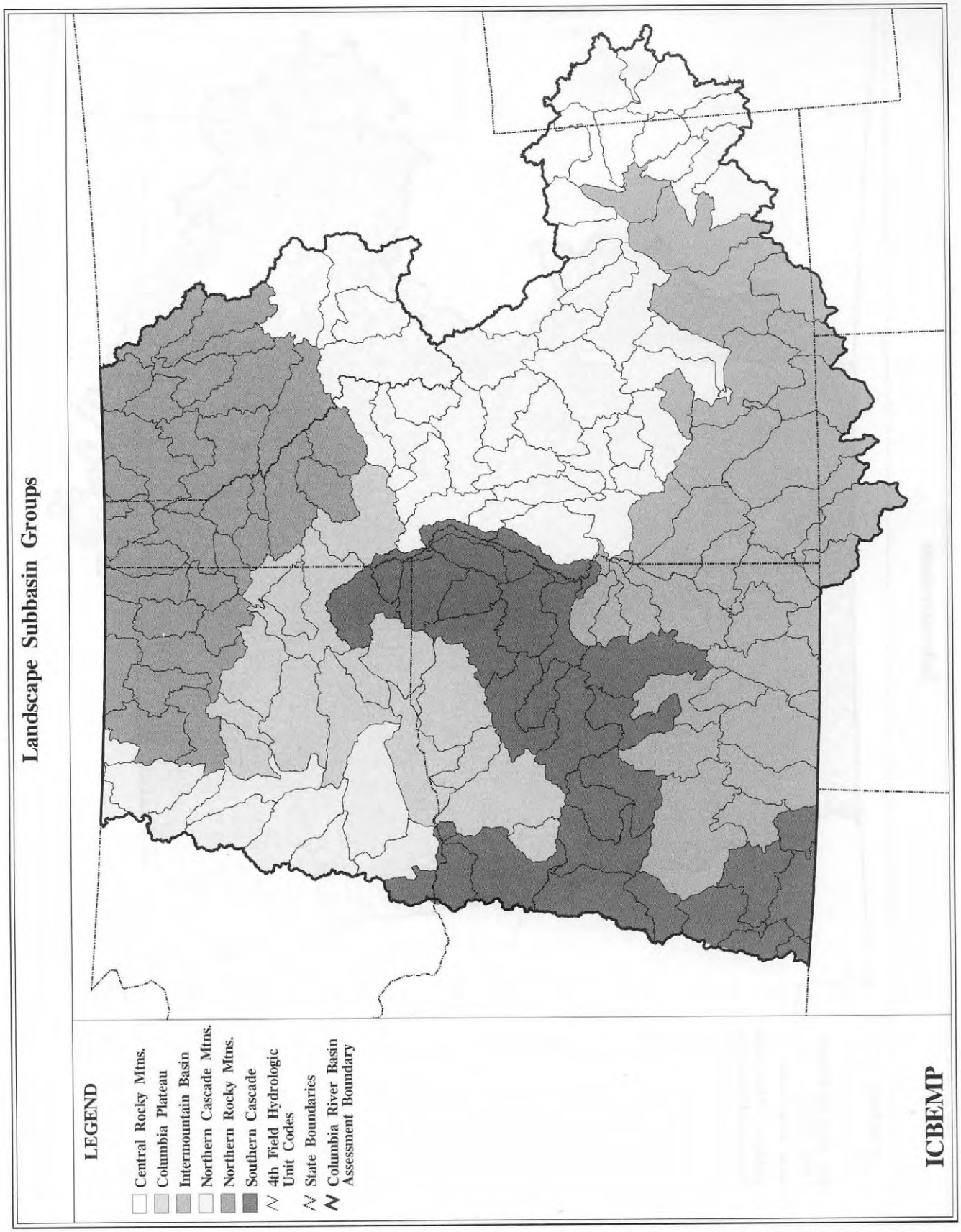


Map 3.1—The landscape characterization area (LCA) for the Basin with ecoregion sections [adapted from McNab and Avers (1994)].



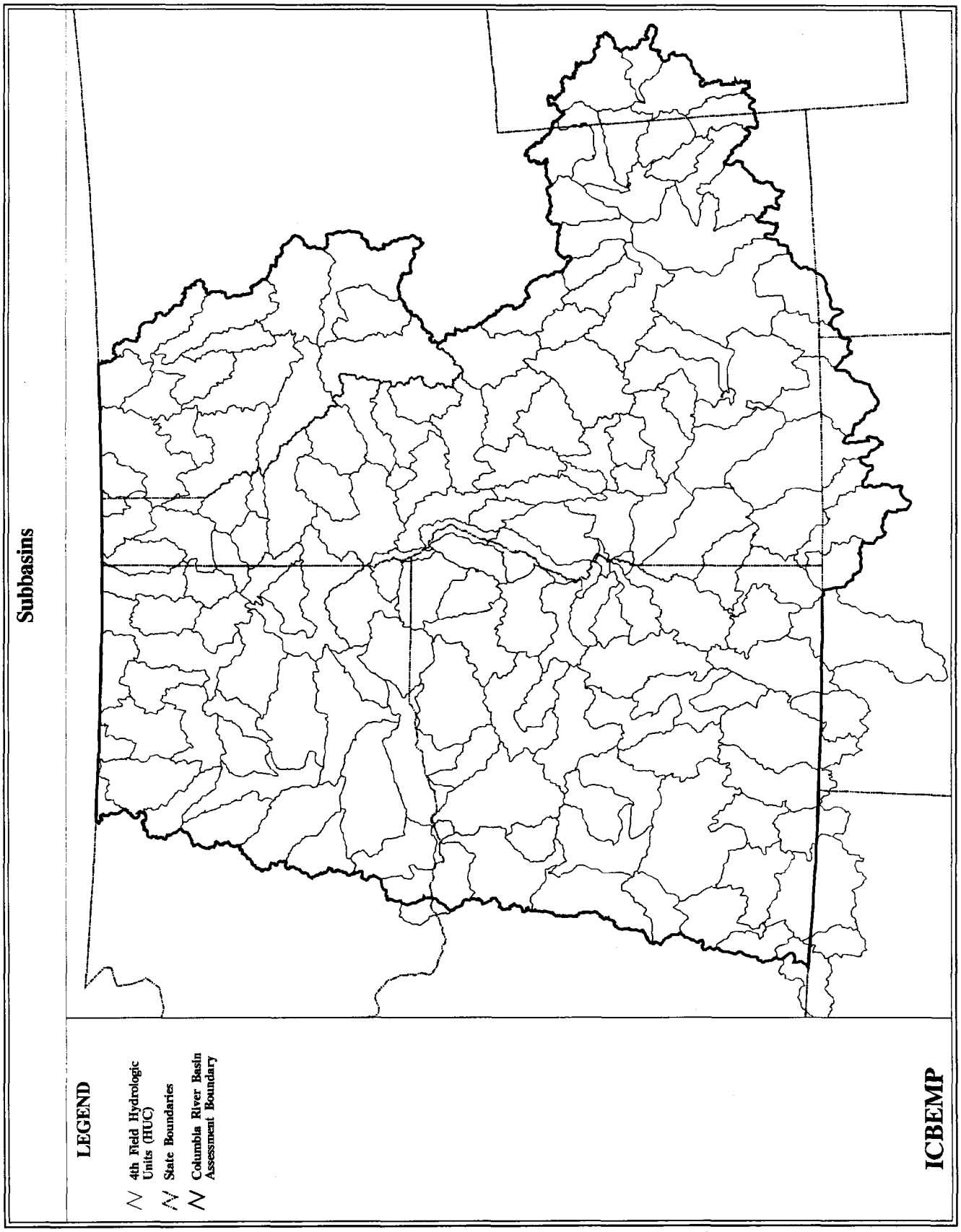
Map 3.2—The assessment area of the Interior Columbia Basin and portions of the Klamath and Great Basins (referred to as the Basin) reflecting Forest Service- and BLM-administered lands.

Map 3.3—The Ecological Reporting Units (ERUs) of the Basin. ERUs are aggregates of subwatersheds (6th field hydrologic unit codes) that generally represent similar terrestrial and aquatic characteristics (see map 3.5).



Map 3.4—The landscape subbasin groups of the Basin. These groups are aggregates of subbasins (4th field hydrologic unit codes) that generally reflect common terrestrial, aquatic, and landscape characteristics (see map 3.6).

Map 3.5—Subwatersheds (6th field hydrologic units) of the Basin. There are 7,469 subwatersheds in the Basin, and they range from less than 500 to more than 85,000 hectares in size. This stratification was a basic data element for addressing aquatic and landscape characteristics.



Map 3.6—Subbasins (4th field hydrologic units) of the Basin. There are 164 subbasins and portions of subbasins in the Basin, and they range from approximately 500,000 to 1,000,000 hectares in size. This stratification was the basic data element for addressing ecological integrity and landscape patterns.

The biophysical template may be altered by any disturbance (or repeated disturbances) that change the relationships between the biotic and abiotic systems. Altered biophysical templates may occur as a result of incremental changes occurring over geologic and evolutionary periods, or they may occur as a result of catastrophic geomorphologic events. Dynamic equilibrium or balance, and thus predictability, is maintained when incremental changes occur slowly over geologic and evolutionary periods. Over such periods, the rate of change is so slow that the trends are difficult to detect unless an appropriate temporal scale is assessed. These changes are often not of immediate concern from a natural resource management perspective, except to provide context. With the exception of catastrophic events (for example landslides and volcanism), long periods (>10,000 years) are needed to affect topography and parent material. Somewhat shorter timeframes (500-10,000 years) are associated with changes in climate and associated edaphic processes. Catastrophic events usually result in disequilibrium for at least a short period, but equilibrium returns within a predictable time. Because they occur infrequently, catastrophic events are generally only of concern to resource managers after they occur.

It is important to emphasize that human interaction with other species and the environment has been a very important part of the development of biophysical templates over the course of human evolution. Humans have become very effective at altering biophysical templates by altering food web relationships, hydrologic cycles, and carbon-nutrient cycles; application of human technological energy often disrupts interrelated functions and processes. Human-related activities that can alter the biophysical template include invasions by exotic species, extirpation of populations, soil erosion, severe alluvial events, wildland conversion to urban or cropland uses, or the release of toxic pollutants into the air, soil, and water.

In wildland environments, human-induced effects might dominate the succession and disturbance processes for relatively short timeframes, but in the long term, these processes will frequently overpower the "artificial" states that are maintained by subsidies provided by society. For example, mechanical, technological, and other forms of human energy may change the relationships of biophysical and disturbance conditions. These human-induced changes include efforts to exclude fire, floods, insect and disease mortalities, and other disturbance events, and produce commodities such as livestock, big game, forest products, and visual conditions from forests and rangelands. Since Euro-American settlement of the Basin, most of these efforts have been conducted in ways that have simplified landscape conditions (that is, composition, structure, and function). These changed systems typically have higher or lower quantities of on-site biomass than is consistent with their biological capability.

Terrestrial and aquatic communities frequently change within a single year in response to natural disturbances (such as fire, drought, tree windthrow, animals, insects, pathogens, avalanches, floods) and anthropogenic disturbances (such as hunting, fishing, logging, and livestock grazing activities). The subsequent changes in the biotic community, hydrologic system, or soil condition are referred to as secondary succession, stand dynamics, state change, or disturbance recovery (Barbour and others 1980, Gebhardt and others 1989, Oliver and Larson 1996). These types of disturbances are considered secondary disturbances because they do not change the primary evolutionary relationships among the biotic, climatic, hydrologic, pedogenic, geomorphologic, and geologic systems.

Essentially, any factor that changes the ecological cause-and-effect relationships will alter biophysical relationships. This can effect evolutionary adaptations, co-evolutionary relationships, biogeochemical processes, and biophysical development. When humans change biophysical conditions by altering topography, parent material, or soils, introducing exotic species, or causing species or genera extinction, they alter biophysical relationships. Modifications of biophysical relationships, in turn,

change biogeochemical processes. Altered systems respond differently and less predictably to disturbances than do unaltered biophysical templates.

Any exotic species, including plants, animals, and pathogens, that have substantial effects on species composition can alter biophysical conditions. Toxic pollutants can also change the environment of the native biota and thereby alter biophysical relationships. Erosion of soil or removal of soil can alter the site capability and potential for native species. Once the environment, particularly the topsoil, is disrupted in a major way (such as by tilling or mining activities) there is little chance of recovering the cause-and-effect relationships of the native system within human timeframes, even after intensive restoration.

Roads may directly alter biophysical conditions as a result of their effects on soils. In addition, roads may indirectly affect biophysical relationships because they often act as conduits for the spread of exotic plants, they may increase the potential for fire ignitions, and they disrupt hydrologic regimes.

Geographic areas (that reflect differences in climate), potential vegetation types (that reflect moisture and temperature regimes), and landforms (that reflect geomorphologic processes) provide meaningful stratifications for understanding broad-scale biophysical templates and the mechanisms behind mid- and fine-scale landscape patterns. Within a geographic area, we commonly used potential vegetation groups (PVGs) as indicators of biophysical templates (see appendix 3-A for detailed descriptions of the PVGs).

Historical Range of Variability (HRV)

The HRV (Morgan and others 1994) provides a means of understanding biophysical templates and the biodiversity relationships of paleoecological and historical systems. The HRV incorporates the relationships between the energy of the system in terms of biomass accumulation (for example growth, development, transpiration), and the processes of disturbances that convert or physically transport biomass (for example herbivory, fire, avalanche, and flood). Thus, the HRV can serve as a tool for understanding the causes and consequences of change in ecosystem characteristics over time (Morgan and others 1994). Not only can HRV be used to help describe native systems, but it can also serve as a benchmark for understanding the effects of human-induced changes of biophysical templates. We simulated the HRV by developing pre-Euro-American settlement succession/disturbance models for each potential vegetation type (PVT; see appendix 3-A for descriptions of PVTs) in the Basin and simulating change over a 100- or 400-year period from the historical vegetation map (Long and others 1996).

Morgan and others (1994) suggested that the HRV should be assessed for a time period characterized by relatively consistent climatic, edaphic, topographic, and biogeographic conditions. For this assessment, we were most interested in the HRV of contemporary ecosystems. Thus, we focused our assessment of HRV on the biophysical templates that existed during the period between the beginning of the current climatic regime and prior to Euro-American settlement. Mack and others (1983) suggested that the present macroclimate emerged approximately 2,700 years before present. Furthermore, it has been suggested that present plant communities endemic to temperate environments (Schoonmaker and Foster 1991) and the Basin (Mehringer 1996) have been in some state of equilibrium with the environment since about 2,000 years before present. Although the "Little Ice Age" occurred from about 1450 to 1850 A.D. (Wahl and Lawson 1970, Webb and Bartlein 1992) and undoubtedly altered plant communities and their environment, it did not substantially affect the general trend in plant communities (Mehringer 1996; Webb and Bartlein 1992) or disturbance regimes (for example, fire) (Barrett 1995) characteristic of the warmer, post-glacial climates. At the time of Euro-American settlement, some plant communities, environments, and fuels were characteristic of the cooler, moister conditions of the "Little Ice Age" and had not yet adjusted to the warmer environment. Although the "Little Ice Age" shifted the equilibrium of

species ranges and disturbance regimes, it did not result in extinctions or substantial changes in ecological relationships. Thus, prior to Euro-American settlement, broad-scale biophysical relationships in the Basin had been relatively stable for nearly 2,000 years.

We recognized Native American peoples' use of fire as a disturbance process that influenced the HRV, as these cultures have had an integral role on the landscape for at least the last 2,000 years (Mehringer and others 1977, Woods and Horstman 1996). Although Native American cultures were affected by substantial decreases in population as a result of the introduction of Old World diseases during the pre-contact era (between the years 1500 and 1800)(Denevan 1992, Woods and Horstman 1996), their ignitions still substantially augmented wildfires over vast areas of the Basin throughout much of the Nineteenth Century (Barrett and Arno 1982, Ross 1981, Shinn 1980). Their effects on the landscape were especially noticeable near grasslands, low-elevation forests, and in or near major valleys or other significant settlement locations, resource acquisition areas, and travel routes (Barrett and Arno 1982). However, it could also be argued that when considering the relationship between fuel continuity and lightning ignitions of the 2,000 years prior to Euro-American settlement, broad-scale fire regimes would not have been measurably affected by Native Americans. Furthermore, morphological and ecological evolution in plants can occur relatively rapidly as demonstrated by ecotypic variation, perhaps within several decades or less (Woodward 1987). Consequently, it seems that most flora, and probably fauna as well, had adapted to the widespread use of fire by Native Americans over the last 2,000 years.

Although humans have been key drivers of many landscape processes in western North America, their recent historical (that is, post-Euro-American settlement) influences were not considered as part of the HRV. Subsequent to Euro-American settlement, anthropogenic disturbances began to simplify many systems because many endemic plant and animal species had not co-developed with widespread, intense, or frequent human disturbances, as had the endemic species of Africa, Europe, and Asia. The rate of change in ecosystem characteristics is at least as important to the concept of HRV as the magnitude of change (Morgan and others 1994). Humans have the capacity to rapidly alter biophysical environments at a rate and in a spatial array that prohibits many species from dispersing into suitable habitats, or adapting to altered regimes. Thus, in order to provide a context for interpreting the causes and consequences of change of ecosystem characteristics through time, we chose to assess the HRV prior to the period of the most rapid and intense changes, that is at the onset of the Euro-American settlement of the Basin.

The HRV provides a means of referencing the current conditions and differences among various future land-management scenarios. However, land managers may not want to target the HRV as a management objective because it does not account for the influences that humans have had on their environment, nor the values that humans want to produce from their environment (Morgan and others 1994). Humans have commonly modified systems so that food, fiber, visual conditions, wildlife habitat, or other forms of biomass can accumulate. In some circumstances, humans have altered the biophysical template to such an extent that historical disturbance regimes, and landscape compositions and structures are no longer achievable. Although land managers can attempt to mimic the historical system, the HRV can only be obtained within those biophysical systems that have not been substantially altered. In systems that have been altered, the relationships have changed and restoration of historical conditions may be impossible or prohibitively expensive. In addition, humans often desire to process biomass in timeframes that are different from the disturbance regimes of the HRV. Even on lands where the objective is not to extract resources but instead to manage for "natural" processes (for example in wilderness and semi-primitive areas), the size, intensity, or pattern of disturbance events (such as fire) may occur at a scale that is considered unacceptable by society.

Of what value then is the HRV? Without an understanding of biophysical templates and their associated disturbance and succession regimes, it would be difficult to comprehend the cause-and-effect relationships of resource extraction or the responses of biodiversity to system changes. The HRV is useful as a benchmark for assessing or monitoring effects of land management relative to the departure from historical conditions. These departures can be used as a reference against which to evaluate change and to help identify risks to ecosystem sustainability (Morgan and others 1994). The HRV is also useful for assessing or monitoring effects of land management relative to biogeochemical processes, succession, disturbance, and hydrologic regimes. This can help land managers understand tradeoffs between different management strategies with respect to resource production capability, disturbance events, environmental effects, and changes in regimes.

The HRV provides a tool for land managers to design better approaches for the production of resources and the conservation of biodiversity that work more effectively within the biophysical templates, whether the templates have been changed or remain intact.

The HRV also provides a means for understanding the relationships between native species and associated biophysical templates. For example, the areal extent and pattern of a particular habitat can affect the colonization potential of individuals (including exotic species), persistence of individuals, persistence of populations, and the number of species within a landscape (Morrison and others 1992). Three indices of vegetation change are required to better understand the effects of vegetation trends on ecosystem dynamics. First, the proportional change in areal extent of a vegetation type (that is, class change) is informative because it quantifies the change of that vegetation type relative to itself. Second, the proportional change in area of a vegetation type relative to the landscape (that is, landscape change) is also enlightening, because it factors in the dominance of that vegetation type within the landscape. However, substantial areal changes of a vegetation type may still not have substantial ecological ramifications, if those changes occurred within some expected range of variation in which biological entities and processes have evolved (that is, HRV). Consequently, only by comparing the magnitude of change to some historical range of expected conditions can we fully ground the ecological implications of vegetation trends on ecosystem structure and function. Taking this into account, we developed a departure index, which compared current conditions to the HRV.

The conservation of biota at the region or landscape scale requires an understanding of population dynamics and some notion of how various biota may respond to environmental conditions at the scale of interest. Unfortunately, scientists and managers currently have, at best, only vague understandings of how the wide variety of species and populations may respond to varying vegetation patterns within the Basin. In lieu of such information, a premise of this chapter is that the endemic biota of the Basin will have the fewest risks to population persistence if regional and landscape vegetation patterns approximate those in which the biota have adapted over the last two millennia.

Estimation of broad-scale habitat departures from historical ranges of conditions provides an index of broad-scale vegetation changes in the context of natural systems and provides a means of developing coarse-filter inferences of the risks to species persistence (Hunter 1991, Hunter and others 1988). A primary assumption of this coarse-filter approach to habitat assessment is that the conservation of the areal extent of a community or habitat within its historical range could allow species adapted to that range to persist into the future.

In this chapter, the current broad-scale habitat availability within a region or a landscape was compared to the range of conditions expected historically (that is, HRV). It was assumed that a species' persistence within that geographic area was not at risk if the current area of that species' primary habitat (as described in Terrestrial Ecology, Chapter 5 of this document) fell within the

median 75-percent range of the historical data.[5] Risk to persistence increased substantially when habitat availability fell below the median 75-percent range of the historical data. Conversely, persistence likelihood within a geographic area increased as habitat availability exceeded the median 75-percent range of the historical data. Thus, the HRV not only provided a means of grounding habitat trends, but was also helpful in formulating inferences pertaining to the population persistence of species for which little is known.

Succession and Disturbance Regimes

An understanding of spatial relationships of succession and disturbance regimes provides an integrated way to comprehend response to disturbance and resiliency of the system. A regime provides an integrated classification of the relationships of energy, hydrologic, carbon-nutrient, food web, and evolutionary adaptation processes.

Short-term, secondary changes are commonly of more interest to people concerned with natural resource management, since they occur within temporal scales to which society can more easily relate. This is in contrast to primary successional responses which usually develop over much longer timeframes and affect the equilibrium relationships of biotic, climatic, hydrologic, pedogenic, and geomorphologic processes (Allen and Hoekstra 1992, Barbour and others 1980, Forman and Godron 1986, Jenny 1980, Naveh and Lieberman 1994, Rosgen 1996).

The successional response of communities, soil, and hydrologic systems to disturbances are inherent within the limits of a biophysical template. Parent material, topography, climate, associated biota, and adaptations associated with patterns of disturbance define the biophysical template that controls succession and disturbance processes. We refer to this part of a biophysical template as the "succession/disturbance regime." The succession/disturbance regime is the expected spatial and temporal response of biotic communities, soil, and the hydrologic system for a biophysical template.

Various types of disturbance regime classifications have been developed. Fire regimes have been developed by Agee (1994), Christensen (1985), Covington and Moore (1994), Heinselman (1983), Huff and others (1995), Morgan and others (1995), and Williams and Rothermel (1992) that use fire severity, frequency, or behavior as classification variables. Forest insect and pathogen regimes have been characterized by Filip and others (1996), Harvey (1994), Hessburg and others (1994), and Lehmkuhl and others (1994) that emphasize response to specific agents, regime response to groups of insects or pathogens with similar effects, and general insect and pathogen roles in different kinds of environments. Soil processes in relation to disturbance have been characterized by Harvey and others (1994a).

Successional cycles (similar to regimes) following fire and associated disturbances have been characterized by Agee (1995), Covington and others (1994), Fischer and Bradley (1987), Loucks and others (1985), Runkle (1985), and Shiplett and Neuenschwander (1994) using potential vegetation, length of cycles, or type of response to classify response. Oliver (1981) and Oliver and Larson (1990, 1996) classify stand dynamics based on types of forest structural development and frequency of disturbance. Multiple stable states have been described by Laycock (1991) and Tausch and others (1993) that classify stable communities in relation to history of grazing, paleoecological climate change, or invasion of exotics. Archer and Smeins (1991) and Bailey and others (1996) characterize response to grazing disturbance based on temporal or spatial patterns, and associated effects.

For this assessment, we provide a classification that integrates aquatic and terrestrial systems, and complexes of disturbance. We classified succession/disturbance regimes according to: (1) the severity of the disturbance relative to the subsequent change of community composition

[5] The median 75 percent of the historical range indicates the value is within 75 percent of the range from minimum to maximum. This excludes 12.5 percent of the range on each end.

and structure; (2) the time interval between disturbances; (3) the resiliency or rate of community development in response to the disturbance; and (4) the mosaic created by disturbance through time.

Changes in a biophysical template will subsequently alter a succession/disturbance regime. Laycock (1991), Lockwood and Lockwood (1993), and Tausch and others (1993) developed various concepts pertaining to community thresholds and successional response in time and space. A conceptual response of succession and disturbance to a biophysical template is presented in figure 3.6. Example "a" displays the HRV or native dynamics of a community prior to the effects of widespread and rapid human-induced change. The community represented in example "a" experiences frequent disturbances that generally maintain its composition and structure by consuming biomass that accumulates between disturbances. In figure 3.6 example "b," the succession/disturbance regime is changed through the investment of human energy, which increases the interval between disturbances such that biomass accumulates and is then used to produce particular values or commodities. The biophysical template has not been changed in example "b," and the system can return to the community and succession/disturbance regime of example "a" given similar disturbances and intervals as in "a." An example of this scenario includes the exclusion of fire from the dry forest PVG with harvest of the understory at intervals two to three times the HRV underburn-fire interval. In this same example, the succession/disturbance regime can be changed to reduce the interval between biomass reductions (for example by grazing), without altering the biophysical template.

In figure 3.6 example "c," the biophysical template has been altered, thus producing a different community that has a shorter interval between disturbances and an altered production capability. For example, the introduction of exotics such as cheatgrass (*Bromus tectorum*) in the dry shrub PVG, the conversion to dryland agriculture, or the introduction of white pine blister rust (*Cronartium ribicola*) in the moist and cold forest PVGs, has eliminated native species from the community. In this situation, neither protection nor disturbance will return these systems to their native regimes reflected by figure 3.6 example "a." However, a substantial investment of human energy to control disturbance and re-establish perennial species might allow the native system (example "a") to be approximated.

Figure 3.6 example "d" reflects a system where human energy is used to remove disturbance (for example, fire exclusion) or to produce high levels of biomass (for example, big game hiding cover or

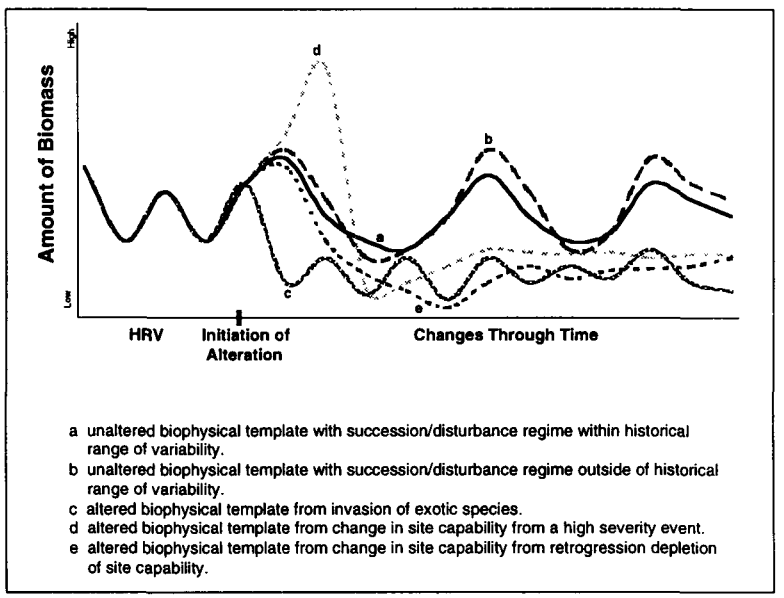


Figure 3.6—Conceptual diagram of the relationship of succession/disturbance regimes to the biophysical template, and the effects of alteration in the biophysical template [adapted from Tausch and others (1993)]. HRV refers to the historical range of variability and is defined as the pre-Euro-American settlement or "native" regime.

cover to maintain a particular visual condition). Eventually, the biogeochemical potential of these systems (that is, biotic and abiotic processes) is substantially disrupted as a result of a severe disturbance with an associated loss of soil and nutrients, and often an associated invasion of exotic species in severely disturbed environments. For instance, the eventual build up of biomass (that is, fuel) is so exaggerated that the ability of society to exclude high-severity fires is reduced.

In figure 3.6, example "e" represents a situation in which disturbances are very frequent (for example, excessive grazing) and do not allow biomass accumulation. Over time, the reduction of biomass disrupts nutrient cycling and is inadequate for soil protection. The subsequent erosion and loss of soil nutrients lessen site productivity as in example "d." In general, the more the biophysical template is altered, the less predictable the responses of the system are to disturbances, and the more human-provided energy subsidies are required to sustain resource outputs and biodiversity.

Landscape Patterns

Landscape patterns are ultimately a consequence of climatic, geomorphologic, and succession/disturbance processes (Forman 1995, Forman and Godron 1986, Oliver and Larson 1996). Geomorphology determines the patterns of soils and topography (that is, slope, aspect, and elevation). Climate and geomorphology are interdependent, and thus climatic patterns influence geomorphologic patterns. The converse is also true. The pattern of succession/disturbance regimes is a consequence of geomorphologic and climatic patterns, as well as biogeochemical processes. Succession/disturbance regimes can be mapped at any scale by classifying the type of landscape pattern and relating each regime to biogeochemical and landform characteristics.

Landforms are highly correlated with the dominant processes (that is, geomorphologic, climatic, and anthropogenic) that constrain the dynamics of landscapes. Landforms are subsequently associated with the spatial orientation of landscape mosaics within the Basin. Ownership patterns and land uses are also correlated to landform. For example, FS- and BLM-administered lands within the Basin were dominated by the foothills and mountains, and plains broad-scale landform types (table 3.2).

In most landscapes, the profile of landforms from the watershed divide to the drainage bottom follows a generalized and consistent pattern: transition from ridge to slope, to footslope, to terrace or plain, to toeslope, and then to the channel zone/draw. Different types of landscapes may vary in the profile of these landforms, both in presence of the different landforms and in their individual size, shape, slope, aspect, and juxtaposition to other landforms. However, we speculate that this generalized pattern occurs on all landscapes, regardless of size (for example subbasins, watersheds, subwatersheds). The shape and extent of the profile vary according to the broad-scale landform.

Table 3.2—Areal distribution of broad-scale (coarse) landforms[1] types on lands administered by the BLM and FS.

Landscape Landform	BLM/FS Land Ownership Area[2] (percent)
Foothills	12
Foothills and Mountains	39
Mountains	9
Plains	35
Mixed[3]	5
Total	100

[1]Dominant landform or mixture of landforms by subbasin.

[2]Data used from EIS data version; the area evaluated for the EIS data version is slightly larger in extent than is the areal extent of the earlier Assessment data version.

[3]Mixed = Plains, Foothills, and Mountains.

For example, in plains landforms, the landscape profile is extended and the ridge and channel zone/draw landforms may be many kilometers apart. Conversely, ridge and channel zone/draw landforms may occur within 1 kilometer of each other in the mountains broad-scale landform. Although landscape patterns are ultimately defined by biogeochemical processes, there are strong correlations between pattern and composition of potential vegetation types, landforms, land uses, and succession/disturbance regimes.

Biogeochemical Processes

Biogeochemical processes involve the transfer of chemical elements between biotic and abiotic components of an ecosystem. These processes can be described in terms of the accumulation, transfer, and recycling of chemical components associated with biological and physical energy cycles. At the regional scale, our assessment of biogeochemical processes focused on primary productivity, and the flow of carbon, nutrients, and water through the ecosystem. The assessment of biogeochemical processes may reveal the fundamental biological, physical, and chemical relationships responsible for vegetation dynamics. Quantifying and mapping the spatial distribution of fundamental processes such as photosynthesis, transpiration, and respiration can help identify areas that are productive; areas where carbon accumulates; and areas where vegetation may be physiologically stressed by water or nutrient deficiencies, insects, disease, or herbivory. Biogeochemical processes were simulated using a mechanistic biogeochemical model (BGC) (see Keane 1996) to provide a coarse summary of the productivity and the ecophysiological robustness of historical, current, and projected future vegetation under several climatic conditions.

Proper Functioning Landscapes

The investment of energy via human activities and subsidies that alter the rates and routes of key ecosystem processes, will likely produce landscapes having higher tendencies of equilibrium. A function or process that has been essentially removed from a system must be artificially provided in order to restore and maintain equilibrium within the context of the key ecosystem processes (Allen and Hoekstra 1992). Assessment and management that strive to achieve ecological equilibrium can be accomplished in two ways. An inherently complex strategy would be to develop a thorough understanding and a restoration plan of the impaired key ecological processes and functions. Alternatively, a simpler strategy would include an understanding and a restoration plan of the succession/disturbance regimes, life forms, and structures that initiate trends toward equilibrium. A value of the second approach is that it provides a means of rapid assessment of the landscapes composing a region, such that the context of the region can be used to plan the needs of its component landscapes.

In contrast to a state of disequilibrium (fig. 3.4), society can restore and maintain functioning ecological processes at appropriate landscape scales (fig. 3.7). We define "proper functioning landscapes" as those landscapes whose processes are in equilibrium, such that the rates and routes of key processes (including disturbance) are resilient and predictable. In other words, proper functioning landscapes contain the patterns and composition of succession/disturbance regimes, life forms, and structures that provide for ecological equilibrium. In essence, pattern and composition act as a surrogate for the complex relationships of the many processes and elements.

The concept of a proper functioning landscape provides a means of integrating human needs and values with ecological processes. The concept also provides the means of producing

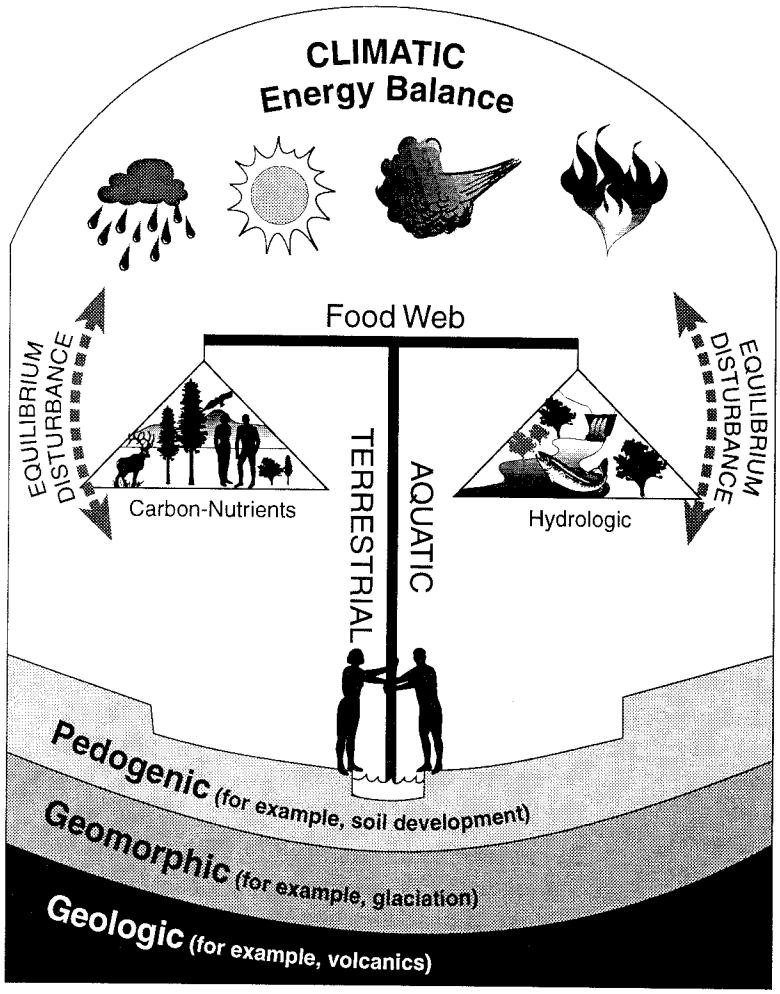


Figure 3.7—Schematic of proper functioning landscapes and re-establishment of equilibrium processes.

a more stable and predictable environment, while conserving biodiversity (Allen and Hoekstra 1992, Hunter 1991). Cumulative effects of humans on ecological processes can be ranked (table 3.3). Ecological functions can then be prioritized for restoration. Production of commodities emerges from this paradigm in response to ecological consequences, rather than as disruptions to system capabilities that result in disequilibrium. For instance, you can pick apples either by using a ladder or by cutting down the tree. Both methods result in an annual crop, but cutting down the tree results in loss of system capability. Assessing proper functioning landscapes provides a framework for a "contextual opportunity and risk analysis", and reiterates the ideas presented by Haynes and others (1996). In addition, the nature of the analysis for proper functioning landscapes provides an iterative system that can be "best fit" for achieving resource management goals within biophysical capabilities and inherent disturbance processes. An understanding of the means in which succession/disturbance regimes and general landscape patterns relate to different wildland management scenarios provides a basis for integrating the key ecological processes with anthropogenic disturbances.

The concept of the proper functioning landscape supports the concepts of sustainability, ecosystem health, and ecological integrity by providing a platform for their spatial integration. The concepts of ecosystem health, sustainability, and ecological integrity have typically been applied to generic ecosystems (such as forest, rangeland, or aquatic), or to specific elements of specific ecosystems (for example, endangered species such as the grizzly bear, spotted owl, or anadromous fishes), but not at a landscape scale. These concepts are difficult to integrate within a landscape that includes anthropogenic processes because they often conflict with one another. Management strategies intending to restore the "health" of one component can have deleterious effects on the health of another component.

Table 3.3 —General categories of human technology and their effects on ecological systems. The rankings are relative and are used simply to indicate intensity and spatial extent of effects on disruption of system processes.

	Human Ecological Activities					
Ecological Systems	**Hunter/ Gatherer**	**Migratory Hunter/ Herder**	**Non-migratory Herder/ Gardener**	**Rural Agriculture-Non-mechanized**	**Rural Agriculture - Industrial**	**Urban Industrial Agriculture**
Energy Input/Outflow						
Human Mechanical Energy	NE[1]	NE	NE	+[2]	++	+++
Fire Processes	NE	NE	+	++	+++	+++
Climatic Processes	NE	NE	+	++	+++	+++
Hydrologic Cycle						
River / Stream Flow	NE	NE	NE	+	+++	+++
Erosion / Sedimentation	NE	NE	+	++	+++	+++
Riparian / Groundwater	NE	NE	+	++	+++	+++
Carbon-Nutrient Cycles						
Photosynthesis	NE	+	+	++	+++	+++
Decay-Fire Consumption	NE	+	+	++	+++	+++
Nitrogen	NE	NE	+	++	+++	+++
Food Web						
Predation	+	+	++	+++	+++	+++
Material Distribution	NE	+	++	+++	++++	++++
Carnivores	NE	+	++	+++	+++	+++
Evolution						
Extinction	+	+	++	+++	++++	+++
Adaptations	NE	NE	NE	+	++	+++
Migration	NE	+	++	+++	++++	++++
Toxins / Pollutants						
Nutrient Excess/Loss	NE	NE	+	++	+++	+++
Toxic / Acidic Elements	NE	NE	NE	+	+++	+++
Carbon / Air Particulates	NE	NE	NE	+	+++	+++
Land Scale	Subregional	Subregional	Regional	Continent	Biosphere	Biosphere
Land - Ocean Connection	Continent-Ocean	Continent-Ocean	Regional-Regional	Subregion-Subregion	Landscape-Oceanscape	Landscape-Oceanscape

[1]NE = No Effect; during this period, human technological applications and/or population density were not intense enough to cause ecologically significant effects at the continental or regional scale.

[2]Relative effects values = Plus signs (+) indicate comparative order of magnitude; a nonlinear, exponential increase where ++ = $+^2$; +++ = $+^3$; and ++++ = $+^4$.

Conceptual Models of Natural Resource Management

We believe that there are two primary paradigms of managing natural resources within wildland settings. The contextual ecological paradigm uses a multi-scaled approach to address opportunities and risks within a landscape context. The independent element paradigm develops production, conservation, and restoration objectives for a single ecosystem element as though it were isolated from all other elements. We refer to these as the ecological and independent (also referred to as traditional) management models, respectively.

Ecological Model

Contextual opportunity and risk analysis using a landscape ecology approach provides a framework to: (1) identify risks at the regional scale for landscapes that have remnant populations of species, high quality habitats, high quality watersheds, or that are otherwise important from a biodiversity perspective; (2) identify conservation and maintenance strategies to sustain the values of high risk landscapes; (3) identify restoration and production opportunities that do not present risks to landscapes within a region; (4) identify restoration and production opportunities that can be scheduled spatially or temporally into low risk landscapes; and (5) identify restoration or production activities that can be scheduled temporally into high risk landscapes as adjacent landscapes are restored, or as particular elements (for example, endangered species) recover. A contextual opportunity and risk analysis requires a multi-scale assessment process (fig. 3.8) involving: (1) assessing trends, risks, and opportunities related to elements and landscapes, and their context within subregional and regional scales (that is, regional and subregional assessments), and (2) assessing the risks and opportunities within landscapes in relation to

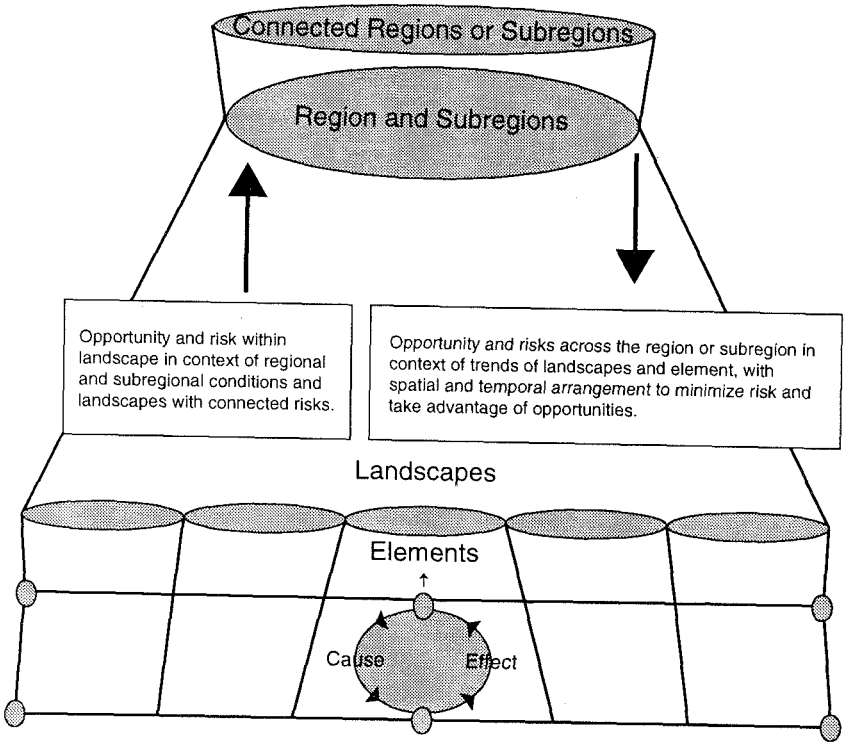


Figure 3.8—Contextual opportunity and risk management with a hierarchical landscape framework.

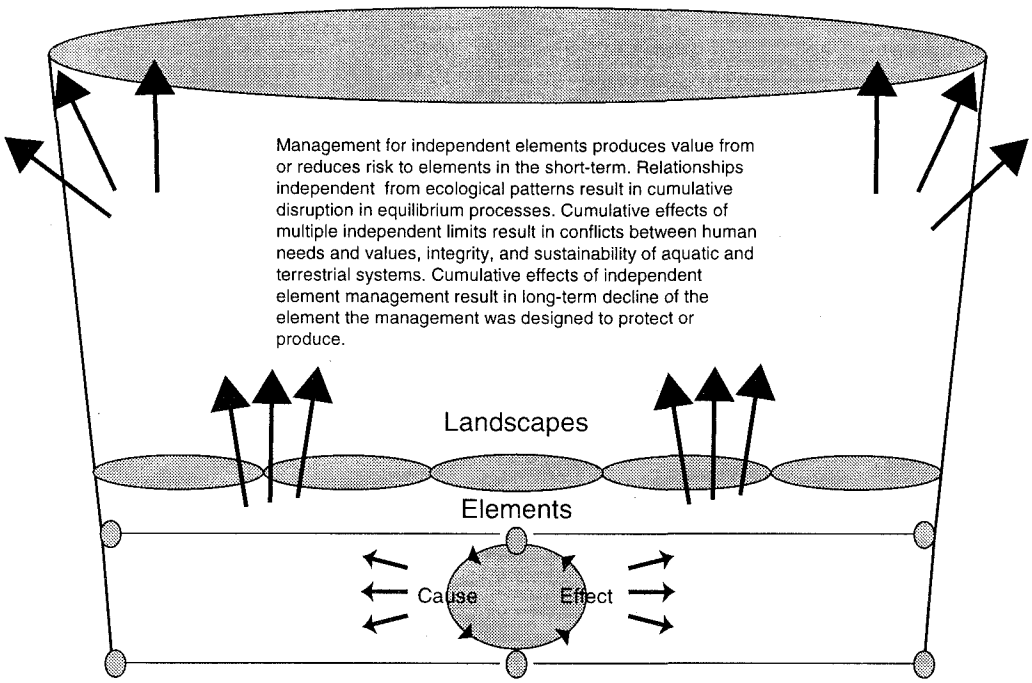


Figure 3.9—Independent element management without a hierarchical landscape framework.

connected landscapes and the context of the region or subregion (that is, landscape assessment). Regional and subregional assessments provide the context for individual elements and landscapes, whereas landscape assessments provide an understanding of mechanistic relationships. Thus, a multi-scale assessment provides the context and mechanisms, as well as the opportunities and risks within the area being studied. As a result, a multi-scale foundation can be developed to strategize a means to spatially and temporally arrange conservation, restoration, and production priorities, thus taking advantage of opportunities, while minimizing risks.

Independent Model

Independent element limits serve as constraints to conservation, restoration, or production activities that were not developed in concert with other elements at multiple scales (region, subregion, landscape), or in association with ecological processes. The independent element limit approach attempts to manage risks and deleterious effects through a "take" or "protect" approach wherever that element occurs (fig. 3.9). Such a strategy results in the cumulative disruption of ecological processes. This has been the traditional management model used for both commodity production and establishment of reserves.

Independent limits are designed to meet specific objectives for human needs and values such as commodity production, the conservation of rare elements, and the preservation of clean air and water. Examples include: socially and economically driven objectives for timber harvests; stream or riparian buffer widths to limit commodity activities; fire exclusion; tree or snag retention guidelines within harvest units (numerical); forest regeneration requirements and limitations of harvest unit size as directed by the National Forest Management

Act of 1976 (16 U.S.C. 1600); and livestock stocking rate and forage utilization guides. These types of independent element limits are designed to protect or exploit a particular ecosystem element, but are not assessed in the context of other elements across a landscape platform.

A management strategy that emphasizes the production or conservation of a single element, without a landscape context, will likely disrupt the pattern and process of other elements. Many independent element limits are also disassociated from their ecological processes. For example, buffer distances for streams and riparian areas are commonly designed using distances that have little relation to the landform and soil conditions. When arbitrary limitations (for example, buffer widths) are implemented, they commonly fragment ecological processes. In the long term, the disequilibrium caused by disruption of landscape patterns and processes may very well cause the decline of the element that the independent limit was designed to protect (Allen and Hoekstra 1992).

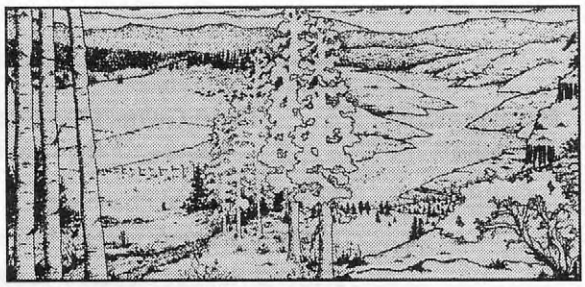
Scenarios of Management

In our assessment of historical and projected future trends of landscape condition within the Basin, we strived to address two very different approaches of managing natural resources. We simulated and evaluated a "contextual opportunity and risk" paradigm, along with the "independent element limits" paradigm. The "active (ecological) management" scenario was designed to incorporate the contextual opportunity and risk model, whereas the traditional "consumptive demand" and "passive" scenarios were designed to address the model of independent element limits. Active management is designed to produce properly functioning landscape patterns, whereas consumptive demand produces traditional commodity landscape patterns, and passive management produces traditional reserve landscape patterns. Although it may at first appear odd that we considered the traditional commodity and reserve landscape patterns to both be produced from one conceptual model, we hypothesize that the long-term effects of each strategy are nearly the same.

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OVERVIEW OF METHODS

Characterization of Multi-scale Landscape Relationships

These methods are an overview of the key analyses that were conducted to assess landscape dynamics. For more detail we refer the readers to Hann and others (1997), Hessburg and others (1996a), Ottmar and others (1996), and Keane and others (1996b).

The broad-scale data for this assessment were coarse grained (low resolution), but continuous across the Basin. Conversely, the mid- and fine-scale data were finer grained (higher resolution), but were sampled from the Basin and therefore not continuous. Using a multi-scale approach improved our understanding of the relationships among fine-, mid-, and broad-scale vegetation attributes.

Plot data (fine-scale) obtained from various agencies were inconsistent in type, methods, and data quality control. Data were relatively consistent within, but not among administrative units. The most consistent statistical correlation of the plot data was found within the administrative unit that collected the data. Very few attributes demonstrated adequate consistency of values and interrelated logical relationships to provide confidence in the use of plot data as a whole. Consequently, we only used a very reduced data set that had consistent and standard methodology, and that had been corrected for errors in logical relationships.

Although mid-scale vegetation inventory map data were available from various sources, such as satellite remote sensing and forest, rangeland, and wildlife habitat inventories, they were as variable and inconsistent as the plot data. Legends were difficult to correlate among different maps; even though map legend attributes were labeled identically among maps, the attributes themselves were often different. Furthermore, most of the vegetation maps did not have corresponding potential vegetation maps of the same scale, and major problems with logical relationships existed for those that were of the same scale. Consequently, we were unable to use existing mid-scale vegetation-inventory maps and were forced to develop a new set of mid-scale data that was consistent and rectified with a potential vegetation layer (see Hessburg and others 1996a). The mid-scale data set was derived from a two-stage, stratified random sample of paired "current" and "recent historical" aerial photography covering 337 subwatersheds from 43 subbasins. The areal coverage of the subsample was equivalent to approximately 5 percent of the Basin. Many of the recent historical data (1930-1960s), particularly on rangelands, were derived from relatively recent aerial photography. Conversely, some of the current aerial photography (also primarily on rangeland-dominated subwatersheds) was relatively old (1980-1990s).

Table 3.4—Total percentages by management region, land ownership group, and management class.

Management Region	Land Ownership Group, Management Class[1]	Percent of Management Region	Percent of Total Basin
EEIS[2]	BLM/FS[3] Natural Processes	9.9	4.8
	BLM/FS Roadless Human-Influenced Processes	1.7	0.8
	BLM/FS Roaded Human-Influenced Processes	25.2	12.3
	BLM/FS Roadless Natural/Human-Influenced Processes	1.2	0.6
	BLM/FS Roaded Natural/Human-Influenced Processes	3.4	1.6
	National Park and Other Wilderness	0.4	0.2
	Private or Other Lands	47.7	23.1
	Tribal, State, or Other Public Land	10.6	5.2
Total		100.0	48.6
UCRB[4]	BLM/FS Natural Processes	14.4	7.4
	BLM/FS Roadless Human-Influenced Processes	5.5	2.8
	BLM/FS Roaded Human-Influenced Processes	30.0	15.4
	BLM/FS Roadless Natural/Human-Influenced Processes	8.7	4.5
	BLM/FS Roaded Natural/Human-Influenced Processes	2.9	1.5
	National Park and Other Wilderness	1.9	1.0
	Private or Other Lands	28.2	14.5
	Tribal, State, or Other Public Land	8.4	4.3
Total		100.0	51.4
EEIS and UCRB Total			100.0

[1]Information from EIS data files.

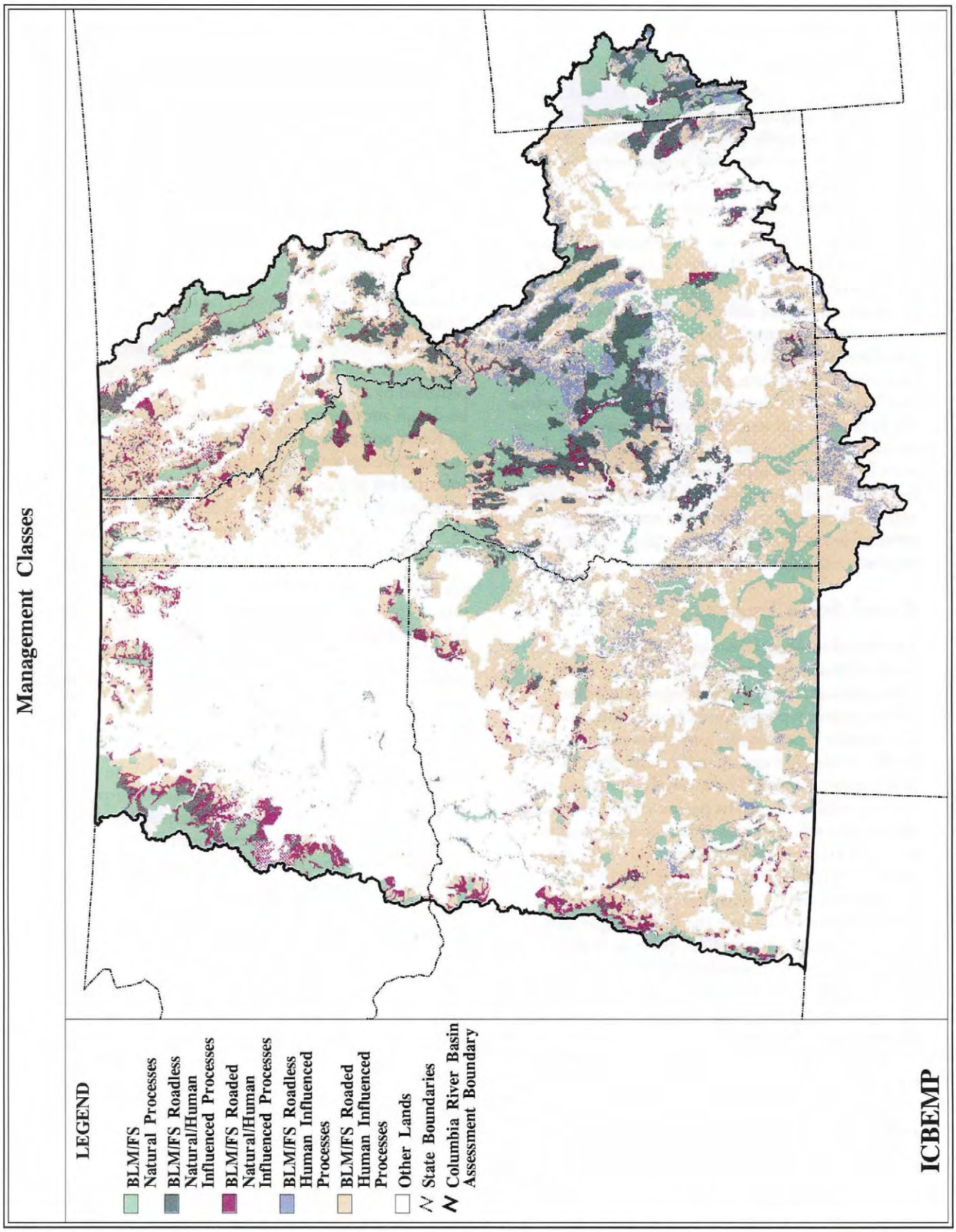
[2]Eastside EIS assessment area.

[3]Bureau of Land Management- and Forest Service-administered lands.

[4]Upper Columbia River Basin EIS assessment area.

Consequently, the recent historical and current photographic pairs spanned various temporal periods [see Hessburg and others (1996a) for further details of the mid-scale sampling design].

The mid- and fine-scale data that were strongly correlated with broad-scale data could be extrapolated across the entire extent of the Basin. We observed several attributes that were correlated among the three scales when stratified by geographic area: land ownership, management strategy, and groups of potential vegetation groups (PVGs). We divided the Basin into two geographic areas or management regions: the Eastside (EEIS) and the Upper Columbia River Basin (UCRB). Land ownership and management strategies were stratified into eight management classes (table 3.4). Because our analysis focused on BLM- and FS-administered lands, we further aggregated the non-BLM- and FS-administered lands into a single "Other" lands category (map 3.7).



Map 3.7—Management classes for the Basin (EIS data). This version of the management classes was developed to incorporate roaded and non-roaded areas as an additional modifier to the management process.

Often, the relationships among the three different scales were complex and not immediately obvious. In order to correctly interpret the differences among scales, we often had to qualitatively or quantitatively develop a broad-scale correlate to assess trends of mid- and fine-scale conditions.

For example, although we could assess the broad-scale areal extent of fires, the mid- and fine-scale patterns of fuel types and fire behavior differed substantially. These differences were apparently due to the management history of an area — which was correlated with the management objectives of that area [for instance, managed as wilderness or roadless areas (wilderness-like), or managed primarily by human-influenced processes (non-wilderness or roaded areas)]. Consequently, mid- and fine-scale fire behavior attributes (that is, crown fire, fire severity, fire interval, and smoke) would not necessarily be the same for two areas having similar types of broad-scale fire and/or physiognomic vegetation conditions.

Broad-Scale Trends

The broad-scale variables used to assess regional levels of change included PVTs, PVGs, cover types, structural stages, physiognomic types, physiognomic type groups, terrestrial communities, disturbance types, roads, and strata of lands having similar ownership and management objectives (management class). These variables were assessed for historical and current period conditions and projected for future scenarios. Current conditions reflected a coarse, general depiction of the Basin circa 1990 (representative of the 1985-1995 decade). Historical conditions reflected a coarse, general depiction of how the Basin might have appeared circa 1850 to 1900, prior to major changes caused by Euro-American settlement. The "native" system refers to the regime prior to Euro-American settlement (that is, the historical range of variability). In some cases "historical" may be used in a generic sense to refer to HRV. The native regime, with respect to the HRV, was simulated. The broad-scale vegetation attributes of the current period were derived from 1991 satellite imagery. We formulated two sets of historical, current, and future projection data. The first set was summarized in 1995 as a preliminary assessment used by the Environmental Impact Statement (EIS) teams to formulate a preliminary set of land-management alternatives. A second set of more refined data was summarized in 1996 for the EIS teams. The processes of defining cover types, structural stages, and PVTs are described by Menakis and others (1996). The vegetation dynamics models are described by Byler and others (1996) and Long and others (1996). A detailed documentation of data analysis procedures was provided by Hann and others (1997). Regional and landscape modeling procedures were documented by Keane and others (1996b). Methods pertaining to the development of primary Geographic Information System (GIS) themes and input layers were described by Menakis and others (1996) and in Chapter 8, Information System Development and Documentation, of this document.

Cover types and structural stages were aggregated into terrestrial communities (appendix 3-B) to assess habitats, and into physiognomic types (appendix 3-C) to assess successional and disturbance processes. Although, the cover types and structural stages assigned to terrestrial communities remained the same between the 1995 and 1996 data sets, assignments to physiognomic types were modified in the 1996 version (see appendix 3-D). The 1995 version of physiognomic types did not incorporate shade-tolerant/shade-intolerant relationships for the forest types, but they were reported in a separate set of tables for the 1995 version. After the 1995 analysis, we incorporated the shade-tolerant/shade-intolerant assignments with the broad-scale physiognomic types. The 1995 version was reported by Hessburg and others (1995), because it was a key summary used by the EIS teams. In the 1996 version, we aggregated the physiognomic types into physiognomic type groups to reduce the number of stratifications. If given another opportunity to analyze the data, we would not have developed two independent groupings of cover types and structural stages (that is, terrestrial communities and physiognomic type groups).

Instead, we would use our final physiognomic type groups, stratified by PVG, for both the terrestrial habitat assessment and the evaluation of succession and disturbance processes.

Menakis and others (1996) compared the broad-scale classes of potential vegetation and current period vegetation, to mid-scale data presented in Hessburg and others (1996a)(table 3.5). The comparison applied to the current condition of the broad-scale PVTs and PVGs, cover types, life forms, structural stages and groups of structural stages, terrestrial communities, and physiognomic types and physiognomic type groups. These comparisons indicated that the broad-scale data was, for the most part, less than 40 percent comparable to the mid-scale data on a cell-to-cell basis. Consequently, we had moderate confidence in cell-to-cell comparisons except for types with large amounts that occur in uniform patches. However, the comparability was substantially improved when the broad-scale data were summarized by relatively large geographic areas. For example, the mid- and broad-scale cover types, structural stages, PVTs, and physiognomic types had an average comparability of 48, 58, and 76 percent at the subwatershed, subbasin, and Basin levels, respectively. For groups or types with large amounts this increased at each scale by 10 to 30 percent. Thus, increasing the size of the geographic area at which the data was summarized, grouping types, and focusing on dominant types increased the comparability of our mid- and broad-scale data.

Of the vegetation attributes tested, structural stages were the most difficult to map with high comparability between the two scales. Aggregation of vegetation attributes into coarser classes (for example, from physiognomic types to physiognomic type groups, or from PVTs to PVGs) or focusing on dominant types or groups also improved the comparability of mid- and broad-scale data. Consequently, we restricted the majority of our analyses of broad-scale landscape dynamics to areal trends of coarse classes or dominant types that were summarized for relatively large geographic areas (such as, subbasins, clusters of subbasins, ERUs, and the Basin).

Biophysical Template

The PVGs (appendix 3-A) were used as indicators of broad-scale biophysical templates. We assessed the historical and current areal extent of each of the PVGs in relation to its general environment, land ownership pattern, composition of physiognomic types, and predominant disturbance regimes. Each of the PVGs was stratified at 1,200 meters mean sea level (MSL) to assess trends above and below that elevational breakpoint. In addition, we used a composite assessment to index the departure of the current PVG from its historical succession and disturbance regimes into three classes: low, moderate, and high.

Data for the assessment of PVGs were then derived from simulations of the historical and current periods using the Vegetation Dynamics Development Tool model (VDDT) (Beukema and Kurz 1995), the Columbia River Basin Succession Model (CRBSUM) (Keane and others 1996b), ecological vegetation and site plot data (Hann and others 1997), and historical vegetation mapping with comparison to current photo points (Losensky 1994, Losensky 1995). The dynamics of the historical physiognomic types were simulated using a single 100-year run of the CRBSUM (Keane and others 1996b). We believed that a 100-year simulation of the historical dynamics captured the majority of the shifts in cover types and structural stages, and the associated succession and disturbance processes that would have occurred prior to Euro-American settlement and industrialization of the Basin. However, through sensitivity testing with the VDDT models we found that a 300-year period was generally required to produce consistent pattern repetitions (Hann and others 1997). Consequently, we conducted an additional CRBSUM historical simulation for 400 years.

Table 3.5—Comparison of broad-scale and mid-scale current vegetation and potential vegetation classes.

		Cell-to-Cell Overlay Comparison			Area Composition Comparison Percent Agreement[1]		
Name	Number of Classes	0[2]	60	90	Complete Subsample (Basin)	4th Field HUC (subbasin)	6th Field HUC (subwatershed)
Cover Types (CT)	41	31.6 (3,156.9)[3]	36.3 (1,984.3)	44.6 (854.1)	NA[4]	NA	NA
CT Groups	26	34.0 (3,156.9)	39.5 (2,012.3)	50.0 (885.6)	84.2	65.6	53.4
CT Lifeform	10	64.3 (3,156.9)	68.9 (2,536.0)	76.7 (1,562.8)	91.7	81.5	74.4
Structural Stages (SS)	20	23.4 (3,156.7)	28.4 (1,689.5)	35.9 (652.5)	63.9	49.9	40.1
SS Group	5	63.7 (3,156.7)	67.3 (2,566.1)	74.2 (1,588.9)	91.6	81.9	74.4
Physiognomic Type Groups (PTG)	12	35.2 (3,146.9)	39.3 (2,043.1)	48.2 (883.6)	80.5	65.6	54.6
Potential Vegetation Types (PVT)	41	22.1 (2,310.5)	24.1 (1,486.0)	27.2 (635.6)	74.3	51.4	44.0
Potential Vegetation Groups (PVG)	14	44.3 (2,307.6)	48.6 (1,650.9)	56.7 (826.4)	88.3	66.8	60.6

Source: Menakis and others (1996).

[1]Complete Subsample = all mid-scale data [3% of the landscape characterization area (LCA); 3,156,873 ha].
4th Code HUC Subset =sampled subbasins (average size: 73,416 ha).
6th Code HUC = sampled subwatersheds (average size: 9,368 ha).

[2]Number of Modal 100-m^2 pixels found in a 1000-m^2 pixel;
Modal = percentage of 100-m^2 cells within 1 km^2 that were classified as the same type;
0 = direct cell-to-cell comparison, no class was required to dominate the 100 cells of mid-scale data;
60 = at least 60 percent of the 100 cells of mid-scale data had to be classified as the same type before a comparison was made with a broad-scale cell;
90 = at least 90 percent of the 100 cells of mid-scale data had to be classified as the same type before a comparison was made with a broad-scale cell.

[3]Percent agreement between mid- and broad-scale pixels (area of sample in km^2).

[4]NA = Not Applicable.

Succession and Disturbance Processes

Vegetation structure and composition changed as a result of the interaction between disturbances and the subsequent successional responses that occurred. These processes changed the live and dead attributes of vegetation composition and structure, and the associated site conditions such as soil cover and soil organic matter.

We used the PVTs and the PVGs (appendix 3-A) to stratify the succession/disturbance regimes by biophysical environment. The PVTs were named for the dominant vegetation that could potentially grow on a site in the absence of disturbance, and were grouped into PVGs based on similar moisture and temperature gradients (Menakis and others 1996). Succession and disturbance processes were described and modeled for each PVT within the Basin (Beukema and Kurz 1995, Byler and others 1996, Hann and others 1997, Keane and others 1996b, Long and others 1996). A VDDT model (Beukema and Kurz 1995) was developed for each PVT to simulate cover type and structural stage changes that were attributable to the predominant disturbances of the historical, current, and future scenarios through time (Byler and others 1996, Keane and others 1996b, Long and others 1996). The VDDT models and Losensky's (1994) historical vegetation information suggested that year 0 of the historical simulation represented a generalized historical condition of cover type and structural stage dynamics. Modeling suggested that the PVTs in the Basin generally required 250 to 400 years to cycle and stabilize at a relatively constant composition of vegetation cover types and structural stages. These models were also used to assess trends of regional and landscape composition and structure.

Our evaluation included what we believed were the primary disturbance regimes. The evaluation took into account fire severity and fire interval (Morgan and others 1996), recent fire occurrence (Menakis and others 1996), roads (Menakis and others 1996), grazing (Burkhardt 1996), climate (Ferguson 1996a, 1996b, 1996c, 1996d), and human activities (Woods and Horstman 1996). In addition, we considered the paleoecological influences reported by Mehringer (1996). The simulations incorporated succession rates and disturbance effects in the modeling of regional and landscape composition and structure changes. Results of historical, current, and future modeling of different types of management were summarized by Keane and others (1996b) and Long and others (1996). Keane (1996) reported the results of modeling ecosystem processes. Response coefficients for modeling fire behavior and effects were adopted from Hardy and others (1996). Results of modeling the different effects of smoke from wildfire and prescribed fire were summarized by Holsapple and Snell (1996). Schoettle and others (1996) summarized the dynamics of air quality.

We developed a classification that separated succession/disturbance regimes into (1) regimes that generally maintained communities and (2) regimes that cycled communities through successional stages (table 3.6). Within these two classes, we provided for subdivisions based on the interval between disturbance, types of structures created by the disturbance, and the associated disturbance severity. Because the classification system was based upon succession and disturbance processes, it allowed us to readily predict succession and disturbance patterns without having detailed information on the causal disturbance agents (for example fire, drought, insect and disease infestation, stress, or wind). These regimes were developed from interpretations of plot data and historical photo points (Hann and others 1997; Losensky 1995) along with reference to the current succession and disturbance literature discussed in the introduction to this chapter.

Morgan and others (1996) mapped fire regimes that were based primarily upon frequency (the interval between successive fires) and severity (the fires' effects on the dominant overstory vegetation). They used two sets of decision rules (one set for historical regimes and another set for the current period regimes) to assign fire regime classes to cover types. Assignments were based upon published literature, a fire history database (Barret 1995), and expert opinion.

Table 3.6—Succession and disturbance regimes developed for broad-scale assessment.

Regime (Code)	Average Disturbance Interval (years)		Severity	Description	Examples
	Intermediate Mixed[1] / Non-lethal[2]	Lethal			
Cycling	NA[3]	1+	Moderate-High	Succession is reinitiated by disturbances that are lethal[4] to most or all of the upper-layer and some or all of the lower-layer vegetation.	
Accelerated Cycle (AC)	5 - 50	30 - 300	Moderate	Intermediate disturbances that accelerate growth of disturbance-adapted species, often creating an irregular fine-scale mosaic of patches of different vegetation structures. Eventually cycled by a lethal disturbance.	Conifer potential vegetation types (PVTs) with non-lethal or mixed fires, insect, or disease effects that thin the stands of susceptible species, allowing the resistant species to accelerate growth; shrub PVTs with non-lethal or mixed fires, insects, disease, grazing, or beaver cutting effects that open-up stands.
Long Cycle (LC)	NA	101 - 300	High	Successional cycle is long, with reinitiation from seedlings and some resprouting. Intermediate disturbances may happen but they have minimal effects on composition, structure, and density.	Conifer PVTs with longer-lived, fast-growing, shade-intolerant, conifer species that dominate after crown fires, insect attacks, windthrow, or other lethal effects that cycle the community.
Moderate Cycle (MC)	NA	5 - 100	Moderate	Successional cycle is moderately long, with reinitiation from a mixture of resprouting plants and seedlings. Intermediate disturbances may happen but they have minimal effects on composition, structure, and density.	Shrub PVTs where succession after lethal burning, herbicide application, chaining, or insect topkill takes from 10 to 25 years to reestablish the dominant shrub layer; conifer or broadleaf PVTs with short-lived, fast-growing, shade-intolerant, conifer or broadleaf species that dominate after crown fires, insect attacks, windthrow, or other lethal effects that cycle the community; floods in floodplain areas that cycle broadleaf, conifer, or shrub vegetation; cutting or flooding by beaver in riparian areas; avalanche paths; conifer PVTs where lethal disturbance cycles the vegetation prior to dominance by conifers, keeping the system in an herb or shrub dominated stage.
Retrogressive Cycle (RC)	NA	10 - 50	Low	Disturbances that reverse successional direction to an earlier seral stage, typically an annual or biannual cycle of grazing stress insect/pathogen mortality, drought mortality, or pollutant mortality.	Conifer PVTs with fire exclusion resulting in a dense upper layer that undergoes relatively little annual mortality from insects, disease, and stress that cumulatively are a lethal effect to the dominant vegetation over a long period (10-50 yrs); grazing that selectively causes mortality in relatively small annual increments such that over a long period there is a complete change in dominant vegetation composition or structure; invasion by exotic plants that can compete more effectively than native plants due to environment or disturbance (grazing, fire, tillage, or roads).

Table 3.6 (Continued).

Short Cycle (SC)	NA	1 - 4	High	Successional cycle is very short with a composition of new seedlings, annuals, biennials, or weedy perennial species.	Annual high water in channel zone/draw area adjacent to the channel; annual tillage in agriculture; soil or gravel surfaced roads with annual grading and runoff; annual grass and weed dominated vegetation with high amounts of bare soil; annual avalanche path areas.
Very Long Cycle (VC)	NA	301+	High	Successional cycle is very long, with reinitiation primarily from seedlings. Intermediate disturbances may happen but they have minimal effects on composition, structure, and density.	Conifer PVTs with a sequence of dominance by shade-intolerant tree species that succeed to shade-tolerant tree species and then are cycled by crown fires, insect attacks, windthrow, or other lethal effects on the dominant upper layer vegetation.
Maintenance	5 - 50	NA	Low	Succession is maintained in one structural stage by periodic disturbances that do not cycle the upper-layer vegetation but are lethal to species in the lower layer that would grow up into and change the upper layer.	
Frequent Maintenance (FM)	5 - 25	NA	Low	Intermediate effects produce relatively uniform upper and lower layers of vegetation with relatively short intervals between maintenance disturbances.	Warm conifer PVTs with non-lethal fires, insects, disease, or grazing effects that selectively remove the susceptible understory species allowing for recruitment of resistant species into the overstory; warm grassland, shrubland, and conifer PVTs with non-lethal and mixed fires, insects, disease, or grazing effects that maintain the dominant grass or forb vegetation.
Less Frequent Maintenance (GM)	26 - 50	NA	Low	Intermediate effects produce relatively uniform upper and lower layers of vegetation with moderate intervals between disturbances.	Cooler conifer PVTs with non-lethal fires, insects, disease, or grazing effects that selectively remove the susceptible understory species allowing for recruitment of resistant species into the overstory; cooler grassland, shrubland, and conifer PVTs with non-lethal and mixed fires, insects, disease, or grazing effects that maintain the dominant grass or forb vegetation.
Irregular Maintenance (IM)	26 - 50	NA	Low	Intermediate effects produce relatively irregular upper layers of vegetation and multiple lower layers.	Wet conifer, broadleaf, or shrub PVTs with mixed fires, insects, disease, or grazing effects that selectively remove small patches of susceptible species in any vegetative layer allowing for recruitment of resistant species into the structure.

[1]Mixed disturbances maintain a salt and pepper, fine-scale mosaic within a patch by cycling clumps and gaps; mixed disturbances leave patches intact, but maintain a rough textural pattern of clumps and gaps; mixed disturbances can be lethal (maintaining scattered gaps or creating gaps); or non-lethal (creating gaps that are intermingled with clumps).

[2]Non-lethal disturbances do not cycle the upper layer of vegetation; non-lethal disturbances selectively thin susceptible plants in all layers of the patch.

[3]NA = Not Applicable.

[4]Lethal disturbances cycle the upper layer of vegetation in the patch, and may cycle the lower layers.

The decision rules for the current regimes reflected the influence of fire suppression, invasion of exotic plants, and other human-caused factors. Neither of the rule sets used vegetation structure nor fuels for modeling potential fire behavior. Consequently, we had less confidence in the current fire-regime map and associated regime change maps, than in the historical fire regime map. However, we believe that the indices of historical and current fire regime classes could be confidently used to assess broad-scale trends. In addition, if used in conjunction with other proxy variables, we believe that the fire regime classes could also be used to estimate potential fire risk and fire behavior.

We used five indices to estimate regional risks of severe fire behavior and severe fire effects. The five indices were based on the proportion of an ERU that had: (1) mixed or lethal historical fire severity; (2) an increase of fire severity or decrease of fire frequency (that is, an increase of infrequent and very infrequent classes) between historical and current periods; (3) a high probability of fire occurrence; (4) a high probability of severe fire behavior; and (5) the presence of rural/wildland interface. Fire-occurrence probabilities were based on seven years (1986-1992) of subwatershed fire-occurrence records. The fire behavior index incorporated elevation, precipitation, and temperature gradients. The overall index of severe fire risk was calculated as the average value of the five indices described above (see Hann and others 1997, Long and others 1996, and Menakis and others 1996 for a more detailed description of methodologies).

We also developed indexes for precipitation, seasonal climate gradients, and topoedaphic conditions to use in assessing succession and disturbance processes (Hann and others 1997). Coefficients were calculated for rule sets to estimate amounts of net wildfire, wildfire suppression cost, forest crown wildfire, forest surface/mixed wildfire, forest insect/disease, smoke, and soil disturbance. Subbasin landforms were developed by identifying the dominant subsection landforms for each subbasin.

Road density classes were mapped from a rule set using categories of land ownership, land use, life form, elevation, slope, and a GIS road data set obtained from United Parcel Service (Menakis and others 1996). The density classes and relationships to the categories were extrapolated from mid-scale subwatershed road data. Although we were not able to test the extrapolation rule set, or conduct a comparison analysis between the final broad-scale road density map and the sampled subwatersheds, we were able to evaluate the logic of the road density classes and refine the rule sets. Although we do not have a high degree of confidence in the absolute values of the broad-scale road density classes, we do believe that they can be appropriately used to assess broad-scale trends of relatively large geographic areas (for example, clusters of subbasins, basins, and ERUs).

The mid-scale subwatershed road data, photo points, and reconnaissance notes were used to develop interpretations of fine-scale effects of roads (Hann and others 1997).

Biogeochemical Processes

Biogeochemical processes were simulated using a mechanistic biogeochemical model (BGC) to improve our understanding of the fundamental processes responsible for vegetation dynamics, and to provide a coarse summary of the productivity and ecophysiological vigor of historical, current, and projected future vegetation under several climatic conditions. The routing of key elements through the critical subsystems of the terrestrial ecosystem was simulated. We believed that the assessment of productivity and the flows of water, carbon, and nutrients through the ecosystem would provide important insights for evaluating landscape relationships.

The BGC model used daily and annual timesteps to simulate the flows of carbon, nitrogen, and water through an ecosystem. The BGC model incorporated the critical subsystems through which carbon, nitrogen, and water must flow,

including the atmosphere, soil, and the roots, stems, and leaves of plants. The model simulated the flow of carbon, nitrogen, and water across these subsystems using physiological process relationships. For example, carbon is transferred from the air to the leaves, stems, and roots via photosynthesis. The carbon lost from leaves, stems, and roots is transferred to the soil and air via litterfall and decomposition. The driving variables used to simulate the physiological relationships included precipitation, temperature, and radiation. Atmospheric carbon is fixed by photosynthetic plants. The rates of photosynthesis, and consequently carbon fixation, are dependent upon available solar energy, temperature, water, and humidity. Carbon is released back into the atmosphere from autotrophic (green plants) and heterotrophic (microbial) respiration processes that are primarily dependent on temperature. Water is absorbed by plants through the roots depending on the soil-water potential and then released into the atmosphere via transpiration. The rate of transpiration is mostly governed by humidity, temperature, and available soil moisture.

The BGC model was developed as an improvement on previous models for single-tree, single-year, daily water balance (H_2OTRANS), and community level processes (Running and Coughlan 1988, Running and Gower 1991). The current version of the BGC model simulated processes across all biomes, including human-altered vegetation such as agricultural and exotic-dominated forblands. Biogeochemical processes were simulated at a 4-square-kilometer resolution because the weather data were only available at that scale. A detailed discussion of the BGC model and its application to the landscape ecology assessment of the Basin is contained in Keane and others (1996b) and Thornton and others (in press).

The current and historical cover type and structural stage maps were used to develop the input layers required by the BGC model. The current data layers described conditions as they occurred circa 1990 (representation of the 1985-1995 decade), while the historical layers described conditions as they occurred around the turn of the century (circa 1850-1900). The number of potential-output variables was limited to gross photosynthesis, maintenance respiration for each carbon subsystem, evaporation, transpiration, and the coefficients controlling soil and litter decomposition. Summary maps were generated in which the grid cells were attributed by the sum of each variable, for the historical, current, and future management scenario maps. The summary maps were used to generate several spatial data layers that projected ecosystem processes in the Basin. Four indices developed by Thornton and White (1996) were selected to assess physiological processes: (1) net primary productivity, (2) carbon stress, (3) water stress, and (4) nutrient availability.

Net primary productivity index

Simply stated, the net primary productivity (NPP) index is an indicator of the growth potential of vegetation within an ecosystem. Net primary productivity was simulated from the annual summaries of gross photosynthesis (GPSN) and maintenance respiration for all carbon subsystems ($\sum$MR). Net primary productivity was estimated as:

$$NPP = GPSN - \sum MR$$

An estimate of growth respiration was not deducted from NPP. Consequently, the estimate of NPP should be reduced by 20 to 40 percent in order for it to be comparable to field estimates.

Carbon stress index

The carbon stress index (CSI) was used to approximate the influence of respiration costs on the production potential of the vegetation. The CSI was estimated from the ratio of maintenance respiration to gross photosynthesis and consequently described the balance between annual gross productivity and maintenance costs. CSI was estimated as:

$$CSI = \sum MR / GPSN$$

CSI values close to 1.0 indicated that most of the annual production of photosynthate was consumed by respiration costs attributable to the maintenance of living tissue. Values near zero suggested that a large surplus of the annual photosynthate production was available for new growth, production of protective compounds, or reproduction.

The CSI functioned as an indicator of ecophysiological health and the vegetation's relative susceptibility to stress, or disease, and insect attack. It was more diagnostic in these respects than NPP, because it placed vegetation types having different productive potentials on the same scale. This allowed for the comparison of relative vigor or, alternatively, their susceptibility to insects and disease. For example, in the comparison of a late-seral forest type with an early-seral forest type, NPP estimates might be higher for the late-seral forest than for the early-seral forest; there is, therefore the potential interpretation that the older forest is more vigorous or less susceptible to disease or drought. Depending on the amount of living tissue being supported in each of these communities, the CSI might reveal that the older forest used 80 percent of its annual photosynthate production in maintenance costs, while the early-seral forest used only 40 percent, thus providing an alternative interpretation of the relative health of the two communities. CSI values of greater than 0.8 indicated high carbon stress and poor ecosystem health. CSI values of 0.6 to 0.8 indicated moderate stress, and values less than 0.6 indicated healthy, unstressed ecosystems. Strong carbon balance (that is, CSI < 0.6) had sufficient carbon available for growth, reproduction, and defensive chemistry. Weak carbon balances had less energy allocated to the carbon sinks.

Some values of CSI exceeded 1.0, which suggested that the annual maintenance respiration costs exceeded the gross production of photosynthate. In the short term, perennial vegetation types capable of using stored carbon are able to tolerate carbon deficits. For example, a mature forest may be able to withstand a particularly dry year or an insect defoliation event resulting in a net loss of photosynthate by using carbohydrate reserves stored in stem and root tissues. However, during these periods, the carbon reserves are reduced and mortality may result if production is low, or respiration costs are high in successive years. Annual plants or seedlings of perennials do not have adequate reserves, and would likely succumb to these conditions in a single year. Since the vegetation types and structural stages used in the simulations were determined externally in the model and no mechanistic feedbacks existed between vegetation types, potential mismatches between site conditions and vegetation type or structural stage could occur. Consequently, CSI values exceeding 1.0 were possible. Similarly, the spatial and temporal variability of meteorological conditions and vegetation communities could result in exceedingly high values for the CSI.

Water stress index

Water availability is a key limiting factor for the vegetation throughout a large proportion of the Basin. The water stress index (WSI), estimated as the ratio of total annual evapotranspiration (ET) to total annual precipitation (PPT), was an indicator of water availability.

$$WSI = ET / PPT$$

Values approaching 1.0 were generally indicative of arid conditions, where low soil moisture likely limited production. Values close to 1.0 may also have occurred in areas having substantial precipitation, but where the evaporative demand was high. Consequently, vegetation having relatively high leaf areas could be susceptible to water stress in such regions. Low WSI values (< 0.65) were indicative of a water surplus, which under annual soil water equilibrium conditions, was manifested as hydrologic outflow. Sites with low WSI values typically occurred in areas having abundant winter precipitation, such as subalpine and alpine areas. However, low values could also occur in sparsely vegetated sites and at lower elevations, where precipitation exceeded bare soil evaporation.

Moderate WSI values of 0.65 to 0.85 suggested that water could be limiting to plant growth during some part of the growing season. High values (> 0.85) indicated water could be limiting to plant growth and most precipitation was probably used by the vegetation or lost through evaporation, and there was little to no hydrologic outflow or groundwater recharge.

Nutrient Availability Index

Many of the components required for a thorough assessment of broad-scale nutrient availability could not be adequately estimated. Although the analysis of the current period lacked many of the components required for a realistic estimation of nutrient availability, a few of the most relevant factors were summarized into the nutrient availability index (NAI). In this analysis, the term "nutrient" applied principally to nitrogen, although some of the following findings were applicable to other nutrients as well.

The decomposition of organic matter in the litter and soil is the principal nutrient source for vegetation that lacks the ability to fix atmospheric nitrogen. We estimated a composite decomposition coefficient that integrated the effects of soil moisture and temperature on the relative decomposition rate. Litter organic matter is the most important pool acted upon by the decomposition coefficient because it has a high nitrogen-to-carbon ratio (N:C), which provides a good substrate for heterotrophs that decompose organic matter. The soil organic-carbon pool, although typically many times larger than the litter organic-carbon pool, is of a poorer quality (lower N:C), decomposes more slowly, and is consequently, less important to plants. Our best indicator of the litter organic pool was the estimate of NPP. However, this assumed that on an annual basis all the organic matter resulting from NPP would be returned to the litter, either as leaf, stem, or root turnover. This is not entirely accurate, since conditions of net growth and net decline of live biomass are common. Nevertheless, it was likely that these components (growth and decline) would be most closely correlated with NPP. Thus, as a relative scalar of potential decomposition, NPP seemed to be a logical choice.

The NAI was derived by multiplying the annual average decomposition scalar (d_s) by the annual NPP, and was therefore comparable across vegetation types.

$$NAI = (d_s)\ NPP$$

The NAI was a crude approximation of the potential nutrient availability based on the rate of decomposition and productivity. The decomposition scalar was a function of daily soil temperature and soil water content summed over the year (Running and Hunt 1993). High values were associated with wet, warm soils and low values were indicative of cold and/or dry soils. The decomposition coefficient represented the potential rate of decomposition, whereas the actual rate of decomposition was dependent on the supply of litter and other organic material on the ground. A reasonably good representation of the potential organic material supply could be portrayed by NPP, since NPP is directly proportional to litter production. The product of NPP and the decomposition coefficient account for the amount of decomposition for a given year. The relationship between NAI and nutrient availability is a function of litter quality or lignin content. No attempt was made to integrate lignin interactions into NAI. Low NAI values (< 0.05) signified low decomposition rates and high amounts of nutrients tied up on the ground and in plant parts. High values (> 0.25) indicated rapid decomposition rates, highly-productive environments, and more nutrients available for plant growth.

Broad-scale Changes in Cover Types

Forty-one broad-scale cover types were mapped at 1-square-kilometer resolution to describe the current and historical period vegetation of the Basin (appendix 3-E). Cover types were named for the vascular plant species having the dominant canopy cover for rangeland types (Shiflet 1994) and the dominant basal area for forest types (Eyre

1980). The current cover type map was created by Hardy and others (1996) by refining a land cover characterization map that was constructed from a 1991 classification of Advanced Very High Resolution Radiometer (AVHRR) satellite imagery (Loveland and Ohlen 1993, Loveland and others 1991). This map was revised using rule sets developed from knowledge of the PVT, a rectification procedure using CRBSUM, and information gained from workshops attended by ecologists familiar with the Basin (Keane and others 1996b, Hann and others 1997; Menakis and others 1996). The historical cover type map was produced by Losensky (1994) using archived maps and government records published near the turn of the century and revised using a rectification process similar to that for the current. Because the base historical map was compiled from many maps of varying scales and quality, it was difficult to cross-reference historical and current cover types. This was especially true for urban and agricultural areas. The derivation of current and historical vegetation layers and rectification with current and historical PVT layers was fully described by Menakis and others (1996) and Hann and others (1997).

Two spatial scales and three indices of change were used in this assessment to quantify areal changes of cover types between historical and current periods. Compositional changes were assessed across the Basin as a whole, as well as within the 13 ERUs (map 3.3) within the Basin. These changes were evaluated with respect to the cover type (that is, class change), to a region (that is, Basin or ERU change), and to the historical range of each cover type (that is, departure index).

Class changes quantified the proportional change of a cover type's area between the historical and current periods. Class change was estimated by:

$$CC = [(CTA_C - CTA_H)/ CTA_H] * 100,$$

where

CC = percentage of class changed,

CTA_C = current area of cover type, and

CTA_H = historical area of cover type.

Regional changes quantified the areal proportion of the region (Basin or ERU) that was altered as a result of the change in areal extent of a cover type. Regional change was estimated by:

$$RC = [(CTA_C - CTA_H) / RA] * 100,$$

where

RC = percentage of region changed,

CTA_C = current area of cover type,

CTA_H = historical area of cover type, and

RA = regional area (Basin or ERU).

Transition matrices of cover types were constructed to further our understanding of class and regional changes (Jones 1996). The transition matrices tracked the flux of individual 1-square-kilometer pixels from one cover type to another between the historical and current periods. For example, did a pixel that was classified as a ponderosa pine cover type during the historical period remain ponderosa pine, or did it change to another cover type in the current period? The dominant transitions within a region (that is, those affecting at least 1% of the Basin or an ERU) were summarized.

Cover type departure indices were determined by comparing the current period areal extent of each type to their modeled median 75-percent and 100-percent historical ranges. The median 75-percent range is 75 percent of the difference between minimum and maximum, which excludes 12.5 percent of the range from each end. We computed the median 75-percent range to exclude some of the more extreme variation. Historical ranges of cover types were simulated for the Basin and individual ERUs using the CRBSUM (Keane and others 1996b). The minimum and maximum values from a single 100-year or 400-year run of the CRBSUM, and appropriate outputs for simulation years 0, 50, 100, 200, 300, or 400 were used to define historical ranges. The initial conditions for the historical simulations and the simulation process were described by Menakis and others (1996) and Long and others (1996), respectively. We then calculated the median 75-percent historical range by adding or subtracting 12.5 percent of the

Table 3.7—Cover type and terrestrial community departure classes.

Departure Class	Relationship of Current Period Area to Historical Ranges
1	A_c[1] < Historical Minimum
2	Historical Minimum ≤ A_c < Median 75% Historical Range
3	A_c is within Median 75% Historical Range
4	Median 75% Historical Range < A_c ≤ Historical Maximum
5	A_c > Historical Maximum

[1]A_c = Current area.

historical range to the historical minimum and historical maximum, respectively. Five departure classes were defined based on the relationship between the current area of each cover type and its simulated median 75-percent and 100-percent historical ranges (table 3.7; fig. 3.10).

We used class changes, regional changes, and departure indices to determine ecologically significant changes of cover types. We judged the absolute value of class changes greater than or equal to 20 percent and regional changes greater than or equal to 1 percent as ecologically significant, but only if the departure indices indicated that the current area of the cover type occurred outside its median 75-percent historical range (that is, departure classes 1, 2, 4, and 5). In turn, areal changes resulting in departures classes 1, 2, 4, and 5, were ecologically significant if either the historical or current period areas of a cover type exceeded 1 percent of the region, and the class change exceeded 5 percent.

The herbaceous wetlands, shrub wetlands, and aspen cover types appeared to be under-represented in the historical vegetation layer and over-represented in the current layer. These types, which generally occur in scattered, relatively small- to medium-sized patches, tend to be underestimated as mapping resolution increases (Turner and others 1989). Because the historical vegetation layer was developed at a coarser resolution than the current period vegetation layer (Menakis and others 1996), it was likely that the two mapping efforts contained different biases. In fact, rectification with the PVTs indicated that the herbaceous wetlands, shrub wetlands, and aspen cover types were likely more abundant on the historical landscape than the data indicated [see appendix 3-F for a description of PVTs, and Menakis and others (1996) for the derivation of the historical vegetation layer]. Changes in these three types were not reported because they could not be accurately quantified.

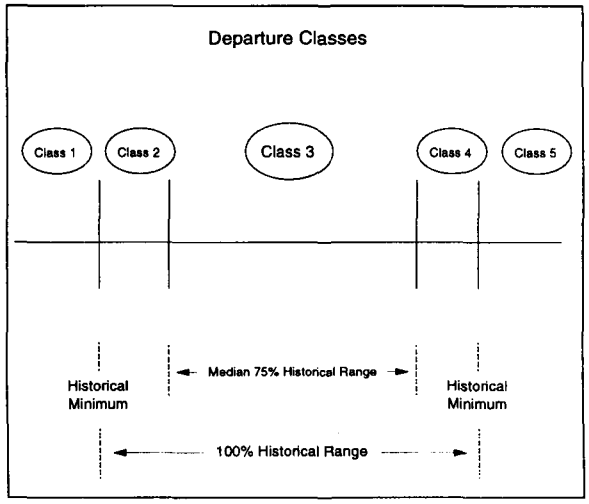


Figure 3.10—Relationship between current areal extent of cover types and terrestrial community types, and their respective median historical ranges.

Broad-scale Changes in Terrestrial Community Types

Twenty-four broad-scale terrestrial community types were derived by aggregating 41 cover types and 25 structural stages (appendices 3-B and 3-G). Structural stages represented the developmental changes in a plant community's structure (Oliver and Larson 1990). Oliver's (1981) original forest structural stages were modified by O'Hara and others (1996) to account for the influence of natural and anthropogenic disturbances on successional development in forest and woodland types. Willard and Villnow (1996) developed a set of structural stages for rangelands that were later revised for use in a coarse-scale application. The current period structural stage map was created from a discriminant analysis of mid-scale data layers extrapolated to the broad scale (Keane and others 1996b). Data of historical structural stages were generated from historical information compiled by Losensky (1994), in which the areal extent of structural stages was summarized by cover type and county, and then extrapolated to Bailey's (1995) ecological section. Historical structural stages were then randomly assigned to pixels based upon the historical cover type and proportional area of structural stage within an ecological section (Keane and others 1996b). Cover types and structural stages were aggregated into terrestrial community types based upon moisture, temperature, elevational gradients, and similar broad-scale structures. Terrestrial community types were mapped at 1-square-kilometer resolution.

As with the analysis of cover types, two spatial scales and three indices of change were used to quantify areal changes of terrestrial communities between historical and current periods. Compositional changes were assessed across the Basin as a whole, and for ERUs within the Basin (map 3.3). These changes were evaluated with respect to the terrestrial community (that is, class change), the region (that is, Basin or ERU), and the historical range of a community's area (that is, departure index).

Class changes quantified the proportion of a terrestrial community's area that varied between historical and current periods, whereas regional changes quantified the areal proportion of the region (Basin or ERU) that was altered as a result of a change in areal extent of a terrestrial community type. The class and regional changes of terrestrial communities were estimated in the same manner as they were for cover types. Transition matrices of terrestrial communities were constructed to further our understanding of class and regional changes (Jones 1996). The dominant transitions within a region (that is, those affecting at least 1% of the Basin or an ERU) were summarized.

As with the cover type departures, terrestrial community type departures were determined by comparing the current period areal extent of each type to their modeled median 75-percent and 100-percent historical ranges. Ecologically significant changes between historical and current period terrestrial communities were determined in the same manner used for cover types.

The same problem was experienced with riparian terrestrial community types as was experienced with riparian cover types. Consequently, the changes of riparian terrestrial communities were not reported because they could not be accurately quantified.

Broad-scale Changes of Physiognomic Types

Cover types and structural stages were aggregated into 20 physiognomic types to assess successional and disturbance processes (appendix 3-C). The physiognomic types corresponded to the terrestrial community types in non-forest (that is, rangeland) settings. However, in forest settings the physiognomic types incorporated shade tolerance/shade intolerance, in addition to structural and seral status. The aggregation of cover types to infer shade-tolerant and shade-intolerant groups should be used cautiously, particularly with model projections of HRVs. Although we believe the data for

mid- and late-seral stages to be fairly reliable, the values for early-seral stages are questionable. Broad-scale physiognomic types cannot be directly associated with forest age, such as regeneration, young, mature, or old. However, we believe physiognomic types can be associated with forest age classes if they are stratified by PVG and disturbance history.

Regional trends of physiognomic types were stratified by PVG and land ownership, and assessed for the Basin and each of the 13 ERUs. In addition, the current areal extent of physiognomic types was compared to the HRV for each strata. The HRV was based upon the historical extent, and a single 100-year run of CRBSUM (using historical disturbance regimes) with outputs at 50 and 100 years. Consequently, three values (historical year 0, historical year 50, and historical year 100) were used to estimate historical minimum and maximum values.

Broad-scale Subbasin Vegetation Departures

Terrestrial community type departures were developed to estimate the magnitude of broad-scale habitat changes in forest and rangeland habitats within subbasins. One-square-kilometer resolution, continuous, broad-scale data summarized by subbasin (map 3.6) was used to assess habitat departures of forest and rangeland ecosystems. After aggregating 41 cover types and 21 structural stages into 24 terrestrial community types, the forest terrestrial community types having late-seral single-layered and late-seral multi-layered structures were further collapsed into a "late" class. Departure classes (table 3.7) were then estimated by subbasin for nine forest terrestrial community types and three non-forest (that is, rangeland) community types. We estimated current period departures for those terrestrial community types that composed at least 1 percent of the area of a subbasin for any output period of the historical CRBSUM run, or for the current period condition. Departure values were not determined for anthropogenic community types (that is, cropland, exotic, and urban), nor community types that remained relatively stable between historical and current periods (that is, alpine, rock/barren, and water community types). Departures were also not estimated for riparian community types because historical occurrence of riparian cover types was typically underestimated and current period occurrence was typically overestimated (Jones and Hann 1996b).

Subbasin departure classes were estimated in a similar manner as were the Basin and ERU departures of cover types and terrestrial communities. However, in the subbasin, the departures were determined on an individual subbasin level. Consequently, the current areal extent of each type within individual subbasins was compared to the modeled median 75-percent and 100-percent historical ranges of each type within a subbasin. Subbasin historical ranges of terrestrial communities were determined for the Basin and ERUs in the same manner as the historical ranges of cover types and terrestrial communities.

The persistence of species within a subbasin was presumed not to be at risk if the current period area of the species' primary habitat fell within or above the median range of historical data. Consequently, we believed it would be informative to assess the fragmentation of areas in which the risks to persistence would be relatively low. We computed four fragmentation indices for subbasins in which a community type occurred within or above its historical range: (1) percent area (percentage of those subbasins in which a community composed a substantial proportion); (2) number of patches; (3) median patch size (count of subbasins within a patch); and (4) maximum patch size.

Broad-scale Changes of Vegetation Patterns

We evaluated the patterns of physiognomic groups and terrestrial communities to assess landscape and regional patterns of vegetation, respectively, within the Basin.

Physiognomic Group Patterns

Physiognomic groups were derived from an aggregation of 41 cover types and 25 structural stages having similar gross compositional and structural characteristics (table 3.8). Physiognomic group patterns were in turn created by classifying subwatersheds (6th field HUCs) (map 3.5) according to their pattern and composition of dominant physiognomic groups. In the coarsest sense, patterns were simplified as "uniform", "mosaic", or "mixed". Uniform patterns existed where the dominant physiognomic group constituted a minimum of 80 percent of the subwatershed. The pattern was classified as mosaic where the dominant physiognomic group composed 60 to 80 percent of the subwatershed. In a mixed pattern, the dominant physiognomic group composed less than 60 percent of the subwatershed. A more descriptive pattern classification was also developed that used a hierarchy of pattern and dominant/codominant physiognomic groups. Changes of physiognomic group patterns were summarized by ERUs (map 3.3).

Transition matrices were prepared for each ERU to summarize the changes of physiognomic group patterns between the historical and current periods. Changes were quantified in relation to the physiognomic group (that is, class change or proportional change) and in relation to the ERU (that is, the proportional change of an ERU due to

Table 3.8—Physiognomic groups used to assess coarse landscape patterns of subwatersheds within the Basin.

Physiognomic Group	Description
Agriculture	Agricultural types including irrigated and non-irrigated crop land, hayland, and seeded pasture.
Forest / Woodland Early-seral	Forest and woodland early-seral structures (that is, stand initiation[1]).
Forest / Woodland Mid-seral	Forest and woodland mid-seral structures including stem exclusion open and closed, understory reinitiation, and young multi-storied stands.
Forest / Woodland Late-seral Multi-layer	Forest and woodland late-seral multi-layered stand structures.
Forest / Woodland Late-seral Single-layer	Forest and woodland late-seral single-layered stand structures.
Herbland	Herbland structures including both native and exotic grasses and forbs, and sedge-dominated open and closed stands.
Low Shrub	Low shrub structures including open and closed shrub stands less than 0.76 meters in height.
Mid Shrub	Mid shrub structures including open and closed shrub stands 0.76 to 2.00 meters in height.
Rock	Rock and barren structures.
Tall Shrub	Tall shrub structures including both open and closed shrub stands exceeding 2 meters in height.
Urban	Urban and industrial areas.
Water	Large bodies of water.

[1]See appendix 3-G for structural stages descriptions.

a change in a particular physiognomic group). The most dominant transitions within an ERU were evaluated to develop an understanding of the major pattern changes that had occurred between historical and current periods. In general, to be considered major, fluxes had to occur across a minimum of 1 percent of an ERU.

A coarse assessment of fragmentation trends was conducted by analyzing the net change in areal extent of ERUs that had fluxed between more uniform or more fragmented landscapes (that is, uniform to mosaic or mixed, and mosaic to mixed). The percentage of the ERU that remained in the same pattern class between historical and current periods was used to estimate a stability index. Conversely, a departure index for ERUs was calculated to quantify the magnitude of change between historical and current broad-scale physiognomic group patterns. The departure index was calculated by:

$$PD = 100 - \left[\frac{200 \Sigma_k \text{minimum} \left(h_k, c_k \right)}{\Sigma_k h_k + \Sigma_k c_k} \right]$$

where

PD = departure index,

k = number of classes,

h_k = the historical value for class k, and

c_k = the current value for class k.

ERU departure indices were classified on a relative scale as low, moderate, and high for values less than 33.3, 33.3 to 66.6, and exceeding 66.6, respectively.

Terrestrial community group patterns

Historical and current period patterns of broad-scale terrestrial community groups were assessed for the LCA, an area that extended slightly beyond the boundaries of the Basin (maps 3.1 and 3.2). The historical and current period vegetation maps were derived using different methods and resolutions (Menakis and others 1996). Consequently, comparisons of landscape patterns between historical and current periods were difficult. To ameliorate the problems associated with resolution, the 1-square-kilometer current and historical vegetation layers were resampled to 4-square-kilometer resolution, and the 24 terrestrial community types were further aggregated into 12 terrestrial community groups (table 3.9). We believe that using a coarser 4-square-kilometer resolution and a coarser classification of vegetation types improved the comparability of historical and current period vegetation patterns. As previously discussed, changes of riparian vegetation types between historical and current periods could not accurately be assessed. Consequently, pattern changes of any riparian community groups were not reported in this chapter.

FRAGSTATS (McGarigal and Marks 1994) was used to estimate class (that is, terrestrial community groups) and landscape metrics to assess pattern changes of the LCA as a whole, as well as pattern changes of each of the 12 community groups occurring within the LCA (table 3.10). Multiple metrics (that is, areal extent, largest patch index, patch number, and mean patch size) were evaluated to assess fragmentation. Indicators of an increase in fragmentation included decline in areal extent, a declining largest patch index, and a declining mean patch size, whereas the number of patches would generally be expected to increase. Conversely, indicators of a landscape becoming more homogeneous and contiguous included increasing areal extents, increasing largest patch index, increasing mean patch size, and declining numbers of patches. Because of the coarse resolution of this analysis and the different mapping methods involved, we assumed ecologically significant changes occurred when current period metrics deviated by 20 percent or more from historical metrics.

Forest and Rangeland Integrity

We conducted ancillary analyses to integrate the broad-scale data and develop an overall ecological integrity index of forest and rangeland ecosystems within the Basin. We could not measure ecological integrity directly. Consequently, relative integrity ratings were estimated from the departures

Table 3.9—Aggregation of 24 terrestrial community types into 12 terrestrial community groups for analysis of broad-scale changes in vegetation patterns.

Terrestrial Community Group	Terrestrial Community Type
Agriculture	Agricultural
Alpine	Alpine
Exotic Herbland	Exotic Herbland
Lower Montane Forest[1]	Early-seral Lower Montane[1] Forest
	Mid-seral Lower Montane[1] Forest
	Late-seral Lower Montane[1] Multi-layer Forest
	Late-seral Lower Montane[1] Single-layer Forest
Montane Forest	Early-seral Montane Forest
	Mid-seral Montane Forest
	Late-seral Montane Multi-layer Forest
	Late-seral Montane Single-layer Forest
Rock	Rock / Barren
Subalpine Forest	Early-seral Subalpine Forest
	Mid-seral Subalpine Forest
	Late-seral Subalpine Multi-layer Forest
	Late-seral Subalpine Single-layer Forest
Upland Herbland	Upland Herbland
Upland Shrubland	Upland Shrubland
Upland Woodland	Upland Woodland
Urban	Urban
Water	Water
NU[2]	Riparian Herbland
NU	Riparian Shrubland
NU	Riparian Woodland

[1]Originally referred to as Ponderosa pine Forest.

[2]NU = Not Used. Patterns were not assessed for the riparian terrestrial community types because these types generally occurred in scattered, relatively small- to medium-sized patches, and tended to be underestimated as mapping resolution increased. Consequently, because the historical vegetation layer was developed at a coarser resolution than the current period vegetation layer, it was likely that the two mapping efforts contained different biases. Therefore, changes of riparian vegetation types between historical and current periods could not accurately be assessed.

Table 3.10—Landscape metrics used to assess broad-scale vegetation patterns.

Metric[1]	Scale[2]	Description (units)
%LAND	Class	Percent of the landscape (%)
CONTAG	Landscape	Contagion Index
PR	Landscape	Patch Richness (#)
SHDI	Landscape	Shannon's Diversity Index
SHEI	Landscape	Shannon's Evenness Index
SIDI	Landscape	Simpson's Diversity Index
SIEI	Landscape	Simpson's Evenness Index
ED	Class / Landscape	Edge Density (m/ha)
LPI	Class / Landscape	Largest Patch Index (%)
MPS	Class / Landscape	Mean Patch Size (ha)
NP	Class / Landscape	Number of patches (#)

Adapted from McGarigal and Marks (1994).

[1]Metric: a means of measuring or specifying values of variability.

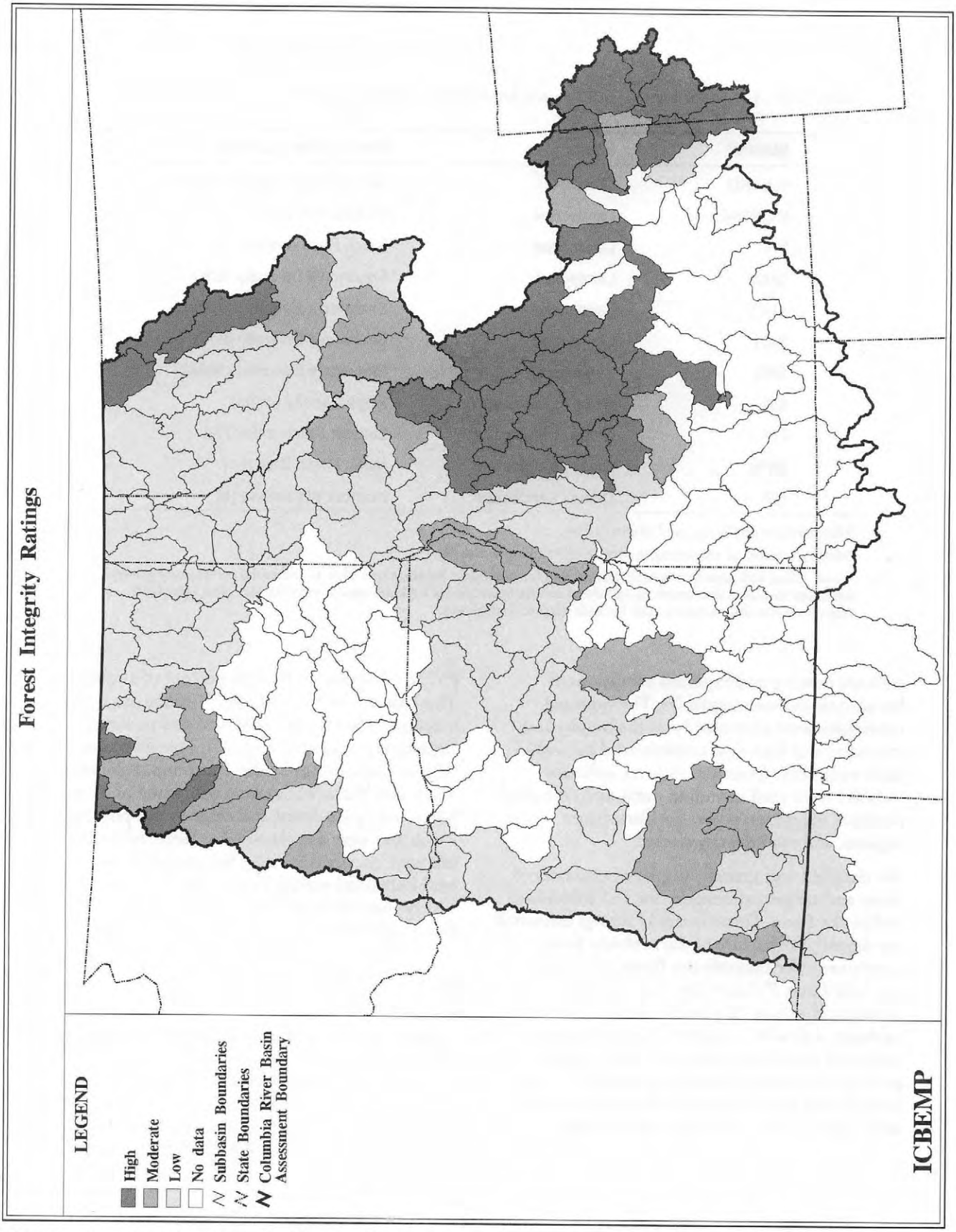
[2]Scale: Class indicates that metric is calculated for individual habitat types (that is, terrestrial community group); landscape indicates that metric is calculated for the landscape as a whole, regardless of habitat type; class/landscape indicates that metric is used for both class and landscape.

between existing and expected conditions of broad-scale indicator variables. The expected conditions were estimated from the biophysical templates and historical conditions of individual subbasins. Both direct and indirect indicator variables were used including forest and rangeland potential vegetation types, fire disturbance regimes, and road density classes.

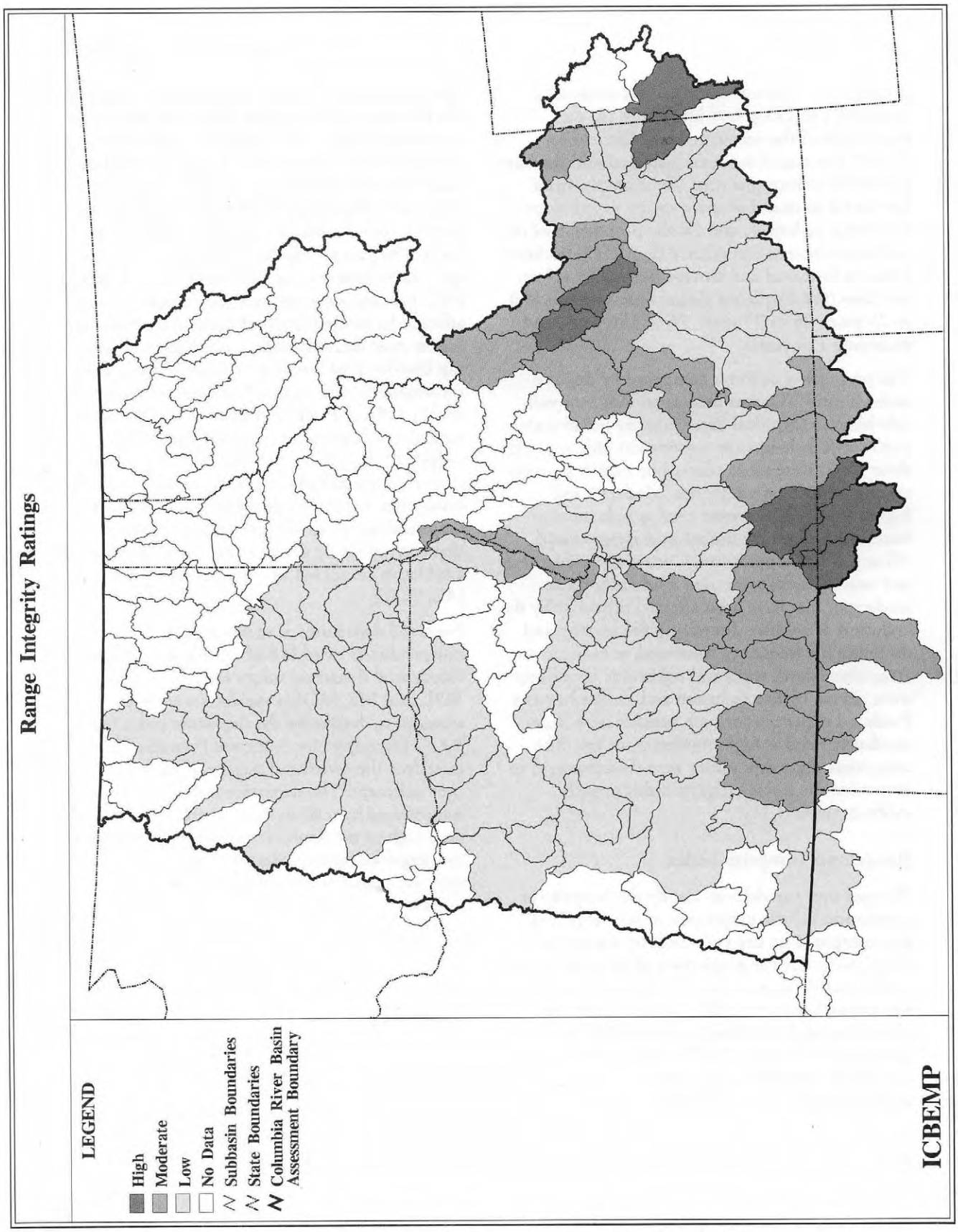
We classified and spatially displayed estimates of forest and rangeland integrity for 163 subbasins within the Basin. Forest integrity ratings estimated the degree of departure of the subbasin forest component (for example dry forest, moist forest, and cold forest PVGs) when that component constituted at least 20 percent of the area of the subbasin. Likewise, rangeland integrity ratings estimated the relative integrity of the rangeland portion of subbasins when rangeland PVGs (for example dry grass, dry shrub, cool shrub, woodland, riparian shrub, and riparian woodland PVGs) composed at least 20 percent of a subbasin. This rule resulted in 112 and 91 subbasins with measurable forest and rangeland components, respectively (maps 3.8 and 3.9). Five subbasins (Upper Crab, Lower Snake-Tucannon, Palouse, Rock, and Walla Walla) were composed of 75 to 88 percent agricultural and other anthropogenic PVGs and were not classified as forest subbasins but were classified as range because of the rangeland imbedded within the agricultural lands. Thirty-nine subbasins were classified as both forest and rangeland.

Forest Integrity Index

Five indicator variables were used to classify the integrity of forests within subbasins: (1) the proportion of the forest area of subbasins composed by dry and moist forest PVGs (D+M/TOT); (2) the proportion of the subbasin that was estimated to have road densities of at least 0.43 kilometers per square kilometer (RD_MOD+); (3) the



Map 3.8—Forest integrity ratings of subbasins. These ratings were developed as relative indexes of ecological integrity.



Map 3.9—Rangeland integrity ratings of subbasins. These ratings were developed as relative indexes of ecological integrity.

proportion of the subbasin that was essentially unroaded (WILD ≤ 0.06 km/km^2); (4) the proportion of the subbasin where fire severity (F_SEV) increased between historical and current periods by at least one class (for example, from non-lethal to mixed severity, mixed to lethal, or non-lethal to lethal); and (5) the proportion of the subbasin where fire frequency (F_FREQ) declined between historical and current periods by at least one class (fire frequency classes were intervals of 0 to 25 years, 26 to 75 years, 76 to 150 years, and exceeding 150 years).

The proportion of forest composed by dry and moist forest PVGs was used as an indicator variable because empirical data from the broad-scale and mid-scale landscape assessments indicated that these PVGs were most affected by timber harvests and fire suppression activities. Moderate and higher road densities were used as indicators of established access for timber management and efficacy of fire suppression. Conversely, wilderness and roadless areas were used to identify those landscapes that have been affected primarily by the exclusion of wildfire. Increasing fire severity and declining fire frequency were used to indicate the areas where cover types and structures were likely most altered by fire exclusion and timber harvests. Predicted departures of each variable were independently rated as high, moderate, or low. The categorical departure values were then averaged to determine the forest integrity index of each subbasin (table 3.11).

Rangeland Integrity Index

We used four variables to classify the integrity of rangelands: (1) the proportion of the rangeland area composed by dry grass and dry shrub PVGs (Dry/TOT); (2) the proportion of the subbasin in which road densities were at least 0.43 kilometers per square kilometer (RD_MOD+); (3) the proportion of the subbasin composed by the agricultural PVG (AG/TOT); and (4) the proportion of the subbasin composed by the juniper-sagebrush cover type (Jun/TOT).

The proportion of rangeland PVGs composed by the dry grass and dry shrub PVGs was used as an indicator variable of rangeland integrity because empirical data from the broad-scale and mid-scale landscape assessments suggested that these PVGs were most affected by excessive livestock grazing pressure and the invasion of exotic grasses and forbs. The juniper-sagebrush (*Juniperus-Artemisia* spp.) cover type was used instead of the woodland PVG because the latter underestimated the area affected by juniper encroachment. Moderate and higher road densities were used to indicate increasing likelihood of invasion by some exotics, where incursions have been correlated with road densities (Baker 1986, Forcella and Harvey 1983). Lastly, agricultural conversion occurred primarily in rangeland ecosystems. We assumed that conversion of rangeland physiognomic types to agricultural types was the single greatest alteration of rangeland integrity. We estimated the extent of that conversion by determining the proportion of a subbasin composed by the agricultural PVG (AG/TOT).

Predicted departures of each variable were independently rated as high, moderate, or low. Categorical departure values for Dry/TOT, AG/TOT, and RD_MOD+ variables were then averaged to determine the departure index (table 3.12). The departure index was then modified to reflect the estimated degree of juniper encroachment. The departure index of a subbasin was reduced by 0.67 or 0.33 when juniper areas were high or moderate, respectively, to determine the rangeland integrity index. Juniper encroachment estimated as low did not alter the integrity index.

Table 3.11—Forest departure and integrity indices.

Departure Index[1]	Indicator Variables					Relative Integrity Index[7]
	D+M/TOT[2]	F_sev[3]	F_freq[4]	RD_ Mod+[5]	Wild[6]	
	Percent					
High (1)	>66	>66	>66	>66	<25	<1.8 (Low)
Moderate (2)	33 - 66	33 - 66	33 - 66	33 - 66	25 - 50	1.8 - 2.0 (Mod)
Low (3)	<33	<33	<33	<33	>50	>2.0 (High)

[1]Departure index = the departure of existing conditions from that expected from the biophysical templates and historical conditions.

[2]D+M/TOT = the proportion of the forest within the subbasin comprised of dry forest and moist forest PVGs.

[3]F_sev = the proportion of the subbasin in which fire severity increased by at least one class (that is, non-lethal to mixed, non-lethal to lethal, and mixed to lethal.

[4]F_freq = the proportion of the subbasin in which fire frequency decreased by at least one class. Fire frequency classes have intervals of: 0 to 25 years, 25 to 75 years, 75 to 150 years, and more than 150 years.

[5]RD_Mod+ = the proportion of the subbasin comprised of estimated road densities of at least 0.43 kilometer per square kilometer.

[6]Wild = the proportion of the subbasin comprised of roadless areas.

[7]Relative Integrity Index = average categorical departure values.

Table 3.12—Rangeland departure and integrity indices.

Departure Index[1]	Indicator Variables				Relative Integrity Index[6]
	Dry/TOT[2]	Ag/TOT[3]	RD_ Mod+[4]	Jun/TOT[5]	
	Percent				
High (1)	>66	>25	>66	>15	<1.68 (Low)
Moderate (2)	33 - 66	10 - 25	33 - 66	5 - 15	1.68 - 2.66 (Mod)
Low (3)	<33	<10	<33	<5	> 2.66 (High)

[1]Departure index was based on the comparison of existing conditions and that expected from the subbasin biophysical environment.

[2]Dry/TOT = the proportion of the rangelands within the subbasin comprised by dry shrub and dry grass PVGs.

[3]Ag/TOT = the proportion of the subbasin comprised by the agricultural PVG.

[4]RD_Mod+ = the proportion of the subbasin comprised by estimated road densities of at least 0.43 kilometer per square kilometer.

[5]Jun/TOT = the proportion of the subbasin comprised by the juniper-sagebrush cover type.

[6]Relative integrity index = average categorical departure values.

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Regional and Landscape Similarities of Historical and Current Vegetation Conditions, and Succession/Disturbance Regimes

We assessed the degree of regional and landscape similarity between the historical and current conditions by using a similarity index computed by:

$$\text{Percent Similarity} = \left[\frac{200\Sigma_k \text{ minimum } (h_k, c_k)}{\Sigma_k h_k + \Sigma_k c_k} \right]$$

where

k = number of types,

h_k = the historical value for type k, and

c_k = the current value for type k.

The similarity assessment conducted at the regional level evaluated compositions of the broad-scale physiognomic types, succession/disturbance regimes, and fire regimes that existed during the current period with the compositions that were projected for the 400-year historical simulation. Regional similarities were evaluated for the Basin as a whole, as well as for BLM/FS lands within the Basin. Landscape similarities were conducted at the subbasin level and were stratified by landform, management class, and PVG. Vegetation conditions (such as, broad-scale physiognomic types, fine-scale data pertaining to tree and snag densities, canopy cover, fuel loading, and assumptions of mid-scale mosaic patterns) and succession/disturbance regimes similar to native, reserve, and traditional commodity management systems were assessed at the landscape level (figs. 3.11a, b, c; 3.12a, b, c; and 3.13a, b, c). We created a category for "Other" patterns of physiognomic types and succession/disturbance regimes because some areas had been converted to anthropogenic types (for example, agriculture, exotics, and urban), or physiognomic types that would not be expected to change between the historical and current periods. Very few areas having Other patterns occurred on BLM/FS lands. Landscape similarities were not determined for those areas within a subbasin that were classified as having Other patterns. Landscape similarities were determined for individual subbasins as a whole, as well as for the BLM/FS lands within each subbasin. Landscape similarities of BLM/FS lands were further stratified by the two EIS areas, three landscape mosaics, and six subbasin groups.

General Landscape Patterns

We developed a framework for the assessment and management of landscapes (that is, subbasins or smaller geographical areas) that linked disturbance regimes (including human uses) across multiple scales of time and space. We wanted to provide a classification system that would simplify the complexity of the spatial and temporal variation of biophysical conditions, vegetation composition and structure, and disturbance regimes (including human uses) across the wide variety of landscapes that occur within the Basin. Furthermore, we hypothesized that the classification scheme would be hierarchical, and that it could be mapped and interpreted consistently across any landscape scale (subbasins or smaller watershed delineation). To be useful, our classification system needed to be based upon relatively simple attributes that could be consistently identified throughout a wide variation in general landscape patterns. Although we recognized that the mechanistic processes regulating succession and disturbance regimes include biogeochemical processes and the mosaic patterns of the terrain, we used broad-scale correlates to explain the variability of landscape features that change in response to fluctuating processes across space and time.

We aggregated the nine subsection landforms developed by Nesser and Ford (1995) (map 3.10) into three broad-scale landforms (that is, mountains, foothills, and plains). Subbasins were classified by their composition of these broad-scale landforms. Classified subbasins were then categorized into three landscape mosaics based on their historical composition of forest and rangeland PVGs: forest, rangeland (or non-forest lands), and forest-rangeland landscape mosaics. These landscape mosaic classes served as correlates of coarse climatic conditions.

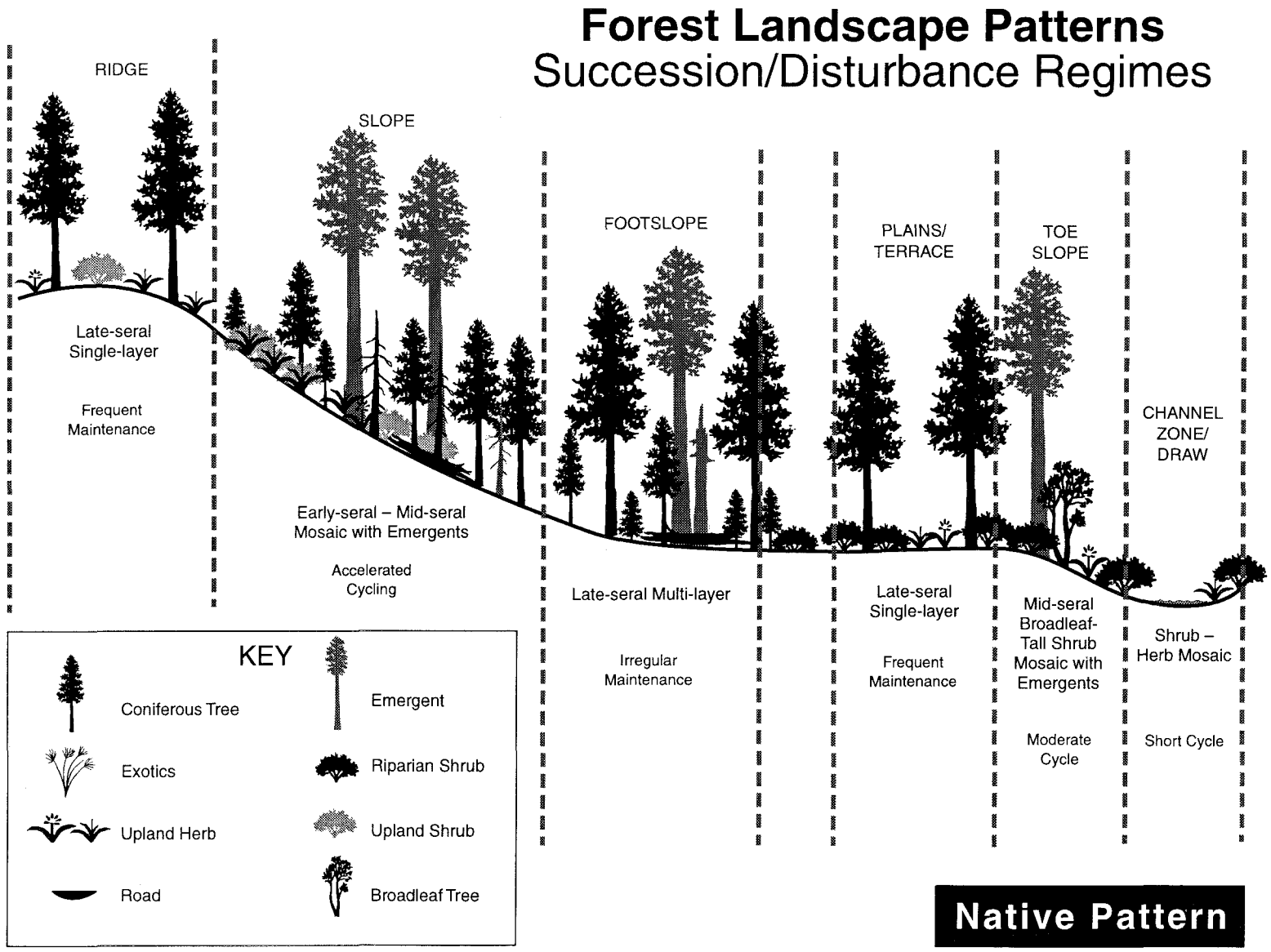
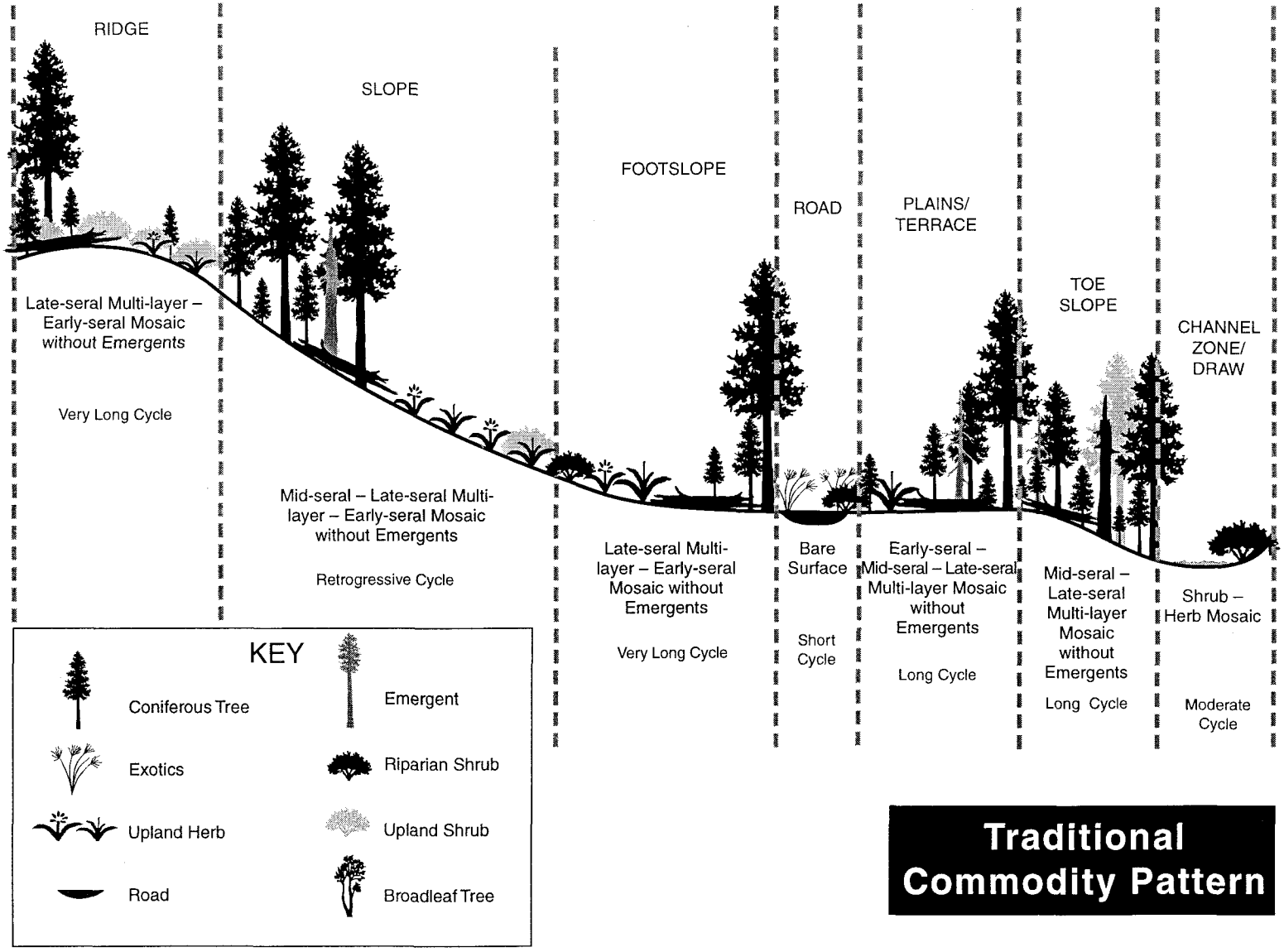


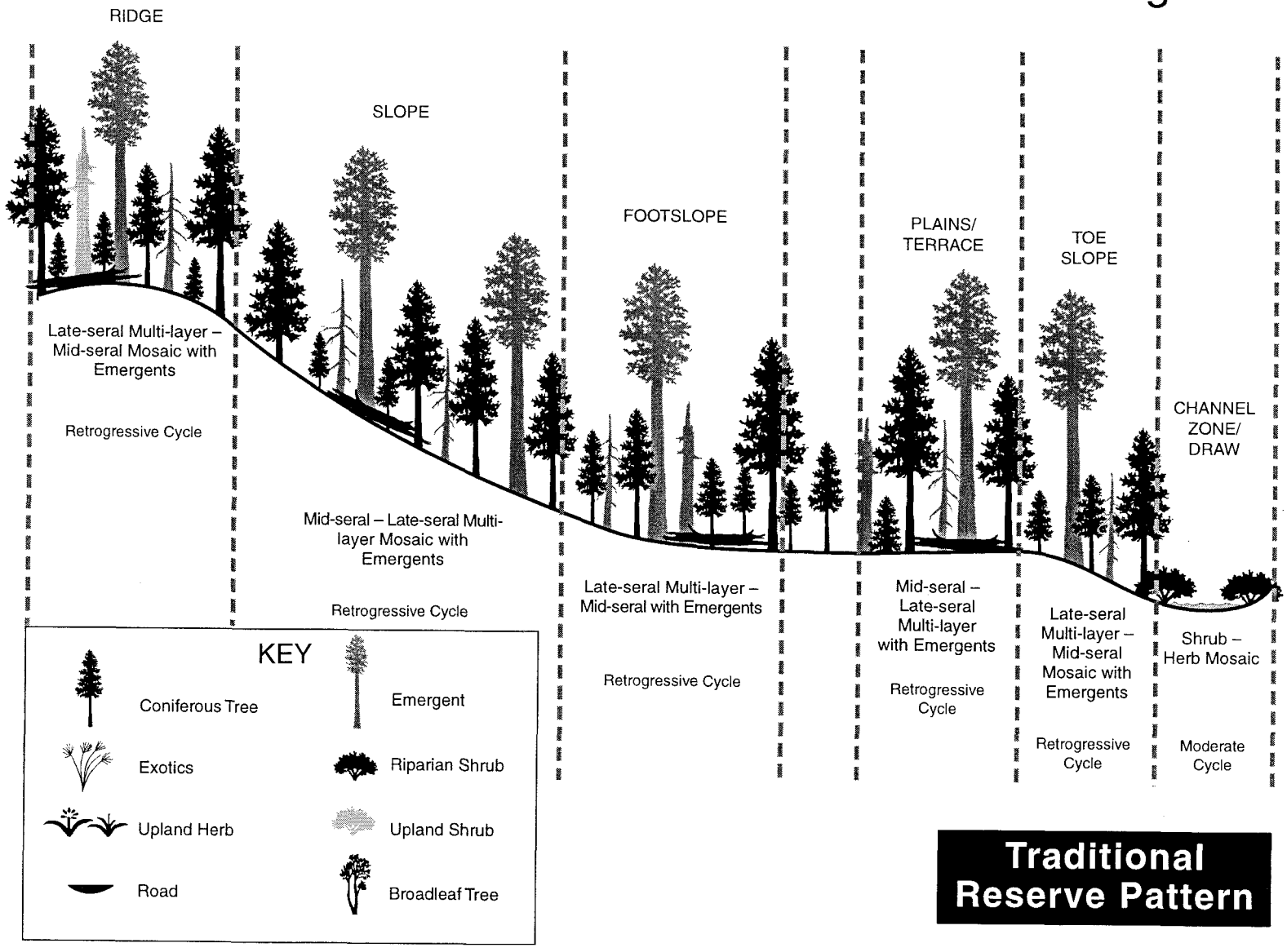
Figure 3.11—Relationship of forest landscape patterns, management regime, landform, vegetation structure, and succession/disturbance regime in areas dominated by forest PVGs.

Forest Landscape Patterns
Succession/Disturbance Regimes



Traditional Commodity Pattern

Forest Landscape Patterns
Succession/Disturbance Regimes



Traditional Reserve Pattern

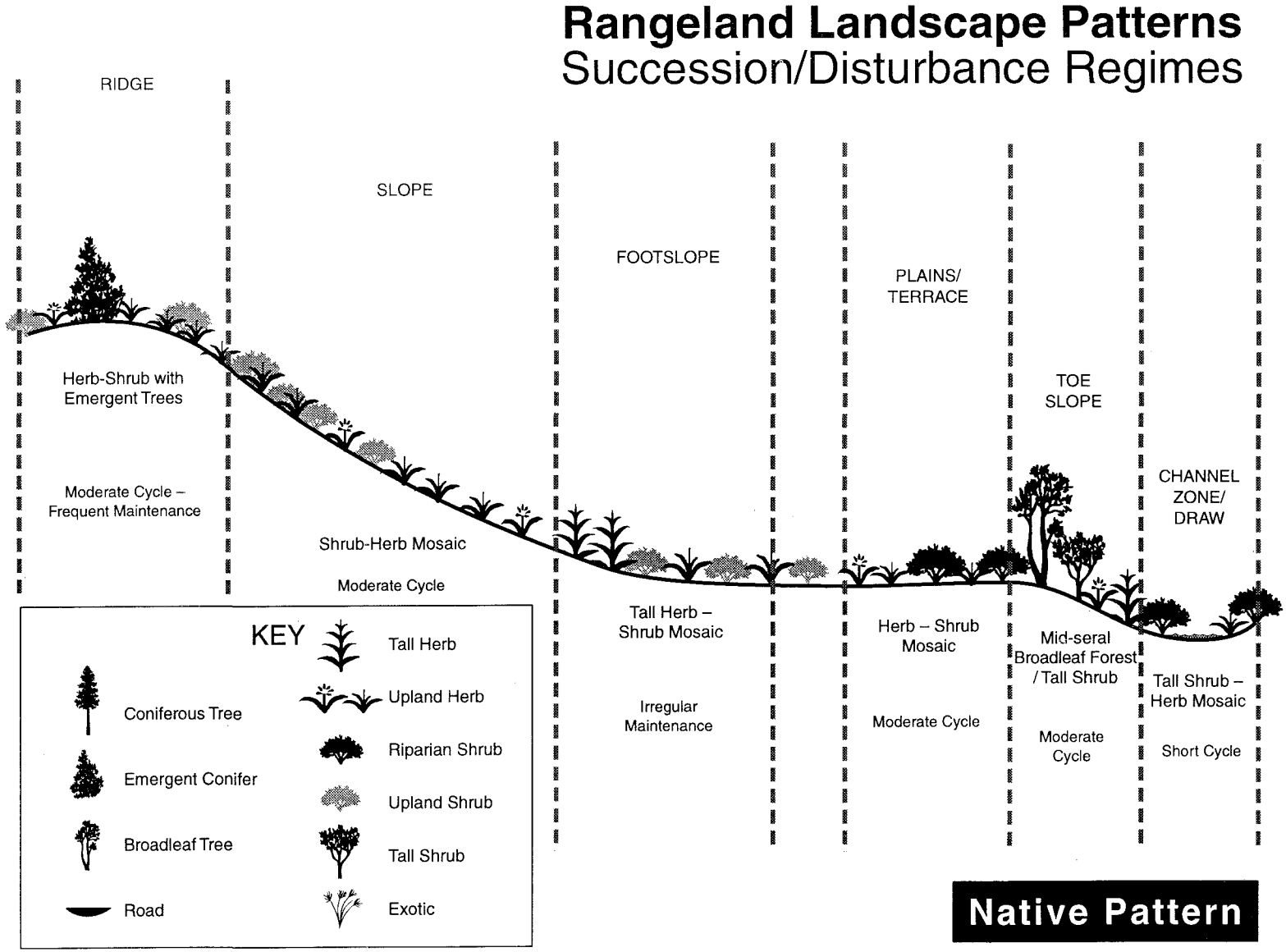
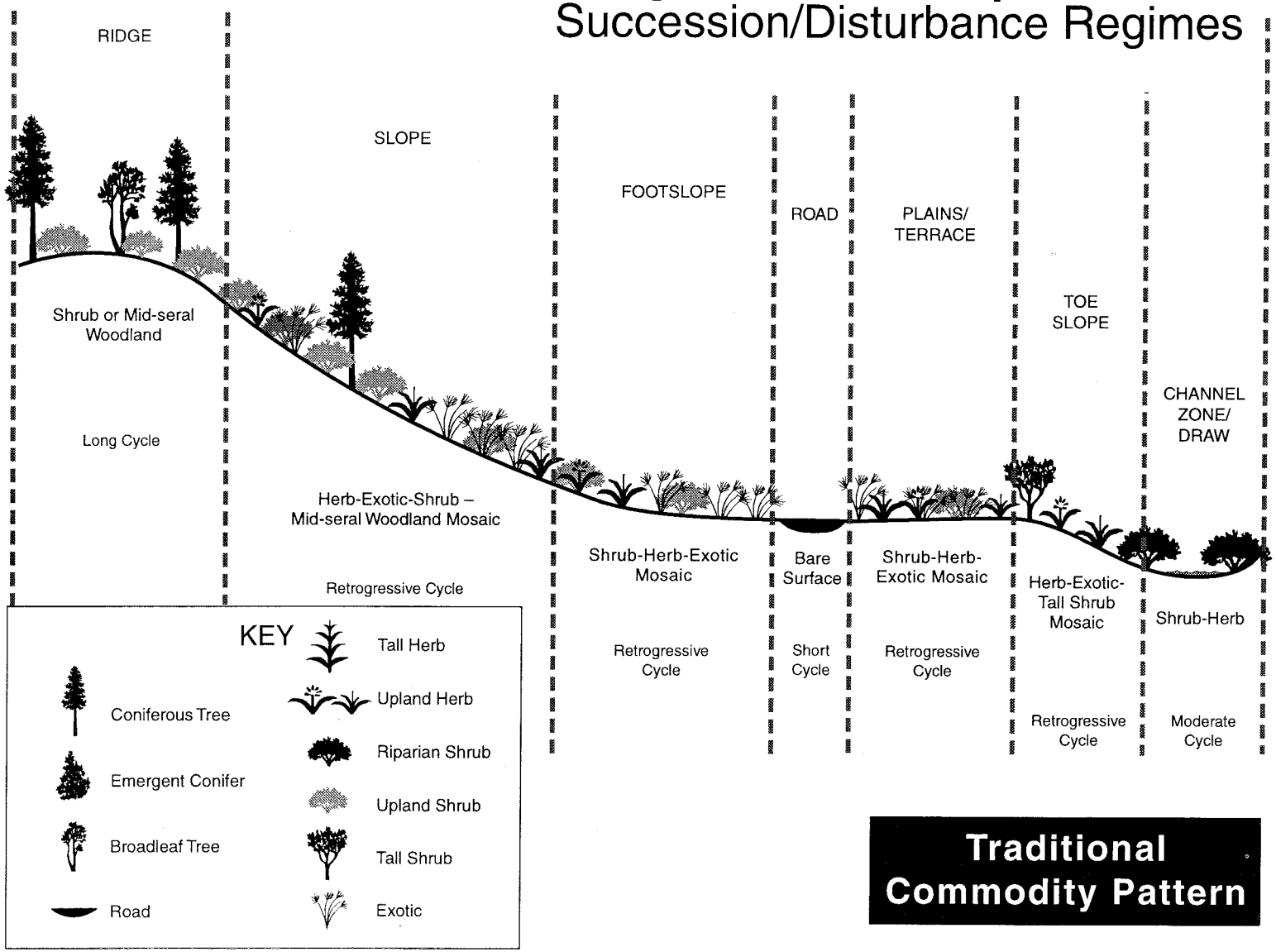


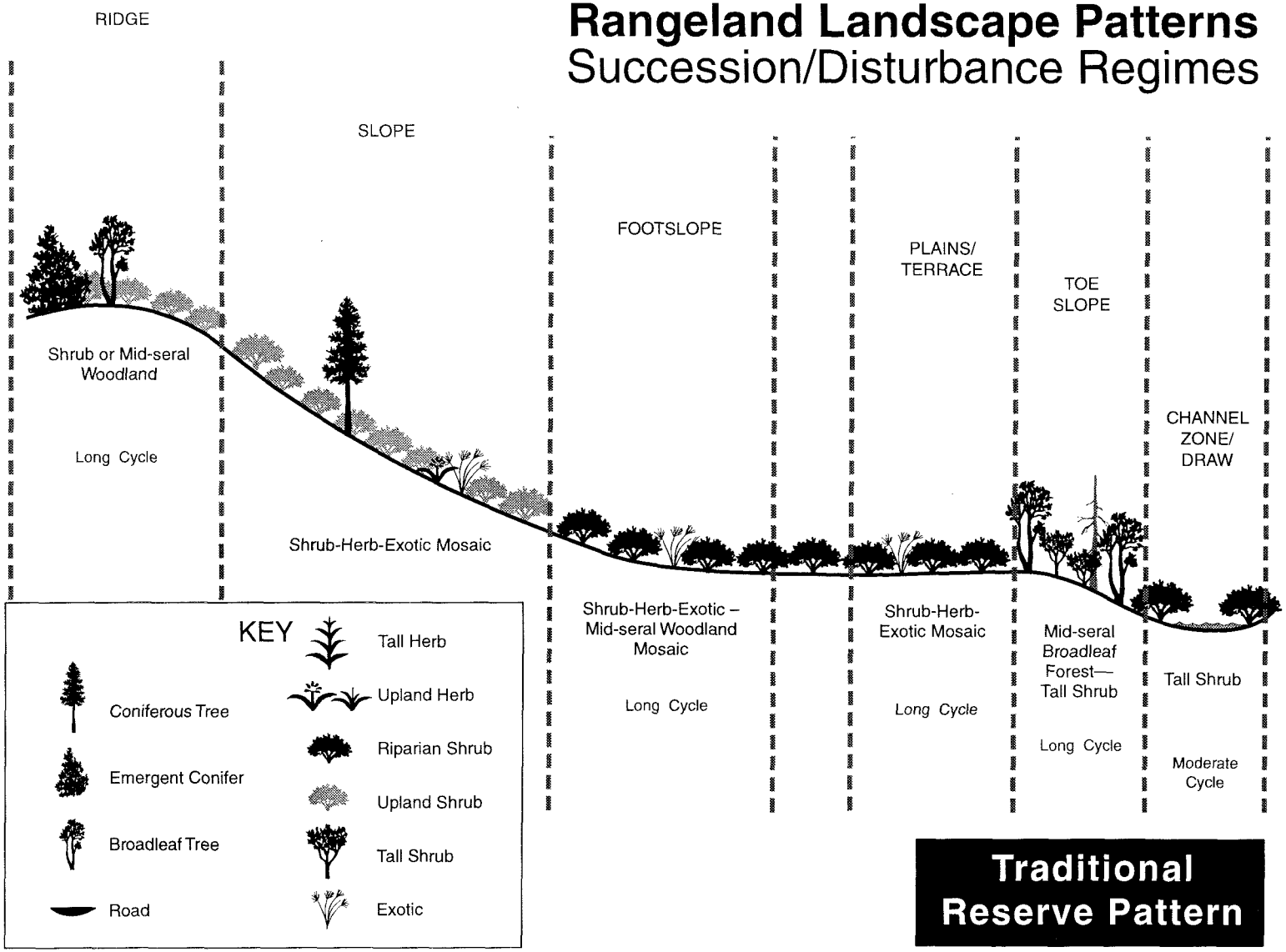
Figure 3.12—Relationship of rangeland landscape patterns, management regime, landform, vegetation structure, and succession/disturbance regime in areas dominated by rangeland PVGs.

Rangeland Landscape Patterns
Succession/Disturbance Regimes



Traditional Commodity Pattern

Rangeland Landscape Patterns
Succession/Disturbance Regimes



Traditional Reserve Pattern

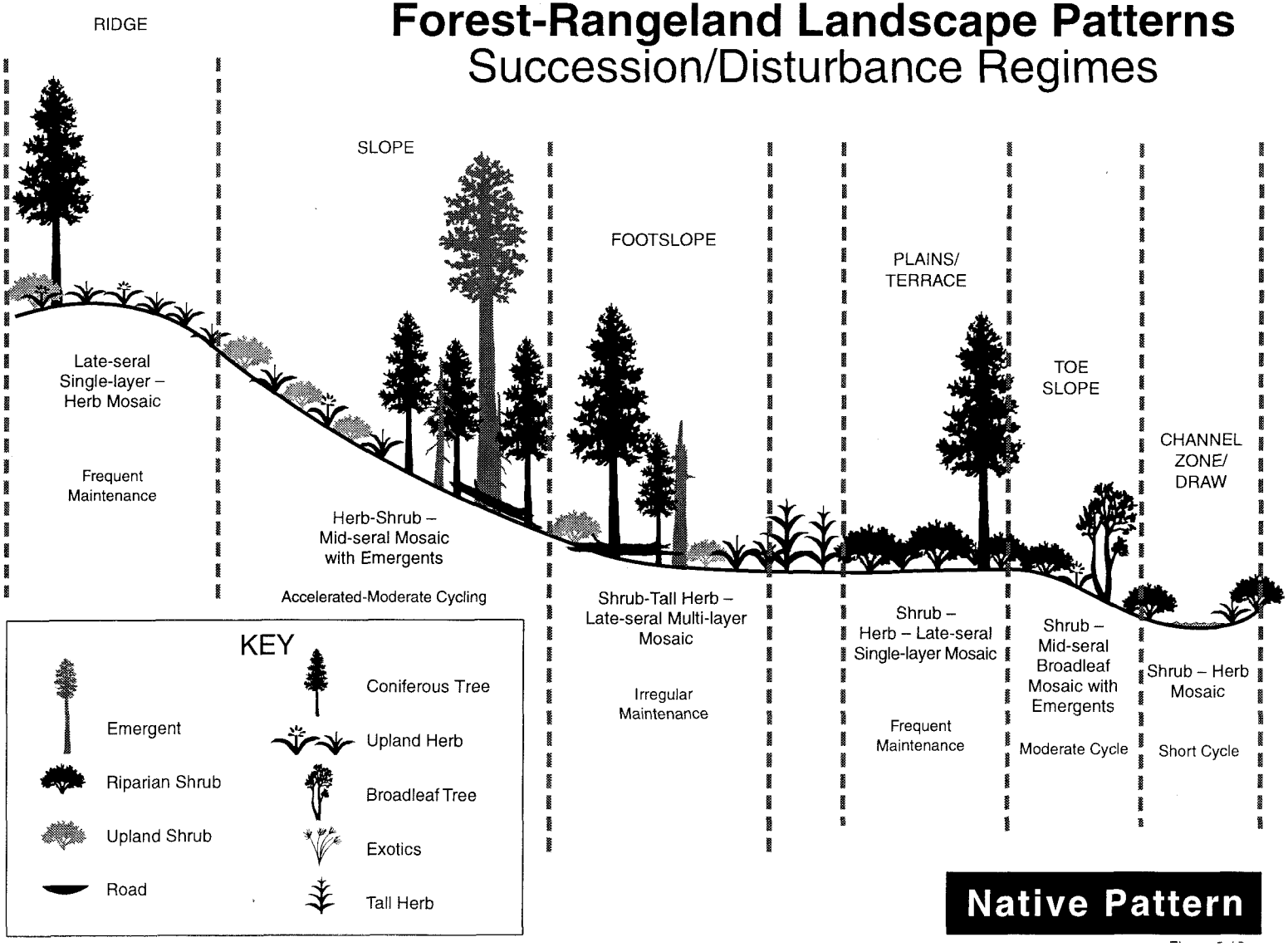
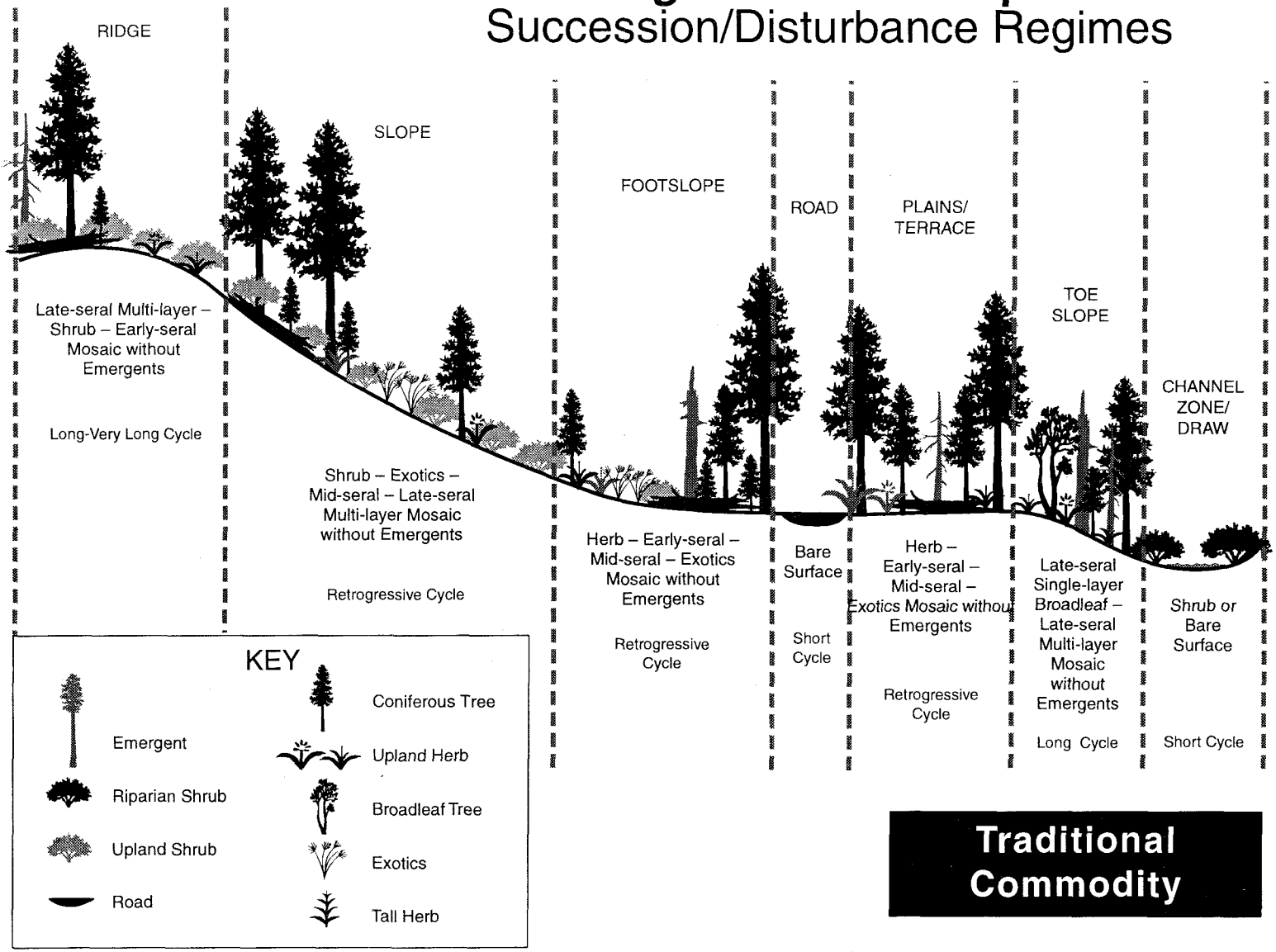


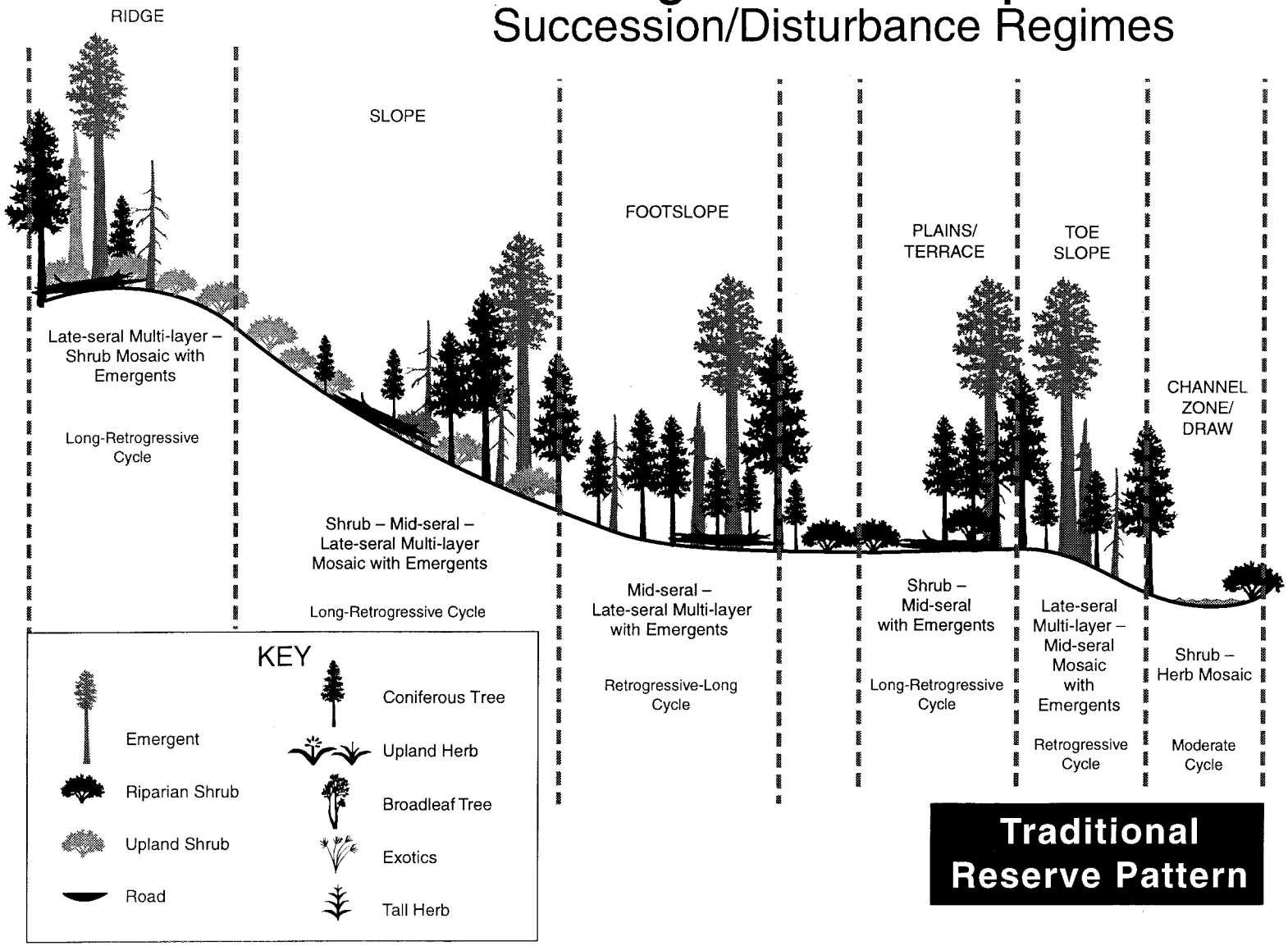
Figure 3.13—Relationship of forest-rangeland landscape patterns, management regime, landform, vegetation structure, and succession/disturbance regime in areas dominated by forest and rangeland PVGs.

Forest-Rangeland Landscape Patterns
Succession/Disturbance Regimes

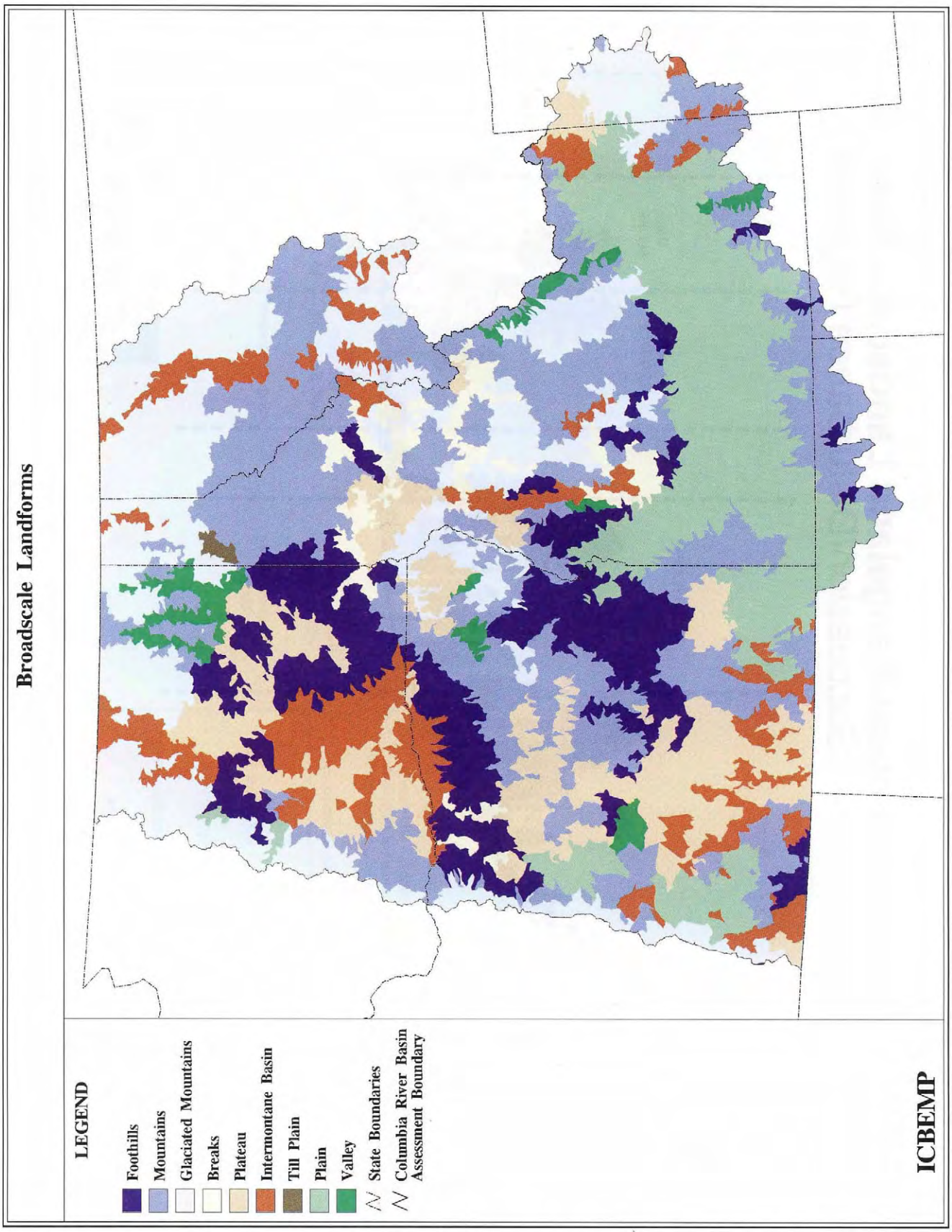


Traditional Commodity

Forest-Rangeland Landscape Patterns
Succession/Disturbance Regimes



Traditional Reserve Pattern



Map 3.10—Broadscale subsection landforms of the Basin. Landforms are based on the dominant subsection landform within subwatershed.

We developed generalized landforms based upon a modal watershed profile that accounted for most combinations of fine- and mid-scale landforms that occurred within the broad-scale landforms. Our classification of generalized landforms was based upon Holdorf and Donahue (1990), McNab and Avers (1994), Nesser and Ford (1995), Peterson (1981), and Rosgen (1994). We named the generalized landforms for ease of interpretation at the subbasin or finer scales. Iterative testing indicated that the generalized landforms provided a biophysical platform that was correlated with the patterns of succession and disturbance regimes, land use, and subsequent vegetation structures and composition (Hann and others 1997). The generalized landforms included:

- Ridge: areas that connect the tops of adjacent slopes, forming a divide between two watersheds. Ridges, for multi-scale purposes, can be narrow to broad, or steep to flat. Ridges typically have shallow or rocky soils and low soil moisture relative to the adjacent slopes. Ridges are always located adjacent to a slope. The slope break between the ridge and slope causes a reduction in upslope wind velocities.
- Slope: an inclined surface that generally has a vertical to horizontal ratio exceeding 10 percent. Slopes connect ridges to other landforms, usually a footslope. Slopes typically have soils that are deeper, less rocky, and more moist than ridges. Slopes typically have winds that are affected by broad-scale landforms. Generally, upslope winds occur during the afternoon and downslope winds occur at night. Slopes adjacent to wider valleys often are subject to thermal heating in the afternoon and thermal inversion during the night. Consequently, these slopes have a warmer environment, particularly in the summer, than would be expected. Steep slopes on river breaks are often influenced by upriver winds in the afternoon, and downriver winds at night.
- Footslope: the bottom end of a slope that is concave in shape. The footslope landform generally has deeper soils, and soils with higher moisture content than the adjacent slope, terrace, or plain. These landforms are commonly located in areas subject to alluvial and colluvial deposition. Footslope landforms often occur in areas where air inversions (that is, areas that retain cold air at night and in the early morning) are common. Winds are typically more erratic on footslope landforms, due to their concave profile, than on the adjacent slope, plain, or terrace landforms. Their concave shape may either impede the wind or promote wind gusts. Footslopes typically connect plain or terrace landforms to a slope, but can also connect a slope directly to a toeslope or channel zone/draw. Footslopes can also be found on gently rolling or inclined plains. Regardless of their position, the subsoil layer within footslopes causes the water table to be close to the surface.
- Terrace or plain: a flat or slightly inclined surface with generally less than a 10 percent slope. Typically these landforms have deeper soils containing fewer rocks than the ridge and slope landforms. Terraces are often affected by cold air inversion during the evening and early morning. Winds are typically controlled by the plain or valley broad-scale landforms. Terraces in valleys are generally subject to upriver winds in the afternoon and downriver winds at night. Plains adjacent to broad-scale mountain landforms are commonly influenced by relatively strong afternoon winds and windstorm events associated with the broad-scale plains and mountains landforms. A terrace will almost always connect a toeslope or channel zone/draw to a footslope or slope landform. A relatively narrow terrace is known as a bench. A plain, on the other hand, may or may not connect with a footslope or slope, but will generally connect with a toeslope or channel zone/draw. The terrace or bench is found within the subsection valley or basin landforms, in narrower valleys of mountains and foothills, and in valleys out in the plains. Terrace areas are commonly in the long-term floodplain. The plain is typically found in the broad-scale plains or basin landforms.

- Toeslope: this landform is a relatively steep incline that connects the slope, footslope, terrace, or plain to the stream channel. Soils are typically coarse. Toeslopes in narrow valleys or draws that connect terraces to channel zone/ draws may occur in the floodplain and can be inundated by floods or beaver ponds, whereas toeslopes in wider valleys may not be affected by flood waters.
- Channel zone/Draw: includes the area affected by the average annual wetted perimeter of intermittent or perennial streams. This is considered the active channel zone. The draw may be dry or have an intermittent stream channel, but usually has subsoil moisture and seeps or springs. Some dry draws may also be subject to alluvial or colluvial events.

The complexities of temporal landscape changes are related to the patterns of succession and disturbances. The succession/disturbance regimes (table 3.6) were correlated with general landforms, dominant PVGs, and land uses in order to identify repeatable relationships. The dynamic relationships among succession and disturbance regimes, landforms, and land uses were developed from various scales of paired oblique photographs from historical and more recent periods (Losensky 1995), field reconnaissance, aerial photos, and interpretations from plot data and photos (Hann and others 1997).

Of the variables tested, general landforms were the most strongly correlated (65%) with succession/ disturbance regimes. The predictability of succession/disturbance regimes was increased incrementally by adding the following variables to our hierarchical model:

1) potential for woody vegetation versus herbaceous vegetation;
2) potential life form (for example, a conifer tree, broadleaf tree, shrub, or herb);
3) management class (that is, the identified land ownership, type of management, and whether an area had been roaded or remained virtually unroaded) (see table 3.4);
4) physiognomic type or terrestrial community; and
5) potential vegetation group.

We did not observe strong correlations between fine-scale potential vegetation types and succession/disturbance regimes. This weak correlation was likely due to compensating environmental variables that can produce a similar environment for plants, but a very different environment for succession and disturbance. For example, a PVT with potential for Douglas-fir can occur on a south-facing bench or terrace with a frequent maintenance regime, as well as on a lower elevation north slope with an accelerated cycle regime. Another case would be a sagebrush PVT on a ridge landform with deep soils and a moderate cycle regime compared to a sagebrush PVT on a steep south-facing slope at higher elevation with a frequent maintenance regime.

We classified subbasins according to their dominant, coarse land-use patterns including traditional commodity or traditional reserve management strategies. These land-use strategies were compared to the native (or HRV) systems.

The native system was based on our understanding of the HRV, which in turn was developed from VDDT and CRBSUM simulations, mid-scale pattern analyses (Hessburg and others 1996a), historical oblique photos (Losensky 1995), the literature, and review of plot data (Hann and others 1997). Traditional commodity management was identified and described using information from modal areas dominated by traditional forestry or livestock management. Traditional reserve management was identified and described using information from modal areas dominated by wilderness and roadless area management objectives.

We described landscape patterns at the subbasin level which incorporated the dominating mosaic of PVGs (forest, rangeland, and forest-rangeland mosaics), general landforms, land-use patterns, vegetation structures, and succession/disturbance regimes.

Rangeland Ecology and Grazing Management

Factors Related to Rangeland Health and Broad-scale Vegetation Changes on Rangelands and Riparian Areas

Detailed reports were written by the project staff on specific topics in rangeland ecology and grazing management, primarily using source material from solicited external contract reports, solicited external peer reviews of selected external contract reports, published literature, and databases. Specific topics in rangeland ecology and grazing management were selected based on their relevance to: (1) rangeland health, which was identified within the "Purpose of and Need for Action" for the two EISs[1], and (2) potential broad-scale vegetation changes on rangelands and riparian areas emanating from landscape modeling and analyses. Specific topics included: woody species encroachment, particularly by western juniper; microbiotic crusts; livestock grazing in riparian areas; and exotic plant invasions (particularly by legally-declared "noxious" weeds). As reports were being written on these topics, three additional topics were selected that we deemed worthy of detailed reports: implications of livestock herbivory in the Basin, cheatgrass invasion, and indicators of susceptibility of rangeland health to management-induced disturbance stresses. These detailed reports were used as primary sources in the "Rangeland Ecology and Grazing Management" subsections of the "Results and Discussion" section of this chapter. Cheatgrass was addressed separately from the noxious weeds because cheatgrass, although an exotic plant, had not been legally declared a noxious weed in the Basin at the time this document was prepared. In addition, we determined that cheatgrass warranted more thorough discussion because of its great areal extent in the Basin and its pivotal role in disturbance regimes.

[1] Purpose of and Need for Action are sections within the Eastside and UCRB Draft Environmental Impact Statements, on file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar, Walla Walla, WA 99362.

Solicited external contract reports and peer reviews are on file with the ICBEMP. External contract reports were subjected to external peer review if we believed the rangeland topic and content of the report were contentious, or the content was narrow in scope. Financial constraints did not permit external peer review of all external contract reports. External peer reviews were, in most instances, additional to peer reviews solicited by the author(s) of the contract reports. Our objectives in seeking external peer reviews were to obtain additional credible scientific documentation that the author(s) of contract reports might have overlooked, and to seek scientifically-substantiated viewpoints different from those presented. The author(s) was not disclosed to peer reviewers. Reports were not solicited for all topics; reports for cheatgrass invasion and indicators of susceptibility of rangeland health to management-induced disturbance stresses were primarily completed by the project staff.

The following lists solicited external contract reports and their solicited external peer reviews, by topic:

1) Herbivory in the Basin by Large Herbivores

- Solicited Contract Reports and Peer Reviews:

  Burkhardt, J.W. 1994. Herbivory in the intermountain West: an overview of evolutionary history, historic cultural impacts and lessons from the past. 49 p.

  Burkhardt, J.W. 1994. Paleoecological relationships of prehistoric *Equus* in the intermountain West: an overview with implications for management of wild horses and burros. 49 p.

- Both Reports Reviewed by:

  Elizabeth L. Painter, Ph.D., Research Associate, Jepson and University Herbaria, University of California, Berkeley, CA.

  Charles E. Kay, Ph.D., Adjunct Assistant Professor, Department of Political Science, Utah State University, Logan, UT.

2) Western Juniper Expansion

- Solicited Contract Report and Peer Reviews:

  Eddleman, L.E.; Miller, R.F.; Miller, P.M.; Dysart, P.L. 1994. Western juniper woodlands (of the Pacific Northwest): science assessment. 131 p.

- Reviewed by:

  James P. Dobrowolski, Ph.D., Associate Professor, Department of Rangeland Resources, Utah State University, Logan, UT.

  A. Joy Belsky, Ph.D., Staff Ecologist, Oregon Natural Resources Council, Portland, OR.

3) Microbiotic Crusts

- Solicited Contract Report:

  Williams, J.D. 1994. Microbiotic crusts: a review. 56 p.

4) Livestock Grazing in Riparian Areas

- Solicited Contract Reports:

  Kindschy, R.R. 1994. Riparian restoration and management. 54 p. + illus.

  Rasmussen, C. 1994. Riparian community and bank response to management: a comparison of old and new surveys in the Prineville District, Bureau of Land Management. 32 p. + illus.

5) Exotic Plant Invasion

- Solicited Contract Report:

  Sheley, R.L., ed. 1994. The identification, distribution, impacts, biology and management of noxious rangeland weeds. 366 p.

We restricted our analysis of exotic plant invasions in the Basin to a set of 25 exotic plants (24 legally-declared noxious species and cheatgrass; see table 3.13), many of which were selected based on their inclusion in Sheley (1994). In addition, information was compiled on nine exotic plant species [one of which, squarrose knapweed (*Centaurea virgata*), was also included in the set of 25 species] that were selected based on their proposed status as new, or potentially new, exotic plant invaders of the Basin. Thus, information on exotic plant invasion was collected and analyzed for 33 species.

The basic components of our exotic plant invasion analysis included: (1) mapping of the areal extent of the 25 exotic plant species at the county level within the Basin; and (2) developing a Susceptibility to Invasion Index (for the 25 previously mentioned species) of the broad-scale cover types in the Basin. The Invaders database Release 6.2 (Karl 1995), published and unpublished literature, and personal observations by numerous exotic plant experts, were the primary sources used in this analysis.

The Invaders database is housed at the University of Montana and is maintained by Peter M. Rice,[2] a contractor of the ICBEMP. The Invaders database is a collection of distribution records of primarily exotic plant species that reside in Washington, Oregon, Idaho, Montana, and Wyoming. The Invaders database Release 6.2 contains 64,217 distribution records, of which 51,587 (80%) are for exotic plant species. Of these 51,587 records, 14,438 (28%) are for legally-declared noxious weeds. Of these 14,438 records, 7,445 (nearly 52%) pertain to the 24 noxious weed species included in table 3.13. The records were collected for the 199 counties, five-state area, of which only 97 counties lie totally or partially within the Basin. Thus, not all 7,445 records were collected within the Basin.

Distribution records were collected from an array of sources, including: five of the six largest regional herbaria (Oregon State University, Washington State University, University of Idaho, University of Montana, and Montana State University); State Department of Agriculture surveys, Animal and Plant Health Inspection Service (APHIS)/Cooperative Agricultural Pest Survey (CAPS) surveys; U.S. Forest Service Intermountain Region ECODATA and Pacific Northwest Region

[2] Peter M. Rice. Research Associate, Division of Biological Sciences, University of Montana, Missoula, MT 59812.

Table 3.13—Exotic plant species found within the Basin that have a widespread county distribution or a somewhat restricted distribution [assessed in Karl and others (1995)]. With the exception of cheatgrass which has not been legally-declared noxious in the Basin, all species have been legally-declared noxious in at least one of these five states: Washington, Oregon, Idaho, Montana, and Wyoming.

Widespread[1]		Somewhat Restricted[2]	
Common Name	**Number of Counties[3]**	**Common Name**	**Number of Counties**
Bull thistle	71	Common crupina	6
Canada thistle	97	Dyers woad	33
Cheatgrass	97	Halogeton	11
Dalmatian toadflax	80	Mediterranean sage	16
Diffuse knapweed	84	Medusahead	37
Hoary cress (whitetop)	86	Orange hawkweed	23
Leafy spurge	72	Rush skeletonweed	48
Musk thistle	72	Squarrose knapweed	4
Oxeye daisy	48	Sulfur cinquefoil	35
Purple loosestrife	49[4]	Yellow hawkweed	18
Russian knapweed	83	Yellow starthistle	55
Scotch thistle	71[4]		
Spotted knapweed	92		
Yellow toadflax	69		

[1]At least one-third of the counties in Washington, Oregon, Idaho, and Montana have reported the presence of these exotic plant species.

[2]Exotic plant species reported in fewer than one-third of the counties, in at least one of the four above-mentioned states.

[3]There are a total of 97 counties represented within the five state (Washington, Oregon, Idaho, Montana, and Wyoming) portion of the Basin.

[4]Does not meet the criteria for "widespread" because the plant's reported distribution in Montana is in less than one-third of counties. However, its distribution is widespread in the other states.

Ecology Plots; and a survey of selected regional weed experts.[3] Additional distribution records were obtained from various publications, private collections, a partial data set from the Rocky Mountain Herbarium located at the University of Wyoming, and smaller regional herbaria.

County distribution maps for each of the 25 species in table 3.13 can be found in Karl and others (1995), and Rice and Rider (1995). County distributions were summarized in table 3.13. The county distribution maps were derived from 121 years (1875-1995) of records and included counties in which at least one distribution record for any of the 25 species showed a specific county where a species existed. Counties with distribution records were judged as having definitive presence of a species. Counties without distribution records, however, did not in our judgment provide proof of the absence of a species. The absence of distribution records for a species within a county did not equate to the absence of that species from the county.

[3] Unpublished data. Michael G. "Sherm" Karl. 1996. Rangeland Management Specialist-Ecologist, U.S. Department of Agriculture, Forest Service, Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar, Walla Walla, WA 99362.

The Susceptibility to Invasion Index was compiled from the distribution records within the Invaders database, which were queried to determine the vegetation cover type associated with the distribution record. Several literature sources and the Fire Effects Information System database[4] were used to supplement the query of the Invaders database. The product of the query was a data matrix of 950 cells (38 cover types times 25 exotic plant species). Each cell contained a rating of susceptibility to invasion. The susceptibility ratings were determined at the cover type level because cover types represent vegetation that presently exists on the land surface. Cover types are a result of natural and anthropogenic disturbances. As such, cover type susceptibilities are useful to land managers and others who are interested in detecting infestations of these exotic plant species. The ratings and their definitions are:

- H = High susceptibility to invasion: Exotic plant species invade the cover type successfully and become dominant or codominant even in the absence of intense or frequent disturbance. These exotic plant species are categorized as "invaders" (Bazzaz 1986) to the cover type.
- M = Moderate susceptibility to invasion: Exotic plant species invade the cover type successfully because a high-intensity disturbance or frequency of disturbance alters the soil surface or vegetation cover. These exotic plant species are categorized as "colonizers" (Bazzaz 1986) to the cover type.
- L = Low susceptibility to invasion: Exotic plant species typically do not establish successfully because the cover type does not provide suitable habitat.
- U = Unknown susceptibility to invasion: Several factors could have led to this rating. Distribution data for the species might have been insufficient to permit a susceptibility rating, or ecological requirements of the species might not be available. The cover types associated with the distribution records might be poorly defined, or the cover type might be a minor areal component of the Basin so that the probability of obtaining records within it is exceedingly low.

Susceptibility ratings were proposed for each cell in the matrix if any information judged to be pertinent to the cover type was available. We propose that this resulted in a rather liberal portrayal of susceptibility to invasion, especially where information on susceptible habitats from source material was reported in a coarse context (for example, shrub-grassland or arid rangeland). Judgments were made as to what cover types should be included when coarse habitats were referred to as susceptible.

The Susceptibility to Invasion Index was linked with precipitation data to produce maps of the susceptibility of the Basin to invasion by five exotic plant species including cheatgrass, diffuse knapweed, leafy spurge, spotted knapweed, and yellow starthistle. The cover type theme (ICBEMP GIS CRBSUM Current Vegetation Cover Types Theme[5]) was linked to the "high," "moderate," "low," and "unknown" ratings of the Susceptibility to Invasion Index. These cover type/susceptibility couplets were then overlaid with precipitation zones derived from PRISM precipitation data (ICBEMP GIS Climate-PRISM Precipitation Data Theme[6]) to produce the maps. Precipitation ranges used for these species were 150 to 560 millimeters for cheatgrass, 150 to 890 millimeters for diffuse knapweed, 300 to 760 millimeters for spotted knapweed, and 300 to 635 millimeters for yellow starthistle. Information on precipitation

[4] William C. Fischer. 1987. The fire effects information system [database]. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Intermountain Fire Sciences Laboratory, Missoula, Montana 59801.

[5] ICBEMP GIS CRBSUM Current Vegetation Cover Types Theme. 1995. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management, Interior Columbia Basin Ecosystem Management Project, Walla Walla, WA 99362.

[6] ICBEMP GIS Climate-PRISM Precipitation Data Theme. 1995. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management, Interior Columbia Basin Ecosystem Management Project, Walla Walla, WA 99362.

range for leafy spurge was not available, so only the Susceptibility to Invasion Index was used to produce its map. The "none" category in the maps included cover types with an unknown susceptibility rating; portions of cover types that lie outside the precipitation range of the species; and the barren, water, and urban cover types, which were cover types not included in the analysis. The maps do not spatially delineate the individual cover types in each susceptibility category. However, in the "Exotic Plants-Noxious Weeds" subsection of the "Results and Discussion" section of this chapter, we provide interpretation of the cover type extents in the high susceptibility category for these five species on an ERU scale.

Susceptibility of rangeland health to management-induced disturbance stresses

The National Research Council (NRC), in its text on rangeland health (National Research Council, 1994), defines rangeland health as "the degree to which the integrity of the soil and the ecological processes of rangeland ecosystems are sustained." We compiled information from several sources, primarily Leonard and Karl (1995c, 1995d), Pellant (1996), and U.S. Department of Agriculture (1993),[7] to propose indicators of susceptibility of rangeland health to management-induced disturbance stresses (for example, excessive livestock grazing pressure). We focused on soil properties and climate indicators that could be evaluated from existing coarse-grained data. Soil property indicators included (1) erodibility by water, (2) erodibility by wind, (3) salinity, (4) sodicity, and (5) shrink-swell potential (SSP). Climate indicators included the greater-than-30-centimeters annual precipitation zone, the 25-to-30-centimeters precipitation zone, and the less-than-25-centimeters precipitation zone. These indicators suggest varying levels of inherent "natural" stress in the biophysical system. An increase in the inherent natural stress of the biophysical system is proposed here as conferring a greater level of susceptibility of rangeland health to management-induced disturbance stresses.

Soil property indicators—

1) Erodibility by water: Susceptibility of rangeland health to management-induced disturbance stresses is somewhat dependent on the inherent erodibility of the soil. The soil erodibility factor (K factor) is a measure of the susceptibility of a soil to particle detachment and transport by rainfall. It is a quantitative value that is experimentally determined. A K factor exceeding 0.37 has been used by the Natural Resources Conservation Service (NRCS) as a limiting factor or erosion hazard (USDA 1983). We categorized all soils with a K factor of 0.37 or greater as indicative of a moderate level of inherent natural stress and a moderate susceptibility of rangeland health to management-induced disturbance stresses.

2) Erodibility by wind: A wind erodibility group (WEG) is a collection of soils that have similar properties affecting their resistance to wind. Of the nine WEGs recognized in the STATSGO database (USDA 1993), soils in wind erodibility Groups 1, 2, and 3 are relatively more susceptible to erosion by wind than soils in the remaining groups. We categorized soils in these WEGs as indicative of a moderate level of inherent natural stress and a moderate susceptibility of rangeland health to management-induced disturbance stresses.

3 and 4) Salinity and sodicity: Salinity and sodicity affect plant growth. Both can exacerbate the deleterious effects of soil surface disturbances on plant re-establishment. Salinity is the concentration of all salts more soluble than gypsum, whereas sodicity relates specifically to exchangeable sodium. High concentrations of salts can interfere with the absorption of water by plants and with the exchange capacity of nutrient ions, thereby resulting in nutritional deficiencies. Activities that disturb the soil surface and result in reduced infiltration and greater evaporation rates can lead to greater surface concentrations of salts. The

[7] Also, unpublished data. 1995. Kelly Redmond, Climatologist, Western Regional Climate Center, Atmospheric Sciences Center, Desert Research Institute, PO Box 60220, Sage Building, 5625 Fox Avenue, Reno, NV 89506.

greater surface concentrations of salts exacerbate the negative effects of salts on plant establishment and growth.

The sodium adsorption ratio (SAR) is the standard measure of sodicity. The SAR is the proportion of sodium relative to other cations, and is calculated as:

$$SAR = Na^{+} / \left[\frac{\sqrt{Ca^{2+} Mg^{2+}}}{2} \right]$$

with the cation concentrations presented as milliequivalents per liter (meq/l). Sodic, or alkaline soils, are characterized by a SAR of 13 or greater. The dispersal effect on soil particles attributable to the sodium in sodic soils results in a breakdown of soil structure. Sodic soils, when dry, form large crusty clods that inhibit seedling emergence. When wet, sodic soils have low infiltration and percolation rates. The physical crusting when dry, and the low infiltration rates when wet, hinder plant establishment on these soils. We categorized soils with a SAR of 5 to 12 and/or salinity of 8 to 16 mmhos/cm as indicative of a moderate level of inherent natural stress and a moderate susceptibility of rangeland health to management-induced disturbance stresses. We categorized soils with a SAR exceeding 12 and/or salinity exceeding 16 mmhos/cm as indicative of a high level of inherent natural stress and a high susceptibility of rangeland health to management-induced disturbance stresses. These categorizations are consistent with other interpretations of the limitations of these soil properties to plant growth and establishment of seedings.

5) Shrink-swell potential (SSP): Shrink-swell potential is the susceptibility of soil to volume change attributable to a loss or gain in moisture content. The SSP is related to the type and amount of clay. The SSP is expressed as the change (in percent) in linear extensibility (LE), or as the change (in decimal fraction) of the coefficient of linear extensibility (COLE), from a moist to a dry state. The COLE is calculated as:

COLE = (length of moist sample/length of dry sample) - 1.

Shrinkage of soils characterized by a high SSP (represented by a LE of 6 to 9, or a COLE of 0.06 to 0.09), and soils characterized by a very high SSP (represented by a LE exceeding 9 or a COLE exceeding 0.09), can damage plant roots and limit establishment of many perennial plants. Soils with high or very high SSP are particularly susceptible to invasion by exotic annual plants that have fibrous root systems (for example medusahead) and persist for only one year in place. We categorized soils with a high SSP as indicative of a moderate level of inherent natural stress and a moderate susceptibility of rangeland health to management-induced disturbance stresses. We categorized soils with a very high SSP as indicative of a high level of inherent natural stress and a high susceptibility of rangeland health to management-induced disturbance stresses.

The five soil property indicators were spatially portrayed in the Basin using soil map units derived from the state soil geographic database (STATSGO; USDA 1993). A soil map unit is a delineation on a map of an area dominated by one or more major kinds of soil, or miscellaneous areas (for example, a rock outcrop, or riverwash) that have essentially no soil and support little to no vegetation, or both. Soil map units are named by the taxonomic classification (typically, the soil series) of the dominant soil or miscellaneous area. Map units are individual; each has properties and characteristics that permit it to stand alone. Map units are described in soil surveys published by the NRCS. Soil surveys were not available for the entire Basin, therefore continuous coverage soil-survey level information was not available for the Basin.

Broad-scale assessment of the five soil property indicators that we judged to be indicative of susceptibility of rangeland health to management-induced disturbance stresses was obtained from a more generalized continuous coverage of soils from the STATSGO database. Map units in the STATSGO database typically cover a large area (hundreds to thousands of hectares). They are generally associations of several soil series and are derived from map units described in available soil

surveys from the NRCS, supplemented with schematic data from other sources. STATSGO soils information is general and useful in broad-scale land-use planning and broad-scale identification of areas that are suitable or unsuitable for a variety of uses.

We restricted our spatial portrayal of the soil property indicators to STATSGO soil map units that had at least 75 percent of the soils characterized by one or more of the five soil property indicators. Thus, some soil map units that had less than 75 percent of the soils characterized by a particular soil property indicator were not included. This represents a rather conservative estimate and portrayal of the spatial extent of soils characterized by these soil property indicators. However, we judged this to be suitable to focus attention on the most concentrated, regional areas of susceptibility of rangeland health to management-induced disturbance stresses in the Basin, as indicated by these soil property indicators. Various combinations of soil property indicators were able to be spatially portrayed because soil map units typically had at least 75 percent of the soils characterized by more than one of the five soil property indicators. The 13 soil property indicator(s) that were spatially portrayed are:

1. Erodibility by water.
2. Erodibility by water, and salinity of 8 to 16 mmhos/cm.
3. Erodibility by water, and salinity of 8 to 16 mmhos/cm, and erodibility by wind.
4. Erodibility by water, and high shrink-swell potential, and erodibility by wind.
5. Erodibility by wind.
6. Erodibility by wind, and erodibility by water.
7. Salinity of 8 to 16 mmhos/cm.
8. Salinity of 8 to 16 mmhos/cm, and erodibility by wind.
9. Salinity of 8 to 16 mmhos/cm, and high shrink-swell potential.
10. Salinity of 8 to 16 mmhos/cm, and sodicity (SAR of 5-12).
11. Salinity of 8 to 16 mmhos/cm, and sodicity (SAR of 5-12), and high shrink-swell potential, and erodibility by wind.
12. High shrink-swell potential.
13. High shrink-swell potential, and erodibility by wind.

STATSGO soil map units contained information about the 13 individual or sets of soil property indicator(s). Thus, 13 soil maps indicating various types of stress were portrayed. For clarification, soil map units portrayed for Number 5 (erodibility by wind) were not the same soil map units that were portrayed for any of the other numbered combinations that included erodibility by wind (for example, Numbers 3, 4, 6, 8, 11, and 13). Soil map units portrayed for Number 5 had a 75 percent or greater areal extent of soils characterized by wind erodibility, but none of the remaining four soil property indicators were present in the soils over 75 percent or greater of their extent. For combinations of indicators, for example for Number 11, a soil map unit had to have at least 75 percent of its soil extent characterized by all four of the soil property indicators.

Spatial extents of soils with these soil property indicators were reported and interpreted on an ERU basis, using percent coverage of the ERU. Spatial portrayal of the soil property indicator combinations required special interpretation: we could not assume that the entire extent of soils characterized by an individual soil property indicator also were characterized by other soil property indicators. We judged it safe to assume however, that because we restricted the inclusion of soil map units for analysis to those that had at least 75 percent of the soils characterized by soil property indicators, substantial overlap of soil property indicators could be located within the soil map unit.

Climate indicators—

Climatic factors indicative of rangeland health susceptibility to management-induced disturbance stresses included aridity, frequency of drought, and frequency of favorable periods of precipitation for perennial plant emergence and establishment. These climate factors, supplemented with successional recovery concepts in arid and semi-arid zones, were interpreted and molded into climate indicators, which are zones of annual precipitation greater than 30 centimeters, 25 to 30 centimeters, and less than 25 centimeters. We categorized the greater than 30 centimeters zone as indicative of a moderate to low level of inherent natural stress and a moderate to low susceptibility of rangeland health to management-induced disturbance stresses. In this category, the continuum of susceptibility from moderate to low is a reflection of greater amounts of precipitation received. We categorized the 25-to-30-centimeters zone as indicative of a moderate level of inherent natural stress and a moderate susceptibility of rangeland health to management-induced disturbance stresses, and the less-than-25-centimeters zone as indicative of a high level of inherent natural stress and a high susceptibility of rangeland health to management-induced disturbance stresses.

Frequency of drought and frequency of favorable periods of precipitation for perennial plant emergence and establishment were reported for each of 22 climate divisions existing within the Washington, Oregon, Idaho, Montana, and Wyoming portions of the Basin. Data on precipitation for the 100-year (1895-1994) period for these climate divisions were obtained from the Western Regional Climate Center[8]. Precipitation data were supplied by climate division, month, and year. Monthly precipitation data represented the total amount of precipitation for the 6-month period commencing with the primary month indicated; for example, a value of 26 inches (66 cm) for January 1894 meant that 26 inches (66 cm) of precipitation were received during the 6-month period of January through June 1894. The second 6-month precipitation period extended from February through July, the third from March through August, and so on. Median precipitation levels were calculated for each of these 12, 6-month precipitation periods over a 100-year timeframe. We used the greatest 6-month period of median precipitation for each climate division as the basis for calculating frequency of drought and frequency of favorable precipitation periods for perennial plant emergence and establishment. Drought years were those in which less than 75 percent of the median precipitation was received (for the wettest 6-month period). Favorable precipitation periods for perennial plant emergence and establishment were those in which at least 110 percent of the median precipitation was received (for the wettest 6-month period) for two or more years in succession.

Spatial portrayal of individual or various combinations of soil property indicators was intersected with the climate indicators as follows:

1) Soil map units, or portions of soil map units, lying within the less-than-25-centimeters precipitation zone were categorized as indicative of a high level of inherent natural stress and a high susceptibility of rangeland health to management-induced disturbance stresses. In many instances this raised the susceptibility rating from moderate to high, particularly where a soil property indicator (indicative of a moderate susceptibility of rangeland health to management-induced disturbance stresses) was present within the less-than-25-centimeters zone. Thus, in these instances, the climate indicator overrode the soil property indicator in the determination of the susceptibility rating;

2) Soil map units, or portions of soil map units, lying within the 25-to-30-centimeters precipitation zone were categorized as indicative of a moderate level of inherent natural stress and a moderate susceptibility of rangeland health to management-induced disturbance stresses; and

[8] Unpublished data. 1995. Kelly Redmond, Climatologist, Western Regional Climate Center, Atmospheric Sciences Center, Desert Research Institute, PO Box 60220, Sage Building, 5625 Fox Avenue, Reno, NV 89506.

(3 Soil map units, or portions of soil map units, lying within the greater-than-30-centimeters precipitation zone were categorized as indicative of a moderate-low level of inherent natural stress and a moderate-low susceptibility of rangeland health to management-induced disturbance stresses. As mentioned previously, susceptibility of these lands could shift from moderate to low as precipitation increased. However, the presence of soil property indicators on these lands, particularly in combination on the same land, tends to increase the level of inherent natural stress and shift the susceptibility in the opposite direction, from low to moderate.

Modeling Dynamics of the HRV and Management Prescriptions

The CRBSUM landscape model was used to simulate spatial and temporal dynamics of vegetation, associated disturbances, and related resource and habitat effects. CRBSUM used a multiple pathway approach to model succession and disturbance dynamics where succession classes were linked along succession and disturbance pathways. A succession class was described by a cover type and a structural stage.

Disturbance usually caused a change in succession class, altering the pathway that succession follows in the absence of disturbance. Disturbances were modeled stochastically in CRBSUM using probabilities that were stratified both spatially and temporally, given a certain scenario and management class (table 3.4). A scenario defined the limits of a broad-scale, general, land-management strategy. The "historical (native or HRV) scenario" depicted successional and disturbance processes prior to the extensive influence of Euro-American settlement. The "passive scenario" reflected minimal commodity production, where lands were predominantly used for recreation, education, and research. In the "consumptive demand scenario," the goal was to maximize commodity production through grazing, timber harvest, and other management practices. The "active management scenario" focused on the maintenance and restoration of native ecosystem functions and processes based on the landscape ecology model of contextual opportunity and risk for proper functioning landscape systems (PFS).

Management classes represented a relatively homogeneous, coarse, management area that reflected similar sets of disturbance activities (table 3.4). Management classes were stratified by "wilderness-like"[9] lands and "non-wilderness" lands. The historical (native or HRV) scenario had only one management class, wilderness-like lands, since disturbance probabilities did not vary geographically due to various management strategies.

Scenarios were designed by adjusting disturbance probabilities by PVT, succession class, and management class to reflect a long-term land-management policy. Within a scenario, each disturbance probability was conditional on the management class. PVT and succession class may have also affected the disturbance probability where, for instance, structural stages in moist, productive PVTs with high timber volume, would more likely be harvested given a certain scenario. Each scenario and management class combination had a unique set of probabilities that determined a succession and disturbance regime for a particular PVT.

Initial successional pathway development and fine tuning of disturbance probabilities used a PC-based succession model, the Vegetation Dynamics Development Tool or VDDT model (Beukema and Kurz 1995). The VDDT used the same algorithms as the CRBSUM and allowed the user to evaluate one PVT at a time. Through a series of workshops that assembled a wide range of forest and rangeland ecologists and resource specialists, over 80 succession models were developed that predicted the succession dynamics of the vegetation within the Basin (Hann and others 1997, Keane and others 1996b, Long and others 1996). The workshop participants defined broad-scale groupings of forest and rangeland potential

[9] In this case the term "wilderness-like lands" is synonymous with "wilderness lands," and "non-roaded areas," and natural process or natural/human process management classes.

vegetation types and assigned successional and disturbance pathways and associated disturbance probabilities. Succession and scenario files developed in the VDDT model were imported into a database and then into the CRBSUM.

Individual probability sets were analyzed and refined using a series of database queries and reference tables, which served to aggregate individual disturbances into disturbance groups. Disturbance groups (table 3.14) represented aggregations of approximately 200 possible disturbances in the CRBSUM. They were useful indicators of a probability set's emphasis on natural and human-caused disturbances and portrayed differences between probability sets. Disturbance group probabilities originated from the probabilities of individual disturbances for every PVT, cover type, and structural stage in a scenario. These probabilities were summed for each unique PVT, cover type, and structural stage combination for each disturbance group. The probabilities of disturbance groups were then averaged across groups of PVGs, and physiognomic types and groups of physiognomic types (aggregations of structural stages and cover types). Summaries of probabilities associated with groups of disturbances were calculated for each scenario.

CRBSUM simulations were also used to evaluate succession and disturbance regimes for each scenario across three generalized subbasin groups within the Basin: the Cascade Mountains, the Rocky Mountains, and the Intermountain region (see table 3.1). Area of disturbance, averaged by decade for a 100-year CRBSUM run for each of the disturbance groups, was summarized across these land areas to characterize disturbance regimes associated with each scenario. The historical scenario data were from a 400-year CRBSUM simulation, with average disturbance hectares calculated using output from years 50, 100, 200, 300, and 400. Distribution of vegetation types representing the average of year 50 and year 100, resulting from long-term management under each scenario, was used to characterize successional regimes. Historical scenario data for average vegetation distribution were from the 400-year CRBSUM simulation and results were calculated using years 50, 100, 200, 300, and 400.

The primary objective of the CRBSUM simulations was to contrast trends in landscape changes as a consequence of alternative land management strategies within the entire Basin. The scenarios were designed so that the CRBSUM simulation would span a range of acceptable management strategies within the Basin, and bounded the extremes of environmental effects for any subsequent management alternative designed for the EISs. A management alternative was a viable, broad-scale, land-use scheme tailored specifically for each management class. All of the initial probability sets developed under the scenarios for each PVT were evaluated through an iterative process of summarizing output from VDDT and CRBSUM simulations. This process resulted in the construction of 18 different "management prescriptions" for each PVT. The prescriptions were designed to cover a continuum of simulation conditions and were arrayed to portray differences in management emphases (table 3.15). The emphases were categorized into "conserve," "restore," "produce" classes or combinations of these classes (table 3.16). In general, conserve was a strategy that would have either minimal active management in areas like reserves, or low levels of active management to maintain or restore ecological conditions. Restore was a strategy involving active ecological restoration and maintenance, producing commodity and resource values where applicable. Produce was a strategy for active commodity production with little emphasis on ecological values. In general, the prescriptions were based on various mixtures of management strategies that emphasized either natural-disturbance processes that maintained native composition and structure, or human-disturbance processes that maintained or departed from native composition and structure.

Table 3.14—Disturbance groups and associated disturbance categories used for analyzing disturbance trends.

Disturbance Groups	Disturbance Categories
Commercial Timber Harvest	Even-age cut[1] with no site preparation
	Even-age cut with site preparation
	Even-age cut with reserve trees
	Shelterwood cut
	Shelterwood cut with reserve trees
	Overstory removal
	Group selection cut
	Individual selection cut
	Partial cut
	Commercial thinning
Exotics	Exotic annual grass
	Exotic forb
Non-impactive Grazing	Successional maintenance, big game grazing
	Successional acceleration, big game grazing
	Successional maintenance, livestock grazing
	Successional acceleration, livestock grazing
Pre-commercial Thinning	Pre-commercial thinning from below (younger, smaller trees)
	Pre-commercial thinning from above (older, larger trees)
Prescribed Fire	Prescribed lethal fire
	Prescribed mixed-severity fire
	Prescribed maintenance (underburn) fire
	Prescribed non-lethal fire
Seeding / Control of Exotics	Herbicide application and seeding
	Vegetation manipulation and seeding
Successional Change Grazing	Successional change, big game grazing
	Successional change, livestock grazing
Wildfire	Wild stand-replacing fire
	Wild mixed-severity fire
	Wild underburn
	Non-lethal wildfire

[1]Examples of even-age cuts are clearcut, seedtree cut, or combinations of cuts that mimic low-frquency, high-intensity fire events.

Table 3.15—Management prescription sets (Rx) for Historic Range of Variability (HRV) and scenario modeling.

Rx	Description
HI	Prescription set to model 100-year and 400-year simulations of HRV.
Ecological Restoration Prescriptions	
A1	Prescription set with moderate levels of ecological restoration. Generally designed for areas that have moderate to high departure from HRV, in roadless or conservation areas.
A2	Prescription set with moderate levels of ecological restoration. Generally designed for areas that have moderate departure from HRV, in areas with road access.
A3	Prescription set with moderate levels of ecological restoration. Generally designed for areas that have high departure from HRV, in areas with road access.
N1	Prescription set with low levels of ecological restoration. Generally designed for maintenance of areas that have low departure from HRV.
N4	Prescription set with low levels of ecological restoration typically for use in visually sensitive areas or where the objective has mixed traditional and ecological restoration objectives. Generally designed for areas that have low departure from HRV.
Traditional Reserve Management Prescriptions (wilderness and semi-primitive roadless areas)	
C1	Prescription set for traditional wilderness, park, and semi-primitive area management with minimal ecological mitigation.
N6	Prescription set for traditional wilderness and semi-primitive area management with minimal ecological mitigation.
P1	Prescription set for traditional reserve management with low probability of successful wildfire suppression.
Traditional Commodity Management Prescriptions	
C2	Prescription set for traditional commodity and resource value production at high levels with some ecological mitigation.
C3	Prescription set for traditional commodity and resource value production at high levels with no ecological mitigation.
N3	Prescription set for traditional commodity and resource value production at moderate levels and some ecological mitigation with higher livestock grazing than N8, and low probability of successful wildfire suppression.
N5	Prescription set for moderate level traditional commodity and resource value production with low emphasis on exotic weed control on rangeland.
N8	Prescription set for traditional commodity and resource value production at moderate levels and some ecological mitigation.
P3	Prescription set for traditional commodity and resource value production at very high levels with no ecological mitigation.
Traditional Management in Visually or Environmentally Sensitive Areas Prescriptions	
N2	Prescription set for moderate level traditional commodity and resource value production in visually sensitive areas with somewhat higher livestock grazing than N7 and minimal ecological mitigation.
N7	Prescription set for moderate level traditional commodity and resource value production in visually sensitive areas with minimal ecological mitigation.
P2	Prescription set for minimal levels of management in visually sensitive areas with no ecological mitigation and low probability of successful wildfire suppression.

Table 3.16—Management prescriptions (Rx) sorted by conservation, restoration, and production emphasis.

Rx Emphasis	Rx Ability to Achieve Emphasis	Management of Forest Non-Wilderness/ Roaded	Management of Range Non-Wilderness/ Roaded	Wilderness/ Non-Roaded Management
		Prescription		
Conserve	High	N1	N1	N1
	Moderate	N4	N4, C1	N6[1]
	Low	P1	P1	C1, P1
Conserve - Produce	High	N2, N7	N4	C1
	Moderate	N4 > N5[2]	N1	N1
	Low	P2[1]		N6
Produce	High	P3 > C3 > C2	C3	C1
	Moderate	N8, N3	N2, N3	N6
	Low	N7 > N5 > N4		
Restore	High	A2	A2	A1
	Moderate	A1	A3	N1
	Low	N4	N1	
Restore - Conserve	High	A1	A2	A1
	Moderate	N1	N1	N1
	Low	N4	N4	
Restore - Produce	High	A3	A3	A1
	Moderate	A2	A2	
	Low	N2 > N4 > N5	N1	N1

[1]Model not commonly used in simulations.

[2]> = greater than; Rx has a greater emphasis than the next Rx.

Proper Functioning Landscape Systems

Proper functioning landscapes include those landscapes whose processes are in dynamic equilibrium (including the production of human values), such that the rates and routes of key processes are resilient and respond predictably to disturbances.

We simulated historical conditions to approximate the native disturbance regimes and vegetation conditions (that is, HRV) at the subbasin scale. Future projections of landscape conditions included the short-term (1st decade) and the long-term (50 to 100 year period). We projected effects assuming a traditional independent limits model for the consumptive demand and passive scenarios, and an ecological model for the active ecological management scenario. We assessed outcomes of selected variables that integrated key ecological systems across the landscape template (background information in appendix 3-M).

The assessment of PFS requires the integration of the key variables responsible for landscape responses to disturbances, and planned (for example, silvicultural treatments) as well as stochastic (for example, drought) events.

To facilitate understanding of the complex, hierarchical, ecological and landscape relationships, no more than six strata should be used to compare

landscapes or management options. If more strata are required to assess conditions then one or more of the first six strata can be subdivided. Stratification should be based on the "driving"[10] variables within the assessment area. PFS provides a process for qualitative as well as quantitative landscape assessment. A qualitative "mockup" may be useful to develop a plan to assess PFS in a quantitative manner.

To assess PFS we emphasized landscape spatial and temporal patterns in relation to integrated succession and disturbance regimes, because of their analytical power for multiple scale assessment. We used a process of assessing landscape pattern responses by assessing succession/disturbance regimes within and between biophysical environments (PVGs). Traditional landscape analysis methods reduce variation in landscape patterns and processes by stratifying environments based on potential vegetation and landform. However, to assess proper functioning landscapes we needed a classification system that addressed the complexity of human, hydrologic, carbon-nutrient, food-web, and evolutionary interactions, yet did not overwhelm us with excessive stratifications. The combination of biophysical environment classifications and types of disturbance-specific regimes produced excessive stratifications. In addition, the wide variety of biophysical environments and associated landscape interactions often compensated to produce the same landscape pattern. The classification of landscape succession/disturbance regimes provided an analytical platform that simplified complex ecological interactions.

Transition to PFS and associated conditions of dynamic equilibrium were based on understanding the interactions of ecological elements, functions, and processes within the constraints of the landscape template. Through modeling outcomes for many different combinations of conditions and management strategies we concluded (as hypothesized in the introduction of this chapter) that there are two basic management models: the traditional independent limits management model (referred to as the traditional model) and the ecological landscape contextual and risk managment model (referred to as the ecological model). The traditional management model includes both management for commodities and management for reserves. Although these two types of traditional management on the surface would appear to have very different outcomes, both result in trend toward disequilibrium. This is because these types of management identify specific elements for commodity production or reserve protection and invest human energy to achieve the objective without considering the interrelationships with the other ecological elements, functions, and processes, or the constraints of the landscape in time and space.

We assessed the effects of management scenarios on PFS only for BLM- and FS-administered lands. For the evaluation of properly functioning systems, we used 20 variables that were integrated or direct measures of the key ecological systems and the landscape template. The first three variables suggest a trend toward proper functioning landscape patterns for range, forest, or forest-range types of landscapes. This pattern classification provides an integration of land use (indicator for the human system), type of biophysical environment and upland-to-channel landform relationships (indicator for hydrologic and land systems), and vegetation structures and succession/disturbance regime (indicators for carbon-nutrient and coarse-filter food-web/evolutionary systems).

The landscape pattern variables indicate the equilibrium relationships of the landscape template, since it is important that the succession/disturbance regimes and vegetation structures be in the right place in the landscape (for instance, the multi-layer old forest conditions belong on the moist footslopes where there is a maintenance succession/disturbance regime, not on the dry slope where there is a cycling regime). For wildlands, the PFS landscape pattern would be similar to the general mosaic patterns of the native (HRV) regime. However, because of alterations

[10] Driving variables are variables that can be correlated with the largest amount of difference in conditions or outcomes.

of biophysical templates, reduction of risk of wildfire in the wildland interface, provisions for human access, and production of human commodities and amenities there are many landscapes where the components of vegetation composition and structure, and succession/disturbance regimes may differ from the native regime and yet result in trends toward equilibrium. The differences are deliberate choices that compensate for alterations in the biophysical template, subsidize "lost" elements or functions at larger scales, or change the process to provide for human use, while trending to dynamic equilibrium.

The eight PVG succession/disturbance regime variables were chosen because they provide a more sensitive indicator than the landscape patterns for what is happening within the carbon-nutrient, food-web and evolutionary systems on different types of enviroments. Succession/disturbance regimes respond relatively quickly to changes in management whereas vegetation patterns change more slowly because of their dependence on changing vegetation composition and structure (for example it takes a long time to grow large shade-intolerant trees in the dry forest or bunchgrasses in the dry shrub, but the type or interval of disturbance can be changed quite rapidly).

Soil disturbance variables were chosen because of their sensitivity to land use, succession/disturbance regimes, and landscape patterns; they indicate risks to long-term soil productivity. Soil disturbance is a measure of the average annual amount of disturbed soil; that is, the amount of soil that is exposed to erosion, displacement, or compaction. The variables are predicted based on the interrelationships of: (1) the amount of different types of disturbance (wildfire, prescribed fire, timber harvest, timber thinning, exotic plant invasion, large herbivore grazing, and range improvements), (2) the type of biophysical environment (PVG), (3) the kind of succession/disturbance regime (type and frequency of disturbance as influenced by vegetation resiliency), and (4) the management prescription models for the scenario. The base values were derived from review of plot data that had measured amounts of bare soil and notes on potential for soil displacement, compaction, or erosion associated with the key types of disturbance.

The base soil disturbance values were stratified by forest and rangeland PVGs, succession/disturbance regimes, and whether the scenario was based on the traditional or ecological management model. The stratification by forest and rangeland PVGs provided sensitivity to the effect of disturbance as well as to resiliency of the vegetation to disturbance. Stratification by the succession/disturbance regimes provided sensitivity to the frequency and severity of disturbance and its interaction with the PVG on resiliency of the vegetation. The stratification to the traditional or ecological management model provided an indicator of the emphasis on mimicking the ecological cause and effect relationships that various soils and vegetation have developed through evolutionary time.

Exotic plant risks variables were chosen because of the major impact exotic plants have had on reductions in native plant diversity and changing succession/disturbance regimes. The CRBSUM modeling of exotics by scenario was only used as a guide in trend of results because of the lack of a current inventory of exotic plants. The key factors used for evaluation of these variables were the prescription emphases for range restoration.

Coarse terrestrial and riparian habitats were chosen because of the importance of a coarse-filter approach in balancing rare species recovery within the ecological management model. In other words, the coarse-filter evaluation emphasizes how well a given scenario achieves recovery of a native pattern of habitats and associated disturbance processes. In comparison, fine-filter analyses evaluate habitat outcomes in respect to population persistence. Both are equally important. For instance, a combined approach may identify that habitat patterns required for recovery of a population are not consistent with the native regimes on BLM- and FS-administered lands. If recovery is desired on BLM- and FS-administered lands the information

can be used to ecologically subsidize the cause-and-effect relationships to produce suitable habitat patterns. In additon, to sustain populations over time in a limited habitat area, populations may need to be subsidized.

Fire risks within the rural/wildland interface were chosen because of the desire to reduce risks to human dwellings as part of the human component of PFS. The response was based on the modeled scenario prescription mapping, and information on fuels and crown fire risks in forests and woodlands.

Desired human commodity and amenity values were chosen as direct indicators of the human system. These variables also provided a valuable comparison of the effects of the traditional models in the consumptive demand and passive scenarios to the ecological model in the active management scenario.

The summary assessment of relative differences between trends of all variables was based on the cumulative transition to PFS. We emphasize that this is focused on the interrelationships and landscape transitions, not on each variable as a separate entity. For instance forest landscape pattern transitions are also linked to trends of forest PVG succession/disturbance regimes, forest soil disturbance, forest exotic plant risk reduction, wildland and urban- or rural-dwelling interface risk reduction, and human commodity and amenity values, as well as linkages to range patterns and forest-range patterns and their associated variables.

There were four key steps to our analysis of PFS. First, we identified the driving variables that were hypothesized to account for disequilibrium landscape relationships between or within the human, hydrologic, carbon-nutrient, food web, and evolutionary systems. These variables were then summarized for each subbasin, adjacent subbasins, province or ERU, and the Basin.

Second, we reviewed our results to identify the dominant element, function, or process for the selected variables. This provided a view of the changes from the native (HRV) regime through the early historical, recent historical, and current period for each subbasin. This information was summarized to the EIS management region and Basin scales.

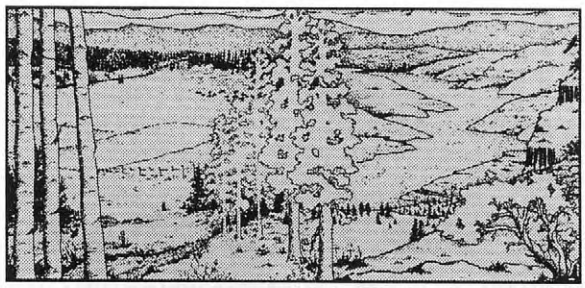
Third, we reviewed the active, passive, and consumptive demand scenarios and prescription strategies (appendix 3-M). This provided us with an understanding of the spatial and temporal relationships of the types of management that were assumed to occur for each scenario for each subbasin.

Fourth, we quantified scenario responses (appendix 3-M), for the selected variables by short-term (1st decade) and long-term (50 to 100 year) futures. This provided us with an understanding of the future outcomes for the driving variables for each scenario for each subbasin. This information was summarized to the EIS management region and Basin scales for interpretation of transition rates and trends to PFS.

Continue

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OVERVIEW OF RESULTS

The results and discussion section of this assessment chapter provides a synthesis of regional and landscape patterns of composition, structure, processes, and conditions in the Basin. Prior to discussing the changes in potential vegetation groups, vegetation, disturbance, and regional and landscape patterns, attention is drawn to maps that depict broad-scale vegetation changes and land use. These maps provide an overall context of the Basin, and may be helpful to the reader prior to reviewing the results. The historical and current period PVG maps (maps 3.11 and 3.12) provide a reference for the major changes in site potentials and development of agriculture. Dominant physiognomic type[1] maps (maps 3.13 and 3.14) provide a comparison between historical physiognomic types and current physiognomic types that are dominant at the subwatershed level. Changes in terrestrial community types are depicted in the historical and current period terrestrial community maps (maps 3.15 and 3.16).

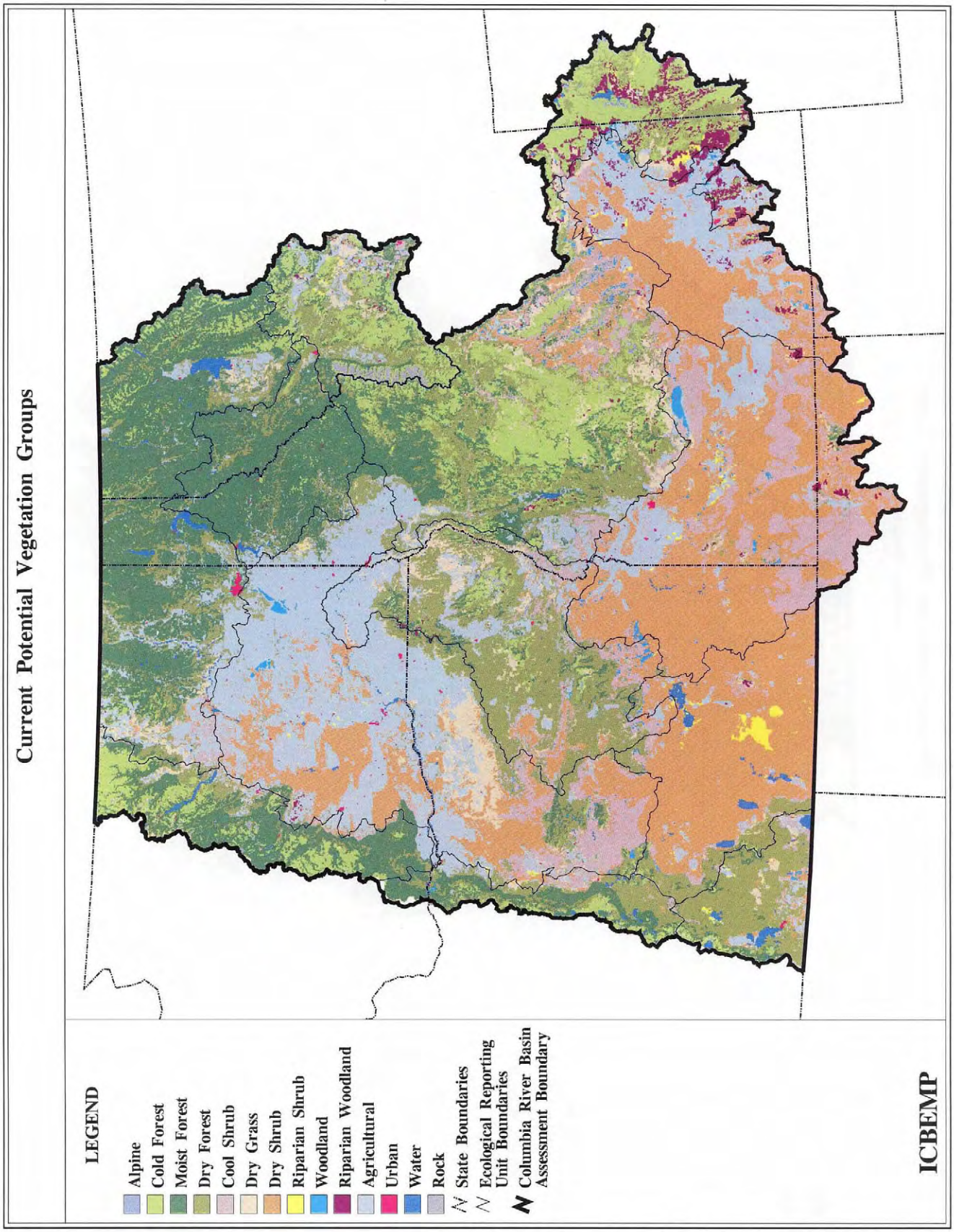
Biophysical Template

The biophysical templates, and their associated succession and disturbance regimes, changed considerably since the settlement of the Basin by immigrants from Europe and other countries. The associated development of agriculture, mining, urban areas, transportation networks, and hydrologic projects directly altered the biophysical templates. Indirectly, these immigrants also changed the biophysical templates as a consequence of fire suppression; forest management; livestock management; the introduction of exotic (non-native) plants and pathogens; and the decline of soil productivity as a result of erosion, compaction, or nutrient depletion (table 3.17). Consequently, agricultural and industrial development of the Basin created a new set of disturbance regimes and succession pathways with which native species had not co-developed.

The development of agricultural croplands, urban areas, and roads were extensive on "Other" lands (lands other than those administered by the Bureau of Land Management or the Forest Service) relative to BLM- and FS-administered lands (BLM/FS lands) within the Basin (table 3.18). Virtually no conversions to agriculture and urban PVGs occurred on BLM/FS lands. The areal extent of roads (table 3.19) was estimated from an extrapolation of subsample areas. Consequently, the estimates were only indicative of the broad-scale trends of road development; absolute values should not be taken at their face value. Approximately 2 percent of the Basin (both BLM/FS and Other lands) occurred as a road PVG during the current period. Most roads on BLM/FS lands were located in non-wilderness forested areas, and to a lesser extent, in non-wilderness rangeland areas.

[1] Physiognomic type is also referred to as "structure group" in other chapters of this document.

Map 3.11—Historical (circa 1850-1900) period potential vegetation groups (PVGs). PVGs reflect the vegetation potentials (without disturbance) in relation to climate and other physical characteristics. This map represents average conditions at the time of Euro-American settlement.



Map 3.12—Current period potential vegetation groups (PVGs). PVGs reflect the vegetation potentials (without disturbance) in relation to climate and other physical characteristics. This map represents average current period (circa 1990) potentials.

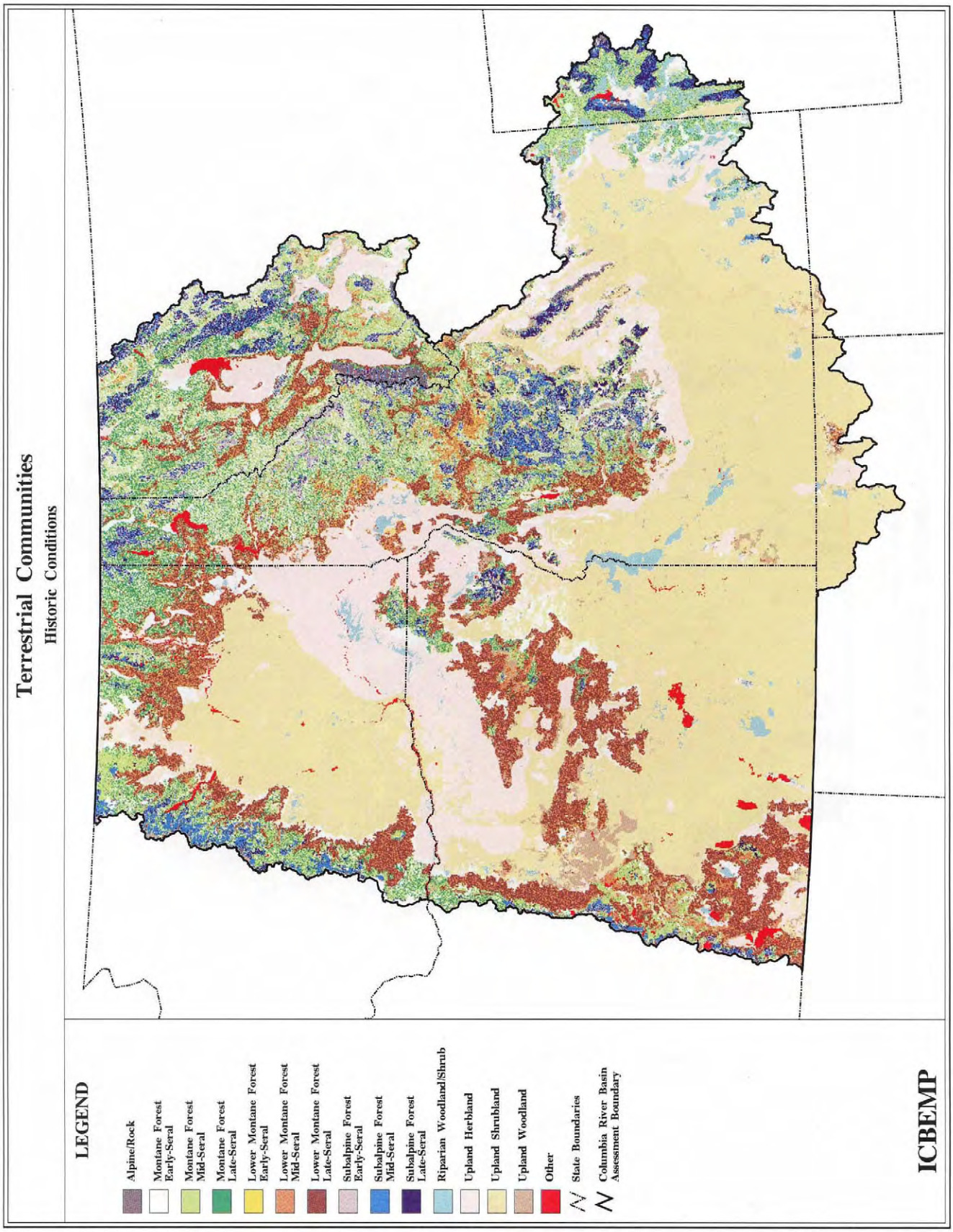
Map 3.13—Historical (circa 1850-1900) dominant physiognomic groups (sometimes referred to as structural groups). Physiognomic groups are aggregations of cover types and structures into similar broad vegetation communities. This map represents average conditions at the time of Euro-American settlement.

Map 3.14—Current period dominant physiognomic types (sometimes referred to as structure groups). Physiognomic types are aggregations of cover types and structures into similar broad vegetation communities. This map represents average current period (circa 1990) conditions.

Continue

Previous

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Map 3.15—Terrestrial communities during the historical period. Terrestrial communities are aggregations of cover types and structures into similar broad vegetation communities that provide terrestrial species habitats. This map represents average conditions at the time of Euro-American settlement (circa 1850-1900).

Map 3.16—Terrestrial communities during the current period (circa 1990). Terrestrial communities are aggregations of cover types and structures into similar broad vegetation communities that provide terrestrial species habitats.

Table 3.17—Potential vegetation groups (PVGs) and potential vegetation types (PVTs) in the Basin; relative change in potential vegetation types from the historical to the current period.

Potential Vegetation Group	Potential Vegetation Type	Relative Change[1]
Agricultural	Dry Crop / Pasture Land	High
	Irrigated Crop Land	High
Alpine Cold Forest	Alpine Shrub - Herbaceous	No Change
	Mountain Hemlock - East Cascades[4]	No Change
	Mountain Hemlock - Inland[4]	No Change
	Mountain Hemlock / Red Fir[4]	No Change
	Spruce-Fir - Dry with Aspen	No Change
	Spruce-Fir - Dry without Aspen	No Change
	Spruce-Fir (LPP > WBP[2])	Low
	Spruce-Fir (WBP > LPP[3])	Moderate
	Whitebark Pine / Subalpine Larch - North	High
	Whitebark Pine / Subalpine Larch - South	Moderate
Cool Shrub	Mountain Big Sagebrush - Mesic - East	Low
	Mountain Big Sagebrush - Mesic - East with Conifer	Low
	Mountain Big Sagebrush - Mesic - West	Low
	Mountain Big Sagebrush - Mesic - West with Juniper	Low
	Mountain Shrub	Low
Dry Forest	Dry Douglas-fir with Ponderosa Pine	Low
	Dry Douglas-fir without Ponderosa Pine	Low
	Dry Grand Fir / White Fir	No Change
	Interior Ponderosa Pine	Low
	Lodgepole Pine - Oregon	No Change
	Lodgepole Pine - Yellowstone	No Change
	Pacific Ponderosa Pine / Sierra Nevada Mixed-Conifer	No Change
Dry Grass	Wheatgrass Grassland	High
	Fescue Grassland	Moderate
	Fescue Grassland with Conifer	Low
Dry Shrub	Basin Big Sagebrush	High
	Big Sagebrush - Cool	Low
	Big Sagebrush - Warm	High
	Antelope Bitterbrush	Moderate
	Low Sagebrush - Mesic	Moderate

Table 3.17 (continued).

Potential Vegetation Group	Potential Vegetation Type	Relative Change[1]
Dry Shrub (continued)	Low Sagebrush - Mesic with Juniper	Moderate
	Low Sagebrush - Xeric	High
	Low Sagebrush - Xeric with Juniper	Moderate
	Salt Desert Shrub	Moderate
	Threetip Sagebrush	Moderate
Moist Forest	Cedar / Hemlock - East	Moderate
	Cedar / Hemlock - Inland	Moderate
	Grand Fir / White Fir - East Cascades	Low
	Grand Fir / White Fir - Inland	Low
	Moist Douglas-fir	No Change
	Pacific Silver Fir	No Change
	Spruce-Fir - Wet	No Change
Riparian Herb	Riparian Graminoid	No Change
	Riparian Sedge	No Change
Riparian Shrub	Mountain Riparian Low Shrub	No Change
	Willow/Sedge	No Change
	Saltbrush Riparian	Low
Riparian Woodland	Aspen	No Change
	Cottonwood Riverine	Low
Road	Road	High
Rock	Rock	No Change
Urban	Urban	High
Water	Water	No Change
Woodland	Juniper	Low
	Limber Pine	Low
	Mountain Mahogany with Big Sagebrush	Low
	Mountain Mahogany	Low
	White Oak	Moderate

[1] Codes to index the amount of change in dominant potential vegetation species and structural stage pathways from historical to current, as a result of exotic invasion or land-use conversion; High - high level of change, such that most successional pathways are altered; Moderate - moderate level of change, such that some successional pathways are unaltered; Low - low level of change, such that most successional pathways are unaltered; No Change - no change in native successional pathways.

[2] Lodgepole pine more abundant than Whitebark pine.

[3] Whitebark pine more abundant than Lodgepole pine.

[4] Shifted from moist forest to cold forest in 2nd version of assessment PVGs.

Table 3.18—Historical and current distribution (historical percent/current percent) of broad-scale potential vegetation groups (PVGs) by elevation class and ownership class.

PVG	Elevation < 1200 m Historical/ Current	Elevation ≥ 1200 m Historical/ Current	Total Historical/ Current	BLM/FS Historical/ Current	Other Historical/ Current
	Percent				
Agricultural	0/75	0/25	0/17 (+100[1])	0/0	0/100
Alpine	0/0	100/100	T[2]/T (0)	83/83	17/17
Cold Forest	1/1	99/99	10/10 (0)	87/87	13/13
Cool Shrub	31/25	69/75	9/8 (-11)	57/66	43/34
Dry Forest	33/31	67/69	19/18 (-1)	54/56	46/44
Dry Grass	69/42	31/58	9/4 (-56)	20/44	80/56
Dry Shrub	40/29	60/71	30/21 (-30)	46/65	54/35
Moist Forest	42/40	58/60	18/18 (0)	63/64	37/36
Riparian Shrub	62/21	38/79	2/T (-80)	14/55	86/45
Riparian Woodland	4/2	96/98	1/1 (-T)	52/54	48/46
Rock	0/0	100/100	T/T (0)	96/96	4/4
Urban	0/81	0/19	0/T (+100)	0/0	100/100
Water	52/52	48/48	1/1 (0)	18/18	82/82
Woodland	30/30	70/70	1/1 (0)	50/50	50/50
Total	37	63	100/100	52	48
BLM/FS Ownership	21	70	52		
Other Ownership	79	30	48		

[1]Percent change from historical to current period; - = a decrease; + = an increase.

[2]T = Trace, < 0.5%.

Table 3.19—Road area estimates by land ownership group in the Basin.

Land Ownership Group	Percent of Ownership Area in Roads
BLM/FS	1.7
Other	2.1
All	1.9

On Other lands, the most substantial change between the historical and current periods was the conversion of approximately 37 percent of the area from native PVTs to agricultural PVTs. Agricultural cropland, pasture, and hayland, were generally dominated by exotic plants. Most of the agricultural development occurred in the dry shrub (nearly 5 million ha), dry grass (nearly 3 million ha), riparian shrub (nearly 1 million ha), and cool shrub (nearly 1 million ha) PVGs. The conversion to urban areas was less than 1 percent, and was not considered to represent a major broad-scale change. However, urban areas, as classified in this assessment, included incorporated towns and cities having high densities of houses, businesses, industrial parks, roads, and associated developments, and not rural areas such as farms, housing developments, gravel pits, and associated developments. Most roads on Other lands occurred in agricultural and forested areas, with lesser amounts on rangeland areas.

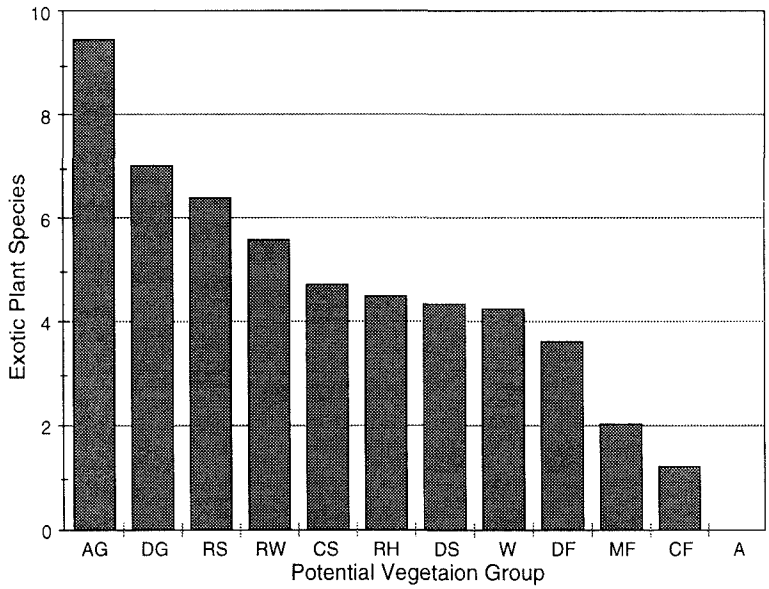


Figure 3.14—This figure shows the average number of exotic plant species [out of 25 exotic plant species (24 legally-declared noxious weeds, plus cheatgrass) assessed in Karl and others (1995)] to which PVGs in the Basin are of high susceptibility to invasion. Our interpretation is that if a PVG is of high susceptibility to invasion by a greater number of species, its potential for invasion by additional exotic plants is greater. This provides only an approximation of a PVG's susceptibility to invasion by exotic plants. PVG acronyms are: AG = agricultural; DG = dry grass; RS = riparian shrub; RW = riparian woodland; CS = cool shrub; RH = riparian herb; DS = dry shrub; W = woodland; DF = dry forest; MF = moist forest; CF = cold forest; and A = alpine. The alpine PVG appears as zero because it is not of high susceptibility to invasion by any of the 25 exotic plant species.

The introduction of exotic plants (for example, annual grasses, and annual, biennial, or perennial forbs) and their establishment in the Basin resulted in the replacement of native cover types and structures, primarily in the dry grass, dry shrub, cool shrub, and riparian PVGs. Although exotic plants invaded the forest PVGs, they typically did not displace the native species to the extent of dominance, partly because exotic plant species were generally shade-intolerant. The establishment of exotic plants in forest PVGs was often dependent upon ample sunlight and was usually associated with roadsides and gaps in forest vegetation. In general, rangeland PVGs on BLM/FS lands including dry grass, riparian shrub, riparian woodland, cool shrub, riparian herb, dry shrub, and woodland (in that order), had a greater potential to be invaded by exotic plants, compared with the forest PVGs (fig. 3.14). These rangeland PVGs cover roughly 43 percent of the BLM/FS lands, and roughly 31 percent of Other lands. The agricultural PVG had the highest susceptibility to the invasion of exotic plants. In contrast, the alpine PVG had the least potential to be invaded by exotic plants. In the current period, we estimated that exotic vegetation dominated at least 3 percent of BLM/FS rangelands and about 1 percent of Other rangelands.

However, since these estimates were based on 1-square-kilometer resolution, the actual area of exotic plant cover was likely much greater and of similar amounts on BLM/FS and Other rangelands.

White pine blister rust, an introduced pathogen, has modified cover types, structures, and successional pathways within the moist and cold forest PVGs. This exotic rust affected the distribution and dominance of western white pine (*Pinus monticola*) and whitebark pine (*Pinus albicaulis*). Historically, these five-needled pines occurred as dominant cover types or residual overstory trees in early- and mid-seral post-fire environments. However, white pine blister rust substantially altered the successional pathways in at least (1) 50 percent of the moist forest PVG, particularly where western white pine occurred as a dominant or common early-seral species; and (2) 50 percent of the cold forest PVG, particularly where whitebark pine occurred as a dominant species. Approximately 19 percent of BLM/FS lands and 8 percent of Other lands were affected by white pine blister rust within the Basin.

Changes of biophysical templates due to the decline of soil productivity were difficult to assess at the broadscale. Excessive livestock grazing pressure on rangelands in the late-1800s and early-1900s caused extensive soil losses from upland habitats. In valley bottom habitats, the local extirpation of beaver, drainage projects associated with agricultural development, and excessive livestock grazing pressure lowered water tables and reduced the areal extent of riparian shrubland and riparian woodland PVGs. In forest ecosystems, changes of biophysical templates due to soil compaction, soil displacement, or nutrient loss were even more difficult to measure than the changes that occurred in rangeland settings. In general, we were unable to detect changes of biophysical templates that were attributable to declines in productivity. The alteration of soil productivity can only be detected using finer-resolution data.

We modified the VDDT models of those PVTs that changed between the historical and current periods as a result of the alterations expressed above (appendix 3-A; table 3.17). Essentially all of the non-forest PVTs had substantial differences in cover types and/or dominant structural stages due to the invasion of exotic plant species. The VDDT models of forest PVTs that had whitebark pine or western white pine as important components of their cover types or structural stages were also changed as a result of white pine blister rust.

General Patterns of Succession and Disturbance Regimes

Because this assessment was focused on the management of BLM/FS lands, we concentrated our study of succession and disturbance regime patterns on areas dominated by wildland forest and rangeland environments. Consequently, we did not address those areas dominated by agricultural and urban land uses in this discussion. The composition of succession and disturbance regimes appeared to be stratified by landforms and their associated PVTs. The three strata that emerged included: (1) foothill and mountain landforms dominated by forest PVGs, (2) basin and foothill landforms dominated by non-forest (rangeland) PVGs, and (3) foothill and mountain landforms dominated by a mixture of forest and non-forest PVGs. For each strata, we compared the composition of succession and disturbance regimes of the native system (that is, HRV) to those resulting from traditional forestry or livestock management systems, and the management of reserves.

Areas in foothill and mountainous terrain dominated by forest PVGs had consistent patterns of succession/disturbance regimes associated with vegetation patterns (figs. 3.11a, b, and c; table 3.20). The dominant disturbances affecting succession in the native system were wildfire, insects, and disease. Harvest practices, fire exclusion, and road development associated with traditional timber management have created more severe disturbance regimes. Current fire regimes in these areas were generally less frequent and consequently had more severe effects than fires in the native system. Insect and disease infestation was generally more

Table 3.20—Relationships of landforms, succession/disturbance regimes, and vegetation structures within forest landscape mosaics.

Structures and Succession / Disturbance Regime Patterns[1]	Landforms						
	Ridge	Slope	Footslope	Plains/Terrace	Toeslope	Channel zone / Draw	Road
Native Structures	Late-seral[2] Single-layer	Early-seral —[3] Mid-seral Mosaic with Emergents[4]	Late-seral Multi-layer	Late-seral Single-layer	Mid-seral Broadleaf — Tall Shrub Mosaic with Emergents	Shrub — Herb Mosaic	NA[5]
Native Regime	Frequent Maintenance	Accelerated Cycle	Irregular Maintenance	Frequent Maintenance	Moderate Cycle	Short Cycle	NA
Traditional Commodity Structures	Late-seral Multi-layer — Early-seral Mosaic without Emergents	Mid-seral — Late-seral Multi-layer — Early-seral Mosaic without Emergents	Late-seral Multi-layer — Early-seral Mosaic without Emergents	Early-seral / Mid-seral / Late-seral Multi-layer Mosaic without Emergents	Mid-seral / Late-seral Multi-layer Mosaic without Emergents	Shrub — Herb Mosaic	Bare Surface
Traditional Commodity Regime	Very Long Cycle	Retrogressive Cycle	Very Long Cycle	Long Cycle	Long Cycle	Moderate Cycle	Short Cycle
Traditional Reserve Structures	Late-seral Multi-layer — Mid-seral Mosaic with Emergents	Mid-seral — Late-seral Multi-layer Mosaic with Emergents	Late-seral Multi-layer — Mid-seral with Emergents	Mid-seral — Late-seral Multi-layer with Emergents	Late-seral Multi-layer — Mid-seral Mosaic with Emergents	Shrub — Herb Mosaic	NA
Traditional Reserve Regime	Retrogressive Cycle	Retrogressive Cycle	Retrogressive Cycle	Retrogressive Cycle	Retrogressive Cycle	Moderate Cycle	NA

[1]See table 3.6 for description of succession/disturbance regimes.

[2]Early, Mid, and Late-seral refer to forests. If broadleaf is not specified it infers conifer.

[3]A "—" between vegetation structures indicates a mosaic of patches of the different types of structures. A " / " between two structures indicates that the second is in the understory below the first.

[4]Emergents = trees that either grow much taller than others, or that are legacies from the stand prior to disturbance in a mixed stand and that appear to emerge above them.

[5]NA = Not Applicable; did not exist in this system.

pronounced due to the composition and structure of vegetation created by fire suppression and timber harvest. Traditional reserve or wilderness management generally emphasized a passive approach to management, involving little direct vegetation management and a very conservative prescribed natural fire program. Guidelines for prescribed natural fires typically only allow fires that have been lightning-ignited and that achieve prescription guidelines to burn within the reserve (fires are not to escape the reserve boundary). Because few lightning-caused fires have met prescription guidelines, rarely have fires been allowed to burn, with the exception of very large wilderness areas such as the Selway-Bitterroot or Bob Marshal complexes. Consequently, management patterns for traditional reserve also caused substantial changes in succession/disturbance regimes and the associated physiognomic types and compositions. As with commodity management patterns for traditional timber practices, the disturbances in reserve areas were less frequent, more intense, and had more severe effects than those of the native system. Typically, vegetation composition, structure, and patch diversity declined under both types of management.

Areas in basin and foothill terrain that were dominated by non-forest (or rangeland) PVGs also had consistent succession and disturbance regime patterns associated with patterns of vegetation composition and structure (figs. 3.12a, b, and c; table 3.21). Traditional livestock management, in conjunction with fire suppression and the introduction of exotic plants, resulted in substantial changes in these patterns. As with the forest PVGs, the change in regime commonly included less frequent fires that were more intense than those that occurred in the native system. Even in areas under traditional reserve or semi-primitive strategies of management, the introduction of exotic plants and the exclusion of fire substantially changed the succession/disturbance regime and associated vegetation composition and structures. In both the traditional rangeland management and reserve management systems, fire suppression, introduction of exotic vegetation, and excessive livestock grazing pressure created disturbance regimes that had more severe effects. As a result, the diversity of vegetation and landscape structure and composition tended to decline.

Areas in foothill and mountainous terrain, that had both forest and rangeland PVGs had inherently diverse community structure and patch patterns (figs. 3.13a, b, and c; table 3.22). Furthermore, this type of terrain had many complex ecotonal relationships. Traditional timber management, introduction of blister rust, livestock management, introduction of exotic plants, and fire exclusion, substantially changed the succession/disturbance regimes and associated vegetation structures and composition. Typically, the regime change produced less-frequent disturbances having larger cumulative effects than the native system. Traditional reserve or semi-primitive management in conjunction with fire exclusion, and the introductions of blister rust and exotic plants, also substantially changed the succession/disturbance regime and associated vegetation structures and composition. Again, the disturbances were typically less frequent, more intense, and had more severe cumulative effects than the native system. Generally, vegetation structure, composition, and patch diversity declined under the traditional reserve and traditional forestry type of managements. In the foothill and mountain environments, the effects of traditional timber, livestock, and reserve management were more severe than in either the forest or rangeland systems. Changes in foothill and mountain environments were more substantial because their energy gradients were typically much steeper, their disturbance regimes were more dynamic due to the forest/rangeland mosaic, and species diversity was higher.

Table 3.21—Relationships of landforms, succession/disturbance regimes, and vegetation structures within rangeland (non-forest) landscape mosaics.

Structures and Succession / Disturbance Regime Patterns[1]	Landforms						
	Ridge	Slope	Footslope	Plains/Terrace	Toeslope	Channel zone / Draw	Road
Native Structures	Herb—Shrub with Emergent[2] Trees	Shrub-Herb —[3] Herb Mosaic	Tall Herb — Shrub Mosaic	Herb — Shrub Mosaic	Mid-seral[4] Broadleaf Forest / Tall Shrub	Tall Shrub — Herb Mosaic	NA[5]
Native Regime	Moderate Cycle - Frequent Maintenance	Moderate Cycle	Irregular Maintenance	Moderate Cycle	Moderate Cycle	Short Cycle	NA
Traditional Commodity Structures	Shrub or Mid-seral[4] Woodland	Herb Exotic—Shrub —Mid-seral Woodland Mosaic	Shrub—Herb— Exotic Mosaic	Shrub—Herb—Exotic Mosaic	Herb—Exotic—Tall Shrub Mosaic	Shrub—Herb	Bare Surface
Traditional Commodity Regime	Long Cycle	Retrogressive Cycle	Retrogressive Cycle	Retrogressive Cycle	Retrogressive Cycle	Moderate Cycle	Short Cycle
Traditional Reserve Structures	Shrub or Mid-seral Woodland	Shrub— Herb—Exotic Mosaic	Shrub—Herb— Exotic Mosaic	Shrub—Herb—Exotic Mosaic	Mid-seral Broadleaf Forest — Tall Shrub	Tall Shrub	NA
Traditional Reserve Regime	Long Cycle	Long Cycle	Long Cycle	Long Cycle	Long Cycle	Moderate Cycle	NA

[1]See table 3.6 for description of succession/disturbance regimes.

[2]Emergents = trees that either grow much taller than others, or that are legacies from the stand prior to disturbance in a mixed stand and that appear to emerge above them.

[3] A "—" between vegetation structures indicates a mosaic of patches of the different types of structures. A " / " between two structures indicates that the second is in the understory below the first.

[4]Early, Mid, and Late-seral refer to forests. If broadleaf is not specified it infers conifer.

[5]NA = Not Applicable; did not exist in this system.

Table 3.22—Relationships of landforms, succession/disturbance regimes, and vegetation structures within forest/rangeland landscape mosaics.

Structures and Succession / Disturbance Regime Patterns[1]	Landforms						
	Ridge	Slope	Footslope	Plains / Terrace	Toeslope	Channel zone / Draw	Road
Native Structures	Late-seral[2] Single-layer /[3] Herb Mosaic	Herb—Shrub—Mid-seral Mosaic with Emergents[4]	Shrub—Tall Herb—Late-seral Multi-layer Mosaic	Shrub— Herb—Late-seral Single-layer Mosaic	Shrub—Mid-seral Broadleaf Mosaic with Emergents	Shrub—Herb Mosaic	NA[5]
Native Regime	Frequent Maintenance	Accelerated - Moderate Cycle	Irregular Maintenance	Frequent Maintenance	Moderate Cycle	Short Cycle	NA
Traditional Commodity Structures	Late-seral Multi-layer—Shrub—Early-seral Mosaic without Emergents	Shrub—Exotics— Mid-seral— Late-seral Multi-layer Mosaic without Emergents	Herb—Early-seral—Mid-seral —Exotics Mosaic without Emergents	Herb—Early-seral— Mid-seral—Exotics Mosaic without Emergents	Late-seral Single-layer Broadleaf—Late-seral Multi-layer Mosaic without Emergents	Shrub or Bare Surface	Bare Surface
Traditional Commodity Regime	Long - Very Long Cycle	Retrogressive Cycle	Retrogressive Cycle	Retrogressive Cycle	Long Cycle	Short Cycle	Short Cycle
Traditional Reserve Structures	Late-seral Multi-layer—Shrub Mosaic with Emergents	Shrub—Mid-seral—Late-seral Multi-layer Mosaic with Emergents	Mid-seral—Late-seral Multi-layer with Emergents	Shrub / Mid-seral with Emergents	Late-seral Multi-layer / Mid-seral Mosaic with Emergents	Shrub—Herb Mosaic	NA
Traditional Reserve Regime	Long - Retrogressive Cycle	Long - Retrogressive Cycle	Retrogressive - Long Cycle	Long - Retrogressive Cycle	Retrogressive Cycle	Moderate Cycle	NA

[1]See table 3.6 for description of succession/disturbance regimes.

[2]Early, Mid, and Late-seral refer to forests. If broadleaf is not specified it infers conifer.

[3]A "—" between vegetation structures indicates a mosaic of patches of the different types of structures. A " / " between two structures indicates that the second is in the understory below the first.

[4]Emergents = trees that either grow much taller than others, or that are legacies from the stand prior to disturbance in a mixed stand and that appear to emerge above them.

[5]NA = Not Applicable; did not exist in this system.

Biogeochemical Processes

Simulations of the four indices of biogeochemical processes [net primary productivity (NPP), carbon stress index (CSI), water stress index (WSI), and nutrient availability index (NAI)] were compared between historical and current period conditions for PVGs of the Basin in table 3.23. Changes of biogeochemical processes within a PVG were primarily a consequence of changes in vegetation structure and composition. There were substantial changes in NPP from historical to current periods in a number of PVGs at the Basin scale. At this scale, substantial changes were those that exceeded 1.0 percent of PVGs that exceeded 400,000 hectares. PVGs of less than 400,000 hectares in size, such as the alpine and urban PVGs, could not be adequately assessed at this scale.

Relationships between the four indices (NPP, CSI, WSI, and NAI) and the effects on long-term site productivity are complex and do not have the same response among different PVGs. NPP is primarily influenced by the vegetation community (for example, high leaf surface area usually equals high NPP). In forest PVGs, forest communities dominated by dense or multiple layers of short-needled conifers have the highest NPP. In rangelands, those communities with more layers (for example shrub/herb communities) and higher biomass, commonly have the highest NPP. In contrast WSI and NAI are influenced by two primary variables, the vegetation and the soil, which interact with each other and NPP. CSI is influenced by the interactions of NPP, WSI, and NAI. On moisture limited uplands, the WSI will increase when NPP and growth processes exceed

Table 3.23—Change between historical and current period biogeochemical indices by potential vegetation group (PVG).

Current PVG	Square km	Average NPP[1]	Average CSI[2]	Average WSI[3]	Average NAI[4]
Agricultural	118,363	5.22	8.54	12.94	-18.21
Alpine	3,727	-7.03	-0.41	-1.88	-4.49
Cold Forest	99,153	2.80	-5.34	0.30	3.05
Cool Shrub	56,952	-4.22	7.95	-0.32	-5.38
Dry Forest	146,615	4.78	4.01	4.88	-6.14
Dry Grass	41,059	-6.54	3.05	1.70	-9.11
Dry Shrub	209,953	-2.16	4.00	0.48	-2.51
Moist Forest	112,104	-2.21	1.25	1.55	-5.51
Riparian Shrub	5,500	-3.29	2.00	3.60	-14.83
Riparian Woodland	12,194	13.15	-9.60	3.18	3.10
Rock	2,299	0	0	0	0
Urban	1,143	0	0	0	0
Water	7,550	0	0	0	0
Woodland	4,748	10.54	-2.39	1.60	10.63

[1]Net Primary Productivity (g C m^{-2}).

[2]Carbon Stress Index (index between 0 and 100).

[3]Water Stress Index (index between 0 and 100).

[4]Nutrient Availability Index (g C m^{-2}).

the availability of water. When the NPP and growth processes exceed the availability of water or nutrients in moisture or nutrient limited environments the CSI will increase. The NAI is influenced by the amount of nutrients in the vegetation and the availability in the soil.

Traditional management activities can directly effect the soil by lowering its long-term productivity, this is particularly true for activities that increase rates of erosion and cause compaction or displacement, which alter the native structure of the soil. These effects reduce water and nutrient storage capacity, as well as changing plant-root relationships to the soil structure. We found that these effects occur at a fine scale, and extensively across traditional commodity landscape patterns; we found a correlation between these effects and amounts of timber harvest, excessive livestock grazing pressure, and roads. However, effects were highly variable depending on the amounts and type of activities, as well as the influence of traditional mitigation and protection measures.

The primary indirect effects of management activities that present a risk to long-term soil productivity include the exclusion of fire, invasion of exotics, and the associated development of vegetation communities on soils that are incapable of supporting increased amounts of accumulated biomass. These communities often develop carbon or water stresses, and are very vulnerable to wildfire. Nutrients are bound up in the woody tissues and are subject to volatization from severe wildfires. Thus, a decline in long-term soil productivity may result. We found that these conditions typically occur in the broad transition zones from non-forest to woodland or forest, and present an equal risk as those attributed to traditional commodity activities. Forested landscapes with high CSI or WSI, and low NAI, are also at risk of severe wildfires that can result in erosion and decline in long-term soil productivity.

Within the agricultural PVG, the NPP, CSI, and WSI increased considerably, whereas the NAI decreased substantially. Consequently, risks of stress, insect, and disease mortality decreased as a result of inputs of water, fertilizer, and pesticides. Areas where little could be done with water, fertilizer, and pesticides to change basic energy and nutrient relationships were considered to be wildlands. In wildland settings, biogeochemical processes were predominantly influenced by soil productivity and vegetation composition and structure. In most wildlands, NPP declined slightly, carbon stress increased substantially, water stress increased slightly, and nutrient availability declined substantially. Consequently, current wildlands tended to be less productive, more susceptible to stress, insects, disease, and fire-related mortality, and to decline in long-term site productivity relative to the historical period.

All of the shrub PVGs (that is, riparian shrub, cool shrub, and dry shrub) decreased in NPP, but for different reasons. NPP in the riparian shrub PVG decreased due to declining shrub leaf area as a result of livestock grazing during the growing season. The NPP of the cool shrub PVG decreased in response to the increase of shrub density and tree cover, which was a result of fire exclusion. Increased stocking levels of shrubs and trees resulted in higher competition for limited nutrients. In the dry shrub PVG, NPP decreased in response to an increased abundance of exotic annual grasses that had lower LAIs, and to an increase of woodland tree cover that resulted in higher competition for limited water and nutrients. There was also a decline in NPP in the dry grass PVG due to changes similar to those observed in the dry shrub PVG.

The cool shrub, dry shrub, riparian shrub, and dry grass PVGs all had higher carbon stress levels in the current period as compared to historical conditions, primarily as a result of succession to woodlands. Water stress did not change in the cool shrub or dry shrub PVGs, and increased a small amount in the dry grass and riparian shrub PVGs. Nutrient availability declined substantially in the cool shrub, dry shrub, riparian shrub, and dry grass PVGs in response to (1) increases in woodland extent and the associated tie up of nutrients in the woody tissues and litter, and (2) the loss of

nutrients from exotic annual grass systems due to erosion and increased volatilization from shorter fire-return intervals. Soils that developed in shrub- and grassland-maintained systems and that changed with succession to woodlands had the highest risk of decline in long-term site productivity. This was due to the fact that carbon and nutrients were stored in the wood, rather than in the soil, and soil nutrients often declined due to erosion. When woodlands experienced high-intensity wildfire conditions, there were high risks of nutrient capital losses through volatilization or erosion. Riparian shrub communities were also subject to long-term decreases in productivity and increases in stress as a consequence of soil compaction and a decline in water availability, due to lowered water tables when adjacent stream channels were incised.

NPP in the woodland and riparian woodland PVGs increased in response to increasing amounts and densities of woody vegetation. The increase of NPP appears to result from the increase of scattered-to-dense tree vegetation relative to shrubs and herbs in these areas, which was caused by fire exclusion and excessive livestock grazing pressure. Carbon stress levels decreased and water stress increased slightly in the woodland and riparian woodland PVGs because of the decrease in total biomass of trees, shrubs, and grasses. An increased water use by trees resulted from a more simplified patch structure as these communities became dominated by a dense, continuous, upper-canopy woodland layer and lost their herb and shrub layers. Nutrient availability increased substantially in these types in response to the loss of the herb and shrub layers, but this lack of herb cover also subjected these types to erosion.

This increased response in the woodland PVGs is opposite to the decline exhibited in the shrub and grass PVGs. Both have increased amounts of woody material, which can tie up nutrients and make them less available. However, the increase in NPP and soil temperature in the woodland PVGs, which was the result of a shift to mid-seral forest and shrubland dominance, caused an increase in nutrient capture and decay rates. These increased rates have, in turn, resulted in increased nutrient availability. However, because of the lack of light, and high competition for moisture within the woodland and shrub types, understory herb production is low. Consequently, most of the nutrients that are available are not used for growth.

NPP in the dry and cold forest PVGs increased in response to the conversion of historical forests dominated by shade-intolerant tree species to current-period forests dominated by shade-tolerant tree species. Shade-intolerant tree species generally have longer needles that are arranged in an open configuration, as compared to shade-tolerant species that typically have a short, dense, two-ranked, needle arrangement. The higher photosynthetic surface area of the shade-tolerant species results in higher productivity unless levels of CSI, WSI, or NAI restrict NPP. Increased densities in forests of shade-tolerant species has resulted in higher NPP for these two PVGs.

This increased dominance by shade-tolerant species occurred in the dry forest PVG as a result of traditional tree harvest practices, tree regeneration practices, and fire exclusion. Although traditional harvest and regeneration practices favored shade-intolerant tree species on some managed patches, when combined with fire exclusion, these practices favored shade-tolerant species at landscape and regional scales. The increased dominance by shade-tolerant species in the cold forest PVG occurred as a result of fire exclusion and blister rust mortality of whitebark pine with a shift to subalpine fir.

In contrast to the dry and cold forest PVGs, NPP in the moist forest PVG declined for two primary reasons: (1) blister rust-caused loss of western white pine, a fast-growing dominant species having high productivity; and (2) the general conversion from structurally complex forested landscapes to simplified landscapes as a result of traditional harvest practices and fire exclusion. Instead of shifting to higher densities of multiple-layer forests and tree species with higher LAI, the shift was to a dense forest of trees species with lower LAI.

Carbon and water stress did not change substantially in the moist forest PVG, but nutrient availability declined considerably. The decline of nutrient availability occurred primarily as a result of nutrients being tied up in litter and live and dead wood, as a consequence of fire exclusion; and the lack of mixed and non-lethal fires that maintained more open-stand conditions and reduced litter accumulation. Carbon stress declined and nutrient availability increased in the cold forest PVG, with no change in water stress. These trends were attributed to an increase of early-seral communities that had less carbon and nutrients stored in live or dead wood and litter. The dry forest had substantial increases in carbon and water stress, and a considerable decline in nutrient availability. In association with the higher NPP driven by the increase of shade-tolerant species, the dry forest PVG was highly stressed and more susceptible to stress-, insect-, disease-, and fire-related mortalities, and risks of declining long-term site productivity.

The biogeochemical relationships on BLM/FS lands were very similar to the responses across the Basin as a whole. The primary difference was the lack of agriculturally influenced biogeochemical processes on BLM/FS lands. There were substantial differences within BLM/FS lands, specifically between areas that had been historically managed using traditional timber harvesting and livestock grazing practices, as compared to areas that had been managed for wilderness and semi-primitive conditions. Areas of wilderness and semi-primitive conditions that were relatively small and where fire exclusion had been successful, generally had lower NPP, higher carbon stress and water stress, and lower nutrient availability. Areas of wilderness and semi-primitive conditions that were moderate to large in size, where fire exclusion had generally not been successful, generally had higher NPP, lower carbon and water stress, and higher nutrient availability.

Relationships to Succession/ Disturbance Regimes

Changes in succession and disturbance regimes were directly related to biogeochemical processes and associated topographic diversity, contagion of vegetation patches, drought frequency, and fire occurrence probability. Although, potential vegetation types were directly associated with biogeochemical processes, they were not well correlated with succession/disturbance regimes at the landscape or regional scales. PVTs occurred in a wide variety of compensating environments and responded to different variables than those that drove succession/disturbance regimes.

The general relationships among biogeochemical processes, the landscape mosaic, and succession/disturbance regimes are summarized in table 3.24. Cycling regimes were typically found in areas where NPP was relatively high and decay rates (as indicated by the NAI) were low to moderate. This relationship between NPP and NAI allowed the accumulation of dead wood and litter, or the development of carbon or water stresses to reach levels that produced a cycling regime in conjunction with a disturbance agent (such as fire, insects, disease, or wind). The accelerated-cycling regime generally had periodic low intensity disturbances that thinned the mature vegetation. Consequently, the accelerated-cycling regime had high productivity and nutrient availability, whereas carbon and water stresses were low to moderate. However, because of the topographic position, contagion to other succession/disturbance regimes, or probability of infrequent but severe droughts, the accelerated-cycling regime eventually experienced disturbance events that cycled. The retrogressive-cycling regime had low productivity because site vegetation was highly stressed by carbon or water availabilities, or was subject to physical impacts from insects, disease, or livestock during the growing season.

Table 3.24—Relationships among biogeochemical processes, succession/disturbance regimes, and the landscape mosaic.

Succession/ Disturbance Regime	Code	NPP[1]	CSI[2]	WSI[3]	NAI[4]	Landscape Mosaic Relationships[5]
Frequent Maintenance	FM	M[6]	L	M	H	Typically in areas with relatively high fire-occurrence probability.
Irregular Maintenance	IM	H	H	L	M	Typically in footslope areas with subsoil water.
Less Frequent Maintenance	GM	M	M	L	M	Typically in colder zones with lower probabilities of drought and fire occurrence.
Accelerated Cycle	AC	H	L	M	H	Typically on upland forest or shrub slopes.
Retrogressive Cycle	RC	L	L-M	L-H	M	Typically a combination of physical impacts on plants, such as herbivory, or high carbon or water stress.
Short Cycle	SC	L	L	L	M	Commonly in river/stream channel, earth flow, or avalanche zones.
Moderate Cycle	MC	H	L	H	M	Commonly on upland forest and non-forest types.
Long Cycle	LC	H	H	M	M	Commonly on upland forest and non-forest types.
Very Long Cycle	VC	H	M	L	L	Typically in valleys or wet areas with low fire-occurrence probability and long intervals between drought.

[1]Net Primary Productivity (NPP).
[2]Carbon Stress Index (CSI).
[3]Water Stress Index (WSI).
[4]Nutrient Availability Index (NAI) - also indicates decay rates.
[5]Topographic position, contagion influences, drought frequency, and fire-occurrence probability.
[6]L = Low; M = Moderate; H = High.

The maintenance regime generally had moderate productivity and high nutrient availability (table 3.24). These systems had decay rates and disturbance intervals that prohibited substantial accumulation of dead wood and litter, and maintained high vigor of the dominant vegetation. Consequently, when disturbance events occurred, the structure and composition of the dominant vegetation did not measurably change. The difference between areas with frequent- versus infrequent-disturbance events was typically related to either climate or the probability of a disturbance event. Colder climates tended to have less dead wood and litter accumulation during a given period of time and lower levels of stress. Consequently, even with a high probability of disturbance occurrence, there may not have been enough dead wood and litter, or stress to provide the conditions suitable for a frequent-maintenance regime. The irregular-maintenance regime typically occurred in a landscape mosaic position where disturbances occurred, but the available subsoil water reduced the severity of those disturbances.

Biogeochemical Assessment Limitations

Our assessment of broad-scale biogeochemical processes had many limitations associated with scale. The scale of our vegetation layers did not always correspond to the scale of the ecophysiological parameters, soils layers, or a digital elevation model. As a result, it was difficult to obtain agreement among spatial locations across all data layers. It was also difficult to develop parameters of the ecophysiological file that corresponded with the vegetation and site layers. Therefore, some fringe areas in the range of a species or lifeform were not modeled with high accuracy. However, we believe that areas representing modal conditions of a particular ecosystem were simulated adequately with the BGC model.

It was especially difficult to mesh the independently-created weather data layers with vegetation data layers and obtain complete correspondence. There were groups of pixels where climate and soils would not support the vegetation depicted in the cover type and structural stage data layers. In these instances, the lack of correspondence between the ecophysiological file and the weather and/or soil data layers could result in negative NPP values. For example, a negative NPP value was produced for the zone between lodgepole pine *(Pinus contorta)* and sagebrush shrublands. The weather data for the lodgepole pine stands was more typical of sagebrush shrublands, which falsely indicated that there was not enough water available to support trees. However, ecophysiological parameters for lodgepole pine forests were used in the BGC model resulting in negative productivity values. Consequently, we set all negative values of NPP to 1.0.

Another serious scale limitation of our application of the BGC model was that each unique combination of cover type and structural stage was assigned a single leaf-area-index (LAI) value based on average values derived from the 1991 Advanced Very High Resolution Radiometer satellite image. Because cover types and structural stages were coarse, we expected the distribution of LAI values to be similar to the average value for each combination. That is, the lower range of the LAI distribution would most likely occur on the more water- or temperature-stressed ranges of the cover type/structural stage combination, and higher LAI values would likely occur on the wetter and warmer sites. As a result, these simulations most likely overestimated stress on the poorest sites (for example, dry sites with artificially high LAI) and underestimated productivity on the best sites (for example, high NPP with a very low LAI). These limitations can be addressed using more sophisticated land cover and structural stage classifications, a more detailed representation of the ecological parameters, and perhaps most effectively, through iterative model simulations that would allow some degree of equilibration between weather, soils, and vegetation input values.

Another limitation of our simulations was the problem of meshing the 2-square-kilometer BGC-model output to other 1-square-kilometer data layers. The composition of the four, 1-square-kilometer pixels comprising a 2-square-kilometer pixel could be quite diverse, especially if they occurred on the edges of a landscape element. This was an unavoidable consequence of using a sophisticated biogeochemical process model to evaluate a region as large as the Basin.

Summary

The relationships between biogeochemical processes and broad-scale vegetation are summarized as follows:

Net Primary Productivity (NPP)

1. Shade-intolerant forests had lower NPP than shade-tolerant forests, probably because of lower leaf areas and higher stem respiration costs.
2. Early-seral forests had higher NPP than late-seral forests and mid-seral forests, and varied in NPP depending on site relationships, composition, and structure.

3. Riparian communities were much more productive than upland sites.
4. Plant communities dominated by exotic species had low structural and species diversity resulting in lower NPP.
5. Productivity across PVGs followed conventional wisdom, with the least NPP values in the driest or coldest ranges of a biome, and values increasing as moisture or temperature increased.
6. Conversion of native grasslands and shrublands to agriculture generally increased NPP, but that increase was mainly due to fertilization and irrigation influences on the high leaf areas of agricultural crops.

Carbon Stress Index (CSI)

1. The PVGs with the highest carbon stress occurred in the driest areas. The productive moist forests had some of the lowest CSI values, indicating less stress.
2. Shade-intolerant forests had higher carbon stress than shade-tolerant forests, because shade-tolerant forests had lower live stem tissue respiration.
3. Single-layer late-seral forests had lower carbon-stress values than multi-layer forests, particularly on dry sites.
4. Upland shrublands and herblands had higher CSI values than riparian sites.

Water Stress Index (WSI)

1. Water stress usually increased with successional status. An increased water availability in early-seral communities was probably due to the lower leaf areas.
2. Although riparian environments have high water availability, they also have high water stress during the summer drought period and are highly sensitive to activities that lower the water table.

Long-term Site Productivity, Nutrient Availability Index (NAI)

1. In general, nutrients were more available in early- to mid-seral forest settings.
2. Single-layer late-seral forests had higher rates of decomposition than multi-layer forests. This is because more sunlight and subsequent warmer temperatures reach the forest soil surface.
3. Herblands and shrublands had higher rates of nutrient turnover than forests because of warmer temperatures and higher relative amounts of herbaceous vegetation.

Succession/Disturbance Regimes

1. The type of regime (cycle or maintenance) had low correlation with potential vegetation types, but had high correlation with potential vegetation lifeform and regeneration strategies of dominant species.
2. The type of regime had high correlation with various combinations of NPP, CSI, WSI, NAI, and the landscape mosaic.

Regional Trends of Succession/ Disturbance Regimes

The succession/disturbance regimes changed substantially between the historical and current periods (table 3.25). For the Basin as a whole, four succession/disturbance regimes were nearly eliminated between the historical and current periods (that is, the accelerated-cycle, frequent-maintenance, less-frequent maintenance, and irregular-maintenance regimes). To the contrary, two successional/disturbance regimes that did not exist historically were apparent during the current period (retrogressive cycle and very-long cycle regimes). Of the four regimes nearly eliminated, only the active management scenario was forecasted to substantially increase its representation within the Basin in the future. The active management scenario was also effective in reducing the extent of the retrogressive cycle and the very-long cycle regimes. The declining and increasing trends

Table 3.25—Basin distribution (%) of succession/disturbance regimes for historical and current periods, and 100-year projection for management scenarios .

Succession / Disturbance Regime	Land Ownership Group	Historical	Current	Scenario[1]		
				CD	AM	PM
			Percent			
Frequent Maintenance	BLM/FS	4.89	0.12	0.08	0.94	0.23
	Other	9.77	0	0	0	0
	All	14.66	0.12	0.08	0.95	0.23
Irregular Maintenance	BLM/FS	7.24	0.68	1.41	6.19	1.40
	Other	3.18	0.03	0.09	0.09	0.09
	All	10.42	0.72	1.50	6.28	1.49
Less Frequent Maintenance	BLM/FS	1.06	0.05	0.08	17.76	0.09
	Other	0.63	0	0	0	0
	All	1.69	0.05	0.08	17.76	0.09
Accelerated Cycle	BLM/FS	7.24	0.41	0.53	7.76	0.53
	Other	3.96	0	0	0	0
	All	11.19	0.41	0.53	7.76	0.53
Retrogressive Cycle	BLM/FS	0	23.03	20.77	0	23.93
	Other	0	17.94	14.71	14.71	13.55
	All	0	40.97	35.48	14.71	37.48
Short Cycle	BLM/FS	0.15	0.42	1.36	0.15	0.69
	Other	0.79	17.21	18.74	18.74	19.42
	All	0.94	17.63	20.09	18.89	20.11
Moderate Cycle	BLM/FS	26.29	12.21	13.19	11.63	10.94
	Other	27.28	4.15	5.28	5.09	5.61
	All	53.57	16.36	18.46	16.72	16.55
Long Cycle	BLM/FS	5.13	12.98	12.49	7.33	12.17
	Other	2.41	8.36	8.94	8.93	8.90
	All	7.53	21.33	21.42	16.25	21.08
Very Long Cycle	BLM/FS	0	1.86	1.87	0	1.77
	Other	0	0.54	0.49	0.69	0.66
	All	0	2.41	2.36	0.69	2.43

[1] Scenarios: CM = Consumptive Demand Management; AM = Active Management; PM = Passive Management.

of the moderate and short-cycle regimes, respectively, were not measurably altered by any management scenarios. The trends of succession/disturbance regimes upon BLM/FS lands mirrored the trends of the regimes across the Basin as a whole. The future projections of an active management scenario on BLM/FS lands reversed the historical trends, resulting in a level that approximated historical conditions for five of the seven regimes that had departed the most between the historical and current periods (that is, the accelerated-cycle, irregular-maintenance, retrogressive-cycle, short-cycle, and very-long cycle regimes). Neither the consumptive demand nor the passive management scenarios were effective in reversing the historical trends of these, or any other regimes. On the other hand, an active management scenario was projected to result in levels of the less-frequent cycle regime that greatly differed from historical conditions on BLM/FS lands. However, this was a deliberate consequence of extending the disturbance interval in frequent regimes to accumulate biomass and to achieve proper functioning landscapes.

We believe active management scenarios will likely reduce the frequency of maintenance-type disturbances in order to accumulate biomass for timber harvest, livestock grazing, and stream protection. Consequently, the preponderance of the less-frequent maintenance regime will probably greatly exceed its extent during the historical period. When stratified by the two management regions, the historical and projected future trends of succession/disturbance regimes were consistent with the trends observed for the Basin (table 3.26).

During the current period, the areal extent of the long-cycle succession/disturbance regime was approximately two and one-half times its historical level on BLM/FS lands (table 3.25). Neither consumptive demand nor passive management scenarios seemed to be effective in reducing the historical to current trend of the long-cycle regime. Although an active scenario was projected to reverse its historical to current trend substantially, the areal extent of the long-cycle regime would likely still exceed historical levels. Even with an active approach, many forest types would probably be managed for a longer cycle of disturbance so that biomass could accumulate for timber products, stream protection, big game security cover, visuals, and other values deemed important by society.

The moderate-cycle disturbance regime dominated BLM/FS lands during the historical period, but was reduced by more than one-half by the current period (table 3.25). The consumptive demand scenario was not projected to be effective in reversing the historical to current trend of the moderate-cycle regime. The declining trend was expected to continue with active and passive management scenarios, but for different reasons. Under an active scenario, fire would likely be intentionally excluded from some portions of the dry shrub PVG to reduce the potential of invasion by exotic forbs and annual grasses. Consequently, a longer-cycle disturbance regime would result, which in this instance, would promote the shift from exotics to a native species community. The fire-return interval would also be extended under a passive management scenario. However, in this case, an increase in fuels would likely increase the potential for very hot and lethal fires. Lethal fires could, depending on the PVG (for example, the dry shrub), lead to an increase in the composition of exotic forbs and annual grasses. This shift in composition (to exotics) would subsequently reduce the fire-return interval and thus, increase the preponderance of the short-cycle regime.

As stated earlier, the retrogressive cycle did not occur at the regional scale during the historical period. However, during the current period, the retrogressive-cycle regime dominated the Basin, regardless of land ownership strata (table 3.25). The dominance of the retrogressive-cycle regime was largely attributable to stress-, insect-, and disease-induced mortality of trees in forest PVGs; and excessive livestock grazing pressure; fire exclusion; and invasions of exotic plants in the cool shrub, dry shrub, and dry grass PVGs. The consumptive demand and passive management

Table 3. 26—Regional distribution (%) of succession/disturbance regimes for historical and current periods, and 100-year projection for management scenarios.

Management Region	Land Ownership Group	Regime Type	Historical	Current	Scenario[1] CD	AM	PM
			..... Percent of Management Region				
EEIS	BLM/FS						
		Frequent Maintenance	5	0	0	1	0
		Irregular Maintenance	4	1	1	5	1
		Less Frequent Maintenance	1	0	0	19	0
		Accelerated Cycle	4	0	0	6	0
		Retrogressive Cycle	0	18	17	0	19
		Short Cycle	0	0	1	0	1
		Moderate Cycle	25	9	10	6	8
		Long Cycle	2	13	12	5	12
		Very Long Cycle	0	1	1	0	1
		Total BLM/FS	42	41	41	41	41
	Other						
		Frequent Maintenance	13	0	0	0	0
		Irregular Maintenance	3	0	0	0	0
		Less Frequent Maintenance	1	0	0	0	0
		Accelerated Cycle	4	0	0	0	0
		Retrogressive Cycle	0	21	18	18	17
		Short Cycle	1	22	24	24	25
		Moderate Cycle	35	4	5	5	5
		Long Cycle	2	12	11	11	11
		Very Long Cycle	0	0	0	0	0
		Total Other	58	59	59	59	59
		Total EEIS	100	100	100	100	100
UCRB	BLM/FS						
		Frequent Maintenance	5	0	0	1	0
		Irregular Maintenance	10	1	2	8	2
		Less Frequent Maintenance	2	0	0	16	0
		Accelerated Cycle	10	1	1	10	1
		Retrogressive Cycle	0	28	24	0	
		Short Cycle	0	0	1	0	1
		Moderate Cycle	27	16	17	16	14
		Long Cycle	8	13	13	10	12
		Very Long Cycle	0	3	3	0	3
		Total BLM/FS	62	62	62	62	62

Table 3. 26 (continued).

Management Region	Land Ownership Group	Regime Type	Historical	Current	Scenario[1] CD	AM	PM
			..... Percent of Management Region				
	Other						
		Frequent Maintenance	6	0	0	0	0
		Irregular Maintenance	3	0	0	0	0
		Less Frequent Maintenance	1	0	0	0	0
		Accelerated Cycle	4	0	0	0	0
		Retrogressive Cycle	0	15	11	11	11
		Short Cycle	1	13	14	14	14
		Moderate Cycle	20	5	6	5	6
		Long Cycle	3	5	7	7	7
		Very Long Cycle	0	1	1	1	1
		Total Other	38	38	38	38	38
		Total UCRB	100	100	100	100	100

[1]Scenarios: CD = Consumptive Demand Management; AM = Active Management; PM = Passive Management.

scenarios did not measurably alter the preponderance of the retrogressive cycle. However, the active management scenario essentially eliminated the retrogressive-cycle regime within a 100-year period.

The short-cycle regime was a minor component of the succession/disturbance regimes of all land ownership strata within the Basin during the historical period (table 3.25). During the current period, it was still only a minor component on BLM/FS lands, but it was a dominant succession/disturbance regime on Other lands. The increased areal extent of the short-cycle regime on BLM/FS lands in the current period was largely associated with the invasion of exotic annual grasses, and on Other lands to annual tillage practices on agriculture lands, in addition to the invasion of exotic annual grasses. On BLM/FS lands, the increasing trend that occurred between the historical and current periods would likely continue under the consumptive demand and passive management scenarios, although the increase would be far greater under a consumptive demand approach. On the other hand, an active management approach would reverse the historical trend, resulting in an extent of the short-cycle regime that would approach historical conditions. On Other lands, the areal extent of the short-cycle regime would continue to increase due to an increasing dominance of exotics, regardless of management scenario. The preponderance of the short-cycle regime on Other lands was projected to be the highest under the passive management scenario because livestock grazing was assumed to increase on Other lands as a result of a reduction in grazing within the reserves on BLM/FS lands.

The very-long cycle regime was virtually absent during the historical period (table 3.25). However, its extent increased substantially by the current period, largely as a result of fire exclusion. Only an active management approach seemed to be effective in reducing the areal extent of the very-long cycle regime to a level approximating its historical.

Table 3.27—Potential net forest insect and disease by scenario for the Basin.

Management Region	Land Ownership Group	Percent Change from Historical	Historical	Current	Scenario[1] CD	AM	PM
		Percent of Area Disturbed Annually					
EEIS	BLM/FS	98.4	8.1	16.1	18.7	11.6	16.0
	Other	39.6	5.4	7.5	11.9	11.9	11.3
	All	70.0	6.5	11.1	14.7	11.8	13.2
UCRB	BLM/FS	98.3	11.1	22.0	20.9	13.1	19.7
	Other	69.3	7.2	12.1	14.0	14.0	13.1
	All	89.9	9.6	18.2	18.2	13.5	17.2
Basin	BLM/FS	98.3	10.0	19.7	20.0	12.5	18.3
	Other	53.8	6.1	9.4	12.8	12.8	12.0
	All	82.1	8.1	14.8	16.5	12.7	15.3

[1]Scenarios: CD = Consumptive Demand Management; AM = Active Management; PM = Passive Management.

We estimated the historical and future trends of insect and pathogen disturbances within forest settings. Tree mortality, resulting from insects and pathogens, affects fire regimes, productivity, habitat suitability, and hydrologic processes. The broad-scale potential of forest insects and diseases has nearly doubled between the historical and current periods for the Basin as a whole, as well as on BLM/FS lands within the Basin (table 3.27). These trends were relatively consistent when the Basin was stratified by the two management regions (that is, EEIS and UCRB). Only the active management scenario effectively reversed the historical trend (potential of insects and diseases) to a level nearer to the historical conditions. The projected level of forest insect and disease potentials under the active management scenario was still relatively high in relation to the historical period. This was because the continued effects of blister rust and the management effects on some forest communities (managed for visuals, big game cover, and watershed protection) would promote relatively high levels of insect and disease disturbances.

We estimated future projections of dominant disturbance activities resulting from consumptive demand, active, and passive management scenarios within forest settings. Average levels for total forest disturbances (that is, wildfire, prescribed fire, thinning, and harvest) on BLM/FS lands were not substantially different between the historical period and projections of the active management and consumptive demand scenarios (table 3.28). However, the activities projected for the passive management scenarios were nearly 30 percent below those of the historical period on BLM/FS lands.

The projections for soil disturbance resulting from vegetation treatments in forest and rangeland settings varied substantially among management scenarios and between the historical and current periods (table 3.29). The amount of soil disturbance during the historical period was approximately 5 percent less than that estimated for the current period on BLM/FS lands. The difference between levels of soil disturbance on Other lands was even more substantial. The projections of soil disturbance were substantially lower for the active

Table 3.28—Percent of forests (that is, forested PVGs) directly affected by forest disturbance (for example wildfire, prescribed fire, thinning, and harvest), by decade, and by scenario within the Basin.

Land Ownership Group	Projection Years	Historical	Scenario[1]		
			CD	AM	PM
		Percent			
BLM/FS	10	21	18	23	14
BLM/FS	100	21	18	24	15
Other	10	29	1	25	29
Other	100	29	18	26	29

[1] Scenarios: CD = Consumptive Demand Management; AM = Active Management; PM = Passive Management.

and passive management scenarios, relative to a consumptive demand scenario, but all management scenarios had projections substantially higher than the projections for the historical period.

Not surprisingly, the historical and projected future trends of broad-scale physiognomic types (appendix 3-H) were associated with the broad-scale trends of succession/disturbance regimes. There were two primary trends that we believe should be emphasized. In the forests, particularly on BLM/FS lands, the succession of early-seral to mid-seral types, and the retrogression of late-seral to mid-seral types, which we observed between the historical and current periods, were transitions that did not occur in native systems. These transitions were caused by two primary trends. The first trend was the exclusion of fire and extensive harvesting of large, shade-intolerant trees that were more resistant to stress, insects, and diseases. As a result, forest dominance shifted to smaller, shade-tolerant trees that were more susceptible to stress, insects, and diseases. Because fires have been excluded from large areas for an extended period of time, and because harvest practices also affected a relatively large proportion of the Basin, the historical trends will be very difficult to reverse unless management activity levels are greatly increased above traditional levels, or traditional activity levels are concentrated to relatively small geographic areas.

The second primary trend pertains to rangelands, and reflects the exclusion of fire, excessive livestock grazing, and invaion of exotics that shifted (1) herb to shrub, woodland, or exotic, and (2) shrub to woodland. The shift of herb to shrub, from historic to current, was primarily detected within dry shrub and cool shrub PVGs. The shift of herb or shrub to woodland was primarily detected within the cool shrub and dry grass PVGs. The changes in disturbance regimes operated to shift herb to shrub or woodland, or shrub to woodland, resulting in a long-cycle regime. However, when the changes in disturbance regime operated to shift herb to exotics, the result was a short-cycle regime, particularly if the exotics were highly-flammable exotic annual grasses. However, with invasion of exotic perennials or loss of soil the regime shifts to a retrogressive system. Thus, the long cycle, short cycle, and retrogressive regimes have become a common component of shrubland and grassland PVGs and act to either lengthen, shorten, or reverse historical succession/disturbance cycles. The increased prevalence of these regimes was attributable to excessive livestock grazing pressure, fire exclusion, and the invasion of exotic plants. The scenarios in appendix 3-H show that in the future, some reversal of the loss of herb and shrub could occur due to the increased use of fire and exotic plant control in the scenarios, which could cause decline in shrub and woodland. However, shrub would eventually increase as a result of use of fire in woodlands and succession from herb to shrub.

Table 3.29—Soil disturbance percent change from the current period for the historical period and from the current period to the scenarios by management region and for the scenarios by management region and for the Basin.

Management Region	Land Ownership Group	Landscape Pattern	Current Period Hectares	Historical[2]	Scenario[1]		
					CD	AM	PM
				..... Percent Change			
EEIS	BLM/FS	Forest	20,597	-84	-1	-61	-38
	Other	Forest	22,408	-86	4	4	18
	BLM/FS	Rangeland	31,816	-97	4	-53	-65
	Other	Rangeland	1,764,590	-100	-1	-1	-1
UCRB	BLM/FS	Forest	22,862	-85	-1	-55	-31
	Other	Forest	15,887	-86	0	0	6
	BLM/FS	Rangeland	22,273	-96	5	-52	-32
	Other	Rangeland	1,086,411	-100	-1	-1	-1
Basin	BLM/FS	Forest	43,459	-85	-1	-58	-34
	Other	Forest	38,295	-86	2	2	10
	All	Forest	81,754	-85	4	-30	-12
	BLM/FS	Rangeland	54,089	-96	5	-52	-48
	Other	Rangeland	2,851,001	-100	-1	-1	-1
	All	Rangeland	2,905,090	-98	2	-27	-25
	All	All	2,986,849	-92	3	-28	-20

[1] Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management. (Average of 50 to 100 year projections.)

[2] Percent difference compared to current. For example Forest BLM/FS in EEIS area historically had 84% less soil disturbance than currently.

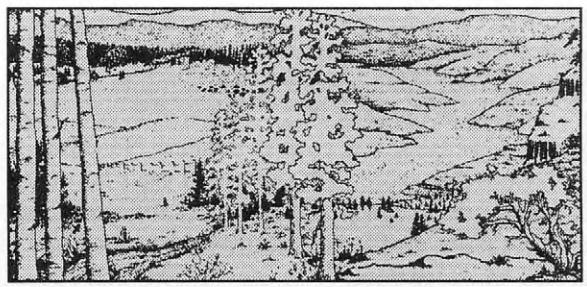
[3] Percent difference compared to current. For example Forest BLM/FS in EEIS area decreases 1%, 61% and 38% from current to future for CD, AM, and PM respectively.

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TRENDS IN REGIONAL AND ECOLOGICAL REPORTING UNIT SYSTEM DYNAMICS



The Basin

Vegetation succession in the Basin was typically driven by the growth and development potentials of the biophysical setting (that is, PVTs and PVGs), which in turn, were limited by moisture or temperature. The presence of woodland or forest PVGs generally indicated adequate soil depth and moisture for woody conifer or broadleaf tree regeneration and growth to maturity. These conditions were found in the woodland, dry forest, moist forest, cold forest, and riparian woodland PVGs (table 3.17). The riparian woodland type was generally found in basins, riparian, or wetland sites where subsoil moisture was higher than in other forest types. However, subsoil moisture was also seasonally dry and adequately aerated in riparian woodland areas, so that broadleaf and conifer riparian woodland species could regenerate and grow to maturity.

The presence of rangeland PVGs generally indicated a very dry climate or very shallow soils that were too dry for successful tree regeneration; a very cold climate with growing seasons too short for tree regeneration; or subsoil water tables that were too wet for tree regeneration. These environments were found in the dry grass, dry shrub, cool shrub, alpine, riparian shrub, and riparian herb PVGs. In general, the dry grass and dry shrub types were found at lower elevations and in lower precipitation zones than forest and woodland PVGs. However, the dry grass type was typically found in greater precipitation zones (> 30 cm/year) than the dry shrub type (< 30 cm/year).

Within the woodland and dry forest PVGs, the dry grass and dry shrub types were often found as inclusions on shallow or rocky soils. The dry grass PVG is typically found in areas of lower elevation, on the western edge of the Rocky Mountains, where winter and spring conditions are cloudy and relatively mild (Daubenmire 1970). This PVG is also found in areas with shallow soils over bedrock, and in areas on the eastern edge of the Basin with a predominance of summer precipitation (that is, a shift to continental climate). The cool shrub PVG was typically found at higher elevations in dry climate zones or mixed with the dry or cold forest PVGs on shallow or rocky soils. The alpine PVG was typically found from 2,150 to 3,700 meters elevation. Riparian shrub and riparian herb PVGs were typically found in areas where subsoil moisture was wet throughout the growing season, or at least during the spring and summer. Riparian herb types were often found where the subsoil water was stagnant and poorly aerated.

The other non-anthropogenic PVGs include water and rock. In this assessment, we did not differentiate between native large bodies of water and reservoirs created by dams, so there was generally no difference in the data between historical and current periods. However, we believe that recent-historical water projects substantially changed the areal extent of the water PVG, and that a more detailed examination is needed to identify where and to what extent the water PVG has changed.

The rock PVG generally occurred within large areas of cliffs and mountaintops, but could also have included some borrow pits and mines. The areal extent of the rock PVG did not change between historical and current periods. However, we believe that more rock and gravel areas have developed in borrow pits, mines, and industrial areas. In more detailed assessments, the rock PVG should be disaggregated into native and anthropogenic types, and then evaluated for change. Water and rock environments do have succession and disturbance relationships, but they were not addressed in this assessment. The anthropogenic PVGs included urban, agricultural, and road types. There are succession and disturbance relationships within urban and agricultural types, but they too were not addressed in this assessment due to our emphasis on the management of BLM/FS ownerships and on other wildlands (for example, forest, rangeland, and riparian). The road PVG was addressed at a very coarse scale in this assessment.

Woodland PVG

Most (70%) of the woodland PVG occurred above 1,200 meters elevation; 30 percent occurred below 1,200 meters elevation (table 3.18). The woodland PVG is a relatively rare type in the Basin, comprising no more than 1 percent of the region. Although there was a relatively high amount of woodland cover types and structures in the Basin during the current period, most had encroached into the cool shrub and dry grass PVGs. Encroachment of the woodland cover types and structures onto these PVGs was primarily a function of two types of events: (1) fire suppression that allowed woody species to survive, and (2) excessive livestock grazing pressure that decreased the competition from herbaceous species. Approximately 50 percent of the woodland PVG occurred on BLM/FS lands (maps 3.11 and 3.12).

The woodland PVG is typically located on edges of mesas, ridges, and knolls where fractured bedrock is near the surface and soil depths are shallow. The restriction of woodlands to these sites has been attributed to fire exclusion (Burkhardt and Tisdale 1976). These sites generally have low soil water availability due to shallow soils. Consequently, herbaceous production is low. The woodland PVG is often found in the driest of the zones that would support conifer or broadleaf tree regeneration and growth to maturity. There has essentially been no historical to current period loss of the woodland PVG; the rocky sites that the woodland PVG occupies were not typically developed for agriculture or urban uses.

Woodland tree regeneration was generally low throughout the Basin, but adequate for replacement of relatively open-growing, mature trees. In the native system, the abundance of upland herb and shrub structures remained relatively stable (about 70% of the woodland PVG) but varied somewhat depending on the length of fire-return intervals. The composition of early-seral, mid-seral, and late-seral structural stages also remained relatively stable at approximately 5, 15, and 5 percent of the woodland PVG, respectively.

The native fire interval was variable depending on the site production of fine fuels and conductivity of those fuels. Fire-return intervals ranged from 5 to 150 years. Approximately 40 percent of the fires were non-lethal and maintained grassland, shrubland, or late-seral single-layer woodland types on the less rocky soils. Thirty percent of fires were mixed regimes that maintained a mosaic of open grass and shrub structures intermingled with patches of woodland. Another 30 percent of fires were generally lethal crown fires that varied in frequency from 20 to 150 years. The mid-seral woodlands probably occurred on ecotone areas that had varying fire regimes, depending on drought and fire cycles. Some areas did not burn because of topographic location, or occurred on very rocky sites that lacked ignition fuels. The fire season was relatively long in this type; it generally began in May and lasted into October.

The dominant change that we detected between the historical and current periods within the woodland PVG was the loss of the upland herbland physiognomic type due to fire suppression (table

3.30). Most (70%) of the PVG was dominated by shrubland types during the current period. The mid-seral woodland physiognomic type increased to approximately 30 percent of the PVG. In the current period, we detected virtually no early-seral or late-seral physiognomic types. We suspected that due to the suppression of underburning fires the older, larger trees of the late-seral stages were dying of drought stress or insect attacks, a consequence of stress induced by dense understories of tree regeneration. Exotic plants did not dominate the woodland PVG but could be found as understory dominants in areas having disturbed soils, especially on sites with a history of excessive livestock grazing pressure. We computed a 58 percent and 85 percent similarity of physiognomic type composition between historic and current periods for the Basin as a whole and for BLM/FS lands respectively (table 3.31). Fire regimes generally shifted, with a majority (95%) exhibiting lethal-fire behavior that killed the shrub or tree overstories. The fire-return interval was 75 to 150 years. The similarity of historical and current fire regimes was 47 and 67 percent for the Basin as a whole and BLM/FS lands, respectively (table 3.31).

There was little similarity of historical and current succession/disturbance regimes of the woodland PVG, regardless of land ownership strata (table 3.31). In terms of overall departure of succession and disturbance ratings, the woodland PVG was rated high. Departures were attributed to road and harvest systems, changes in landscape vegetation composition and structure, and changes in the fire regime. Secondary effects were related to the invasion by exotic plants. In general, these changes lowered the productivity, increased the probability of severe or chaotic events, and decreased the similarity to the temporal, spatial, and habitat diversity of the native system.

Historically, the Leaf Area Index (LAI) for the woodland PVG averaged approximately 2.7, (range = 1 to 24; sd = 2.5). In the current period, the LAI had a mean of 4.4, (range = 0.2 to 32; sd = 3.6). The higher LAI related to the total increase in woody foliage. The large range of values and relatively higher standard deviation generally indicates a less predictable condition.

Dry Forest PVG

During the current period, 69 percent of dry forest PVG occurred above 1,200 meters elevation; 31 percent occurred below 1,200 meters (table 3.18). The dry forest PVG composed 18 percent of the Basin. BLM/FS lands contained 56 percent of the dry forest PVG (maps 3.11 and 3.12). We detected about a 1 percent loss of this type between the historical and current periods, which was mostly attributable to agricultural and urban development on Other land ownerships. Given the current trend of rural development in the dry forest PVG and our low resolution of information pertaining to development, the decrease of this type has probably been more substantial than was indicated and will likely continue into the future.

In general, the dry forest PVG is limited by low moisture availability, but could also be limited by nutrient deficiencies where the surface soil has been eroded or displaced, or tree stocking levels have become dense. In the dry forest PVG, growth rates are generally slow for small regenerating trees and mature trees in dense communities, but are faster for open-grown trees with good root systems. The duration of the herb, shrub, and early-seral forest structures stages are relatively long, often of almost equal length as the mid-seral stage. Shrub and grass structures are fairly productive in open communities, but relatively unproductive in closed communities.

In native disturbance regimes, small tree mortality due to fire, insects, disease, and competition from other trees was common prior to fire suppression. In general, the native system maintained a fairly constant unchanging pattern of open communities with approximately 20 to 50 percent composition in late-seral single-layer structures; 10 to 15 percent in late-seral multi-layer structures; 25 to 30 percent in mid-seral structures; 10 to 20 percent in open and mixed (tree, shrub, and grass) early-seral structures; and 0 to 15 percent in herb and/or shrub structures (table 3.32). The late-seral single-layer structure was maintained by understory fires, which typically occurred in areas of more gentle or

Table 3.30—Percentage of area of current and historical period physiognomic types in the woodland potential vegetation group (PVG) by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	Percent			
BLM/FS Land Ownerships				
Early-seral Forest	0	4	5	6
Early-seral Woodland	+[3]	7	8	8
Exotic Herbland	0	0	0	0
Late-seral Multi-layer Woodland	0	6	7	7
Late-seral Single-layer Woodland	0	1	3	5
Mid-seral Woodland	49	28	22	19
Upland Herbland	0	10	9	8
Upland Shrubland	51	44	46	47
Other Land Ownerships				
Early-seral Forest	0	+	+	+
Early-seral Woodland	1	1	1	1
Exotic Herbland	0	0	0	0
Late-seral Multi-layer Woodland	2	+	+	+
Late-seral Single-layer Woodland	0	1	1	1
Mid-seral Woodland	9	10	8	8
Upland Herbland	0	70	20	14
Upland Shrubland	88	19	70	76
All Land Ownerships				
Early-seral Forest	0	2	2	3
Early-seral Woodland	+	4	5	5
Exotic Herbland	0	0	0	0
Late-seral Multi-layer Woodland	1	3	3	4
Late-seral Single-layer Woodland	0	1	2	3
Mid-seral Woodland	29	19	15	13
Upland Herbland	0	40	14	11
Upland Shrubland	70	31	58	61

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%

Table 3.31—Similarities of current and historical compositions of succession/disturbance regimes, fire regimes, and physiognomic types within potential vegetation groups (PVGs).

PVG	Land Ownership Group	Similarity Index[1]		
		Succession/ Disturbance Regime	Fire Regime	Physiognomic Type
Agricultural	All	0	0	0
	BLM/FS	—	—	—
	Other	0	0	0
Alpine	All	11	100	100
	BLM/FS	14	100	100
	Other	0	99	99
Cold Forest	All	26	66	81
	BLM/FS	26	65	81
	Other	25	64	77
Cool Shrub	All	14	62	76
	BLM/FS	23	69	89
	Other	0	49	56
Dry Forest	All	11	17	66
	BLM/FS	20	20	74
	Other	1	12	50
Dry Grass	All	6	44	61
	BLM/FS	21	65	69
	Other	0	30	44
Dry Shrub	All	10	29	79
	BLM/FS	19	35	93
	Other	0	20	63
Moist Forest	All	23	47	70
	BLM/FS	28	51	78
	Other	14	35	56
Riparian Shrub	All	3	34	47
	BLM/FS	12	43	47
	Other	0	19	33
Riparian Woodland	All	12	71	74
	BLM/FS	15	85	85
	Other	9	56	62

Table 3.31 (continued).

PVG	Land Ownership Group	Similarity Index[1]		
		Succession/ Disturbance Regime	Fire Regime	Physiognomic Type
Rock	All	100	100	100
	BLM/FS	100	100	100
	Other	100	100	100
Urban	All	0	0	0
	BLM/FS	0	0	0
	Other	0	0	0
Water	All	100	100	100
	BLM/FS	100	100	100
	Other	100	100	100
Woodland	All	2	47	58
	BLM/FS	5	67	85
	Other	0	27	33

[1]Similarity Index = $\frac{200\sum_k \text{minimum}(h_k, c_k)}{\sum_k h_k + \sum_k c_k}$,

where

h_k = historical value of class i,
c_k = current value of class i, and
k = classes.

rocky terrain. Patches of early- to mid-seral stages generally occurred in steep areas where fires would carry into the crown. These crown fires were promoted by topographic wind funneling, a high probability of wind events due to geographic location, and poor site productivity, such that most trees would not grow tall enough between fire intervals to survive typical flame lengths. Fire intervals in the dry forest PVG, prior to suppression, generally ranged from 20 to 70 years. In general, the native fire regime of the dry forest PVG consisted of approximately 80 percent nonlethal underburning fires, 5 percent mixed fires, and 15 percent crown fires, usually topographically arranged as described above. The fire season was relatively long in this type, starting in June and extending into September.

Late-seral tree species in the dry forest PVG were shade-tolerant, relatively slow growing, and were generally highly susceptible to mortality from fire, insect attacks, and root disease. In contrast, early-seral, shade-intolerant, relatively fast-growing species were typically much less susceptible to mortality from fire, insect attacks, and root disease. In the native system, the early-seral forest was dominated by shade-intolerant species composing 10 to 20 percent of the PVG, as compared with approximately 1 to 3 percent dominance by shade-tolerant species (table 3.33). In the mid-seral forests, shade-intolerant and shade-tolerant species dominated about 15 to 20 percent, and 10 percent of the PVG, respectively. The late-seral single-layer stage was dominated by shade-intolerant species composing 20 to 45 percent of the PVG, as compared to 1 to 2 percent for shade-tolerant species.

Table 3.32—Percentage of area of current and historical period physiognomic types in the dry forest potential vegetation group (PVG) by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	Percent			
BLM/FS Ownerships				
Early-seral Forest	22	17	16	8
Exotic Herbland	+[3]	0	0	0
Late-seral Multi-layer Forest	23	13	14	18
Late-seral Single-layer Forest	7	24	40	49
Mid-seral Forest	47	36	30	24
Upland Herbland	1	7	+	0
Upland Shrubland	+	2	1	+
Other Ownerships				
Early-seral Forest	13	19	25	8
Exotic Herbland	0	0	0	0
Late-seral Multi-layer Forest	9	10	8	12
Late-seral Single-layer Forest	8	20	34	50
Mid-seral Forest	69	22	32	30
Upland Herbland	+	21	+	0
Upland Shrubland	+	8	1	+
All Ownerships				
Early-seral Forest	18	18	20	8
Exotic Herbland	+	0	0	0
Late-seral Multi-layer Forest	16	12	11	15
Late-seral Single-layer Forest	7	22	37	49
Mid-seral Forest	58	30	31	27
Upland Herbland	1	14	+	0
Upland Shrubland	+	5	1	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.33—Percentage of area of current and historical period physiognomic types in the dry forest potential vegetation group (PVG) for shade-intolerance and shade-tolerance by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	Percent			
BLM/FS Ownerships				
Early-seral Shade-intolerant Forest	17	13	13	7
Early-seral Shade-tolerant Forest	5	4	3	2
Exotic Herbland	+[3]	0	0	0
Late-seral Shade-intolerant Multi-layer Forest	10	9	8	11
Late-seral Shade-intolerant Single-layer Forest	4	22	38	46
Late-seral Shade-tolerant Single-layer Forest	3	2	3	3
Late-seral Shade-tolerant Multi-layer Forest	13	4	6	7
Mid-seral Shade-intolerant Forest	25	24	18	13
Mid-seral Shade-tolerant Forest	22	13	12	12
Upland Herbland	1	7	+	0
Upland Shrubland	+	2	1	+
Other Ownerships				
Early-seral Shade-intolerant Forest	12	17	22	7
Early-seral Shade-tolerant Forest	1	1	2	1
Exotic Herbland	0	0	0	0
Late-seral Shade-intolerant Multi-layer Forest	6	8	6	8
Late-seral Shade-intolerant Single-layer Forest	5	19	33	48
Late-seral Shade-tolerant Single-layer Forest	2	1	1	1
Late-seral Shade-tolerant Multi-layer Forest	4	2	3	4
Mid-seral Shade-intolerant Forest	47	19	24	20
Mid-seral Shade-tolerant Forest	22	3	8	10
Upland Herbland	+	21	+	0
Upland Shrubland	+	8	1	+
All Ownerships				
Early-seral Shade-intolerant Forest	15	15	17	7
Early-seral Shade-tolerant Forest	3	3	3	2
Exotic Herbland	+	0	0	0
Late-seral Shade-intolerant Multi-layer Forest	8	9	7	10
Late-seral Shade-intolerant Single-layer Forest	5	21	35	47
Late-seral Shade-tolerant Single-layer Forest	3	2	2	2
Late-seral Shade-tolerant Multi-layer Forest	9	3	4	6
Mid-seral Shade-intolerant Forest	35	21	21	16
Mid-seral Shade-tolerant Forest	22	8	10	11
Upland Herbland	1	14	+	0
Upland Shrubland	+	5	1	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%

Late-seral multi-layer stages were dominated by shade-intolerant species ranging from 5 to 10 percent of the PVG, as compared to 3 to 5 percent for shade-tolerant species.

Since the implementation of fire suppression and traditional silvicultural practices, the dry forest PVG generally shifted to a predominance of mid-seral structures, which occupied approximately 55 percent of the landscape (table 3.32). Historically common, the large, scattered, residual tree component was typically missing from areas that had been harvested. In the current period, much of the dry forest PVG was dominated by a higher density of smaller-diameter trees due to the lack of thinning fires that accelerated the growth rates of fire survivors. The current period areal extent of the late-seral multi-layer structure was at the upper end of its historical range (approximately 16% composition). During the current period, early-seral physiognomic types generally occurred within their historical range, but areas that had been harvested were missing the scattered, large-diameter trees and snags. Exotic plants invaded the dry forest PVG, and were a common component of early-seral herbland and shrubland, and the late-seral single-layer physiognomic types in the current period. The similarity of physiognomic type composition between historical and current periods was 66 and 74 percent for the Basin as a whole, and for BLM/FS lands, respectively (table 3.31).

The ratio of shade-tolerant to shade-intolerant tree species' dominance changed in the dry forest PVG (table 3.33). The amount of early-seral shade-tolerant and shade-intolerant forests were both at the upper end of their historical range (3 and 15%, respectively). The current period abundance of mid-seral structures consisting of shade-tolerant species occurred at nearly twice their historical amounts. In the current period, areal extent of the mid-seral shade-intolerant forest was approximately 50 percent greater than the historical level; it composed about 35 percent of the dry forest PVG. The late-seral multi-layer structure had approximately twice as much dominance by shade-tolerant species; the current areal extent of shade-intolerant species was less than 25 percent of its historical range. The composition of late-seral single-layer shade-tolerant forest had not changed substantially, but the late-seral single-layer shade-intolerant forest had declined by 25 percent from historical amounts. Consequently, current period landscapes had a mixed composition rather than being dominated by shade-intolerant species. This was particularly true in areas that had been actively harvested and in areas where fire suppression has been effective.

The dry forest PVG occurs in a stressful climatic environment that is often subject to drought. In the unaltered biophysical template, approximately 15 percent of the PVG was dominated by shade-tolerant species. During the current period, the composition of shade-tolerant species in the dry forest PVG was nearly twice that amount. Relative to the historical period, communities were generally more dense and had larger amounts of carbon and nutrients tied up in woody material. As a result, much of the land base in the current period dry forest PVG where management has been extensive (for example, road building, harvesting, planting, thinning, and so on), was highly susceptible to tree mortality from fires, insects, disease, and water stress.

In general, the dry forests that had the highest departure from the unaltered biophysical template, were those that had been harvested, favoring the removal of high value, large, shade-intolerant tree species [for example, ponderosa pine (*Pinus ponderosa*)] and leaving shade-tolerant, fire- and insect/disease-susceptible species [for example, Douglas-fir (*Pseudotsuga menziesii*)].

Fire suppression was generally more effective in the roaded areas. The combination of past harvest practices and more effective fire suppression moved the roaded landscapes much further from their unaltered biophysical templates, as measured by dominant species, structures, and patterns,

relative to unroaded areas. Approximately 1 percent of the dry forest PVG was converted to agriculture and urban types, typically on Other lands adjacent to public lands. The dense mid-seral structures of the dry forest PVG have high risks for crown fire and intense fire events. The current period fire interval doubled or tripled to approximately 40 to 80 years, as a result of the more recent fire suppression programs and improved access. Increasing fire intervals without a corresponding reduction of fuels have produced higher fuel loads and higher fire intensities in recent years. Current period fire regimes within the dry forest PVG comprised 20 percent lethal crown fires, 35 percent mixed fires, and 45 percent non-lethal underburn fires. The similarity of fire regimes between historical and current periods was 17 and 20 percent for the Basin as a whole and BLM/FS lands, respectively (table 3.31).

The development of houses and other cultural facilities in or adjacent to dry forest types has become problematic, increasing fire potential, and decreasing efficient suppression. Consequently, it is rapidly becoming more difficult to protect human lives and property.

The LAI did not change substantially. Historically, it averaged approximately 8.4 (range = 1.8 to 21.5; sd = 4.0). During the current period, the LAI had a mean of 9.6 (range = 0.2 to 58.6; sd = 7.3). The upward trend of the LAI was consistent with the observed increase of overall biomass. The standard deviation and range were considerably higher in the current period compared to the historical period, indicating a less predictable system.

The dry forest PVG was rated high in terms of overall departure of succession and disturbance ratings. The similarity of succession/disturbance regimes between historical and current periods was 11 and 20 percent for the Basin as a whole and BLM/FS lands, respectively (table 3.31). The relatively high departure was attributed to road and harvest systems, changes in landscape vegetation composition and structure, and changes in the fire regime. To a lesser degree, the departure was also related to the invasion of exotic vegetation. Consequently, the current period dry forest PVG had lower productivity, higher probability of severe or chaotic events, and lower similarity to the temporal, spatial, and habitat diversity of the native system.

Moist Forest PVG

Approximately 40 percent of the moist forest PVG occurs at elevations below 1,200 meters; 60 percent occurs at elevations above 1,200 meters (table 3.18). The moist forest PVG composes 18 percent of the Basin, of which nearly 64 percent occurs on BLM/FS lands (maps 3.11 and 3.12). Agricultural or urban development was responsible for only a very minor loss (< 0.5%) of this type from historical to current times.

The moist forest PVG typically has relatively high soil moisture availability in the spring and early summer, but experiences drought stress in the late summer and early fall. Nutrient availabilities can also be limiting in this PVG. Nutrients are commonly depleted through timber harvest practices or through multiple burns, which displace or erode surface soil, or remove too much of the large woody material, litter/duff, or small branch needle/leaf foliage that carries the bulk of the nutrient capital. In general, rates of tree growth are fairly rapid and the early-seral structural stage is typically short-lived in comparison to the mid-seral stage.

The native system for the moist forest PVG was fairly dynamic. The early-seral forest structure composed 20 to 30 percent of the PVG, fluctuating to either end of the range in as little as 50 years. The mid-seral structure composed 40 to 50 percent of the moist forest PVG, typically being cycled back to the early-seral stage by lethal crown or mixed-fire events. However, in many cases, underburns or mixed-fire regimes maintained the mid-seral stage or moved it into the late-seral single-layer stage. The mid-seral structure composed 5 to 10 percent of the PVG. The late-seral multi-layer structure typically developed in cool, moist bottoms and basins where fires generally

Table 3.34—Percentage of area of current and historical period physiognomic types in the moist forest potential vegetation group (PVG) for shade-intolerance and shade-tolerance by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	Percent			
BLM/FS Ownerships				
Early-seral Shade-intolerant Forest	14	21	14	15
Early-seral Shade-tolerant Forest	9	8	4	5
Late-seral Shade-intolerant Multi-layer Forest	4	12	13	16
Late-seral Shade-intolerant Single-layer Forest	1	7	5	6
Late-seral Shade-tolerant Multi-layer Forest	6	7	12	15
Late-seral Shade-tolerant Single-layer Forest	2	1	1	1
Mid-seral Shade-intolerant Forest	33	30	36	28
Mid-seral Shade-tolerant Forest	31	15	15	14
Other Ownerships				
Early-seral Shade-intolerant Forest	11	27	15	16
Early-seral Shade-tolerant Forest	4	3	6	5
Late-seral Shade-intolerant Multi-layer Forest	2	16	15	17
Late-seral Shade-intolerant Single-layer Forest	1	16	10	10
Late-seral Shade-tolerant Multi-layer Forest	4	3	9	11
Late-seral Shade-tolerant Single-layer Forest	2	1	1	1
Mid-seral Shade-intolerant Forest	42	28	34	29
Mid-seral Shade-tolerant Forest	35	6	11	12
All Ownerships				
Early-seral Shade-intolerant Forest	13	23	14	15
Early-seral Shade-tolerant Forest	7	6	5	5
Late-seral Shade-intolerant Multi-layer Forest	3	14	14	17
Late-seral Shade-intolerant Single-layer Forest	1	10	7	7
Late-seral Shade-tolerant Multi-layer Forest	5	5	11	13
Late-seral Shade-tolerant Single-layer Forest	2	1	1	1
Mid-seral Shade-intolerant Forest	36	29	35	28
Mid-seral Shade-tolerant Forest	33	12	13	13

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

burned in a creeping, low-intensity behavior, maintaining the stage with a gap mosaic pattern. Late-seral structures historically composed 20 to 30 percent of the PVG.

Native fire regimes within the moist forest PVG were variable. Non-lethal underburns occurred at relatively frequent intervals (15-25 years) on benches and ridges that composed about 25 percent of the PVG. Lethal crown fires varied from 20 to 150 years, and generally occurred in the upland slope environments across 25 percent of the moist forest PVG. The mixed-fire regime occurred across 40 to 45 percent of this PVG with highly variable intervals most commonly ranging from 20 to 150 years, but with some at intervals of up to 300 years. The fire season was relatively short, generally starting in July and extending into September. Typically, most fires were very small, but occasionally, some fires grew very large.

In the native system, the early-seral forests were dominated by shade-intolerant species that composed 15 to 25 percent of the moist forest PVG, as compared to approximately 5 percent composition of shade-tolerant species (table 3.34). In mid-seral physiognomic types, shade-intolerant species dominated about 28 to 35 percent of the PVG, as compared to 6 to 15 percent for shade-tolerant species. The late-seral single-layer physiognomic type was dominated by shade-intolerant species that composed 5 to 10 percent of the PVG, as compared to 1 percent for shade-tolerant species. The late-seral multi-layer shade-intolerant physiognomic type averaged about 15 percent composition of the PVG, whereas shade-tolerant species dominated 5 to 15 percent of the PVG. In areas having relatively infrequent fire intervals, there were long periods where shifts from shade-intolerant to shade-tolerant species occurred over 50 to 150 years, due to natural succession processes. The variability in the shade-tolerant species dominance of the late-seral multi-layer system was generally due to this cyclic shift.

The moist forest PVG has changed since the implementation of fire suppression and traditional silvicultural activities (table 3.35). In general, the forests that had the greatest departures from the unaltered biophysical template were those that have been roaded and harvested with clearcuts or partial cuts, favoring the removal of large, shade-intolerant tree species [for example, western larch (*Larix occidentalis*), western white pine, and ponderosa pine] and leaving shade-tolerant fire- and insect/disease-susceptible species [for example, grand fir (*Abies grandis*), western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and Douglas-fir]. Fire suppression has also been more effective in roaded areas, and consequently, changed the composition and structure within those areas. These effects have been compounded by the extensive loss and poor regeneration of western white pine as a result of white pine blister rust infestations.

The similarity of the composition of physiognomic types between historical and current periods was 70 and 78 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). In the current period, the areal extent of the early-seral physiognomic type (20%) was at the low end of its historical range. Most of the disturbances that created early-seral physiognomic types were even-age harvests (for example, clearcuts and seed tree cuts). These activities did not retain the snag structure or create an environment that could maintain the historical community composition and structure. Consequently, most current period early-seral structures within this PVG were very different in composition and structure relative to the native biophysical template. The areal extent of the mid-seral forest physiognomic types (approximately 70%) were more abundant in the current period than those which typically occurred in native systems. Most of the current period mid-seral stage had much higher tree densities and higher fuel loadings than were typically present in the native system. In addition, within roaded areas, many of the large, scattered, residual trees have been harvested, which also dramatically changed the community structure.

Table 3.35—Percentage of area of current and historical period physiognomic types in the moist forest potential vegetation group (PVG) by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	..... Percent			
BLM/FS Ownerships				
Early-seral Forest	23	29	18	20
Mid-seral Forest	65	45	51	42
Late-seral Multi-layer Forest	9	19	25	31
Late-seral Single-layer Forest	3	7	6	6
Other Ownerships				
Early-seral Forest	15	30	21	21
Mid-seral Forest	77	34	45	41
Late-seral Multi-layer Forest	5	19	24	28
Late-seral Single-layer Forest	3	16	11	10
All Ownerships				
Early-seral Forest	20	29	19	21
Mid-seral Forest	69	41	48	42
Late-seral Multi-layer Forest	8	19	25	30
Late-seral Single-layer Forest	3	11	8	8

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

The ratio of shade-tolerant to shade-intolerant tree species' dominance changed in the moist forest PVG from the historical to the current period. The current period proportion of the early-seral shade-tolerant type was about the same as the native system, but the abundance of the early-seral shade-intolerant physiognomic type decreased substantially. The current period areal extent of the mid-seral shade-tolerant forest was almost three times its historical range, whereas the amount of current period shade-intolerant forest was at the upper end of its historical range. The shade-intolerant species which historically dominated the late-seral single-layer stage had essentially been lost, while shade-tolerant species dominating this stage doubled.

In the current period, multi-layer late-seral physiognomic type, shade-intolerant species constituted only 20 percent of the historical abundance, whereas the dominance of shade-tolerant species had not changed substantially. Most current period landscapes within the moist forest PVG were dominated completely by shade-intolerant species, or a mixture of shade-tolerant and shade-intolerant species. This change was particularly evident in areas that were actively harvested and where fire suppression has been highly successful.

The moist forest PVG has a productive environment that can rapidly produce biomass and accumulate fuel, and where insects and pathogens are

potentially very active. The exotic blister rust, as well as past harvest activity, has caused a decline in western white pine. As a result, much of the moist forest PVG comprises a mixture of compositions and structures that are highly susceptible to mortality from fires, insects, disease, and stress.

The similarity of fire regime composition between the historical and current periods was 47 and 51 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). The current period fire regime has become simplified relative to the historical regime. As a result of higher fuel loads, increased stocking levels of trees, and high late summer moisture stress levels, most of the moist forest PVG shifted to lethal crown fire or mixed-fire regimes. About 10 percent of the PVG, typically associated with the single-layer late-seral or open mid-seral physiognomic types, retained a non-lethal underburn potential. Approximately 60 to 70 percent of the PVG had a high potential for crown fire, and 20 to 30 percent of the type had a mixed-fire regime. With recent suppression efforts, the general fire interval had almost tripled in length to approximately 75 to 150 years. Increasing fire intervals without a corresponding reduction in fuels have resulted in higher-intensity fires.

The LAI for the moist forest PVG did not change substantially between historical and current periods. Historically, the LAI averaged approximately 13.2 (range = 5.2 to 36.8; sd = 6.0). In the current period, the LAI had a mean of 14.6 (range = 0.2 to 57.9; sd = 8.0). This trend was consistent with the observed increase in biomass of the moist forest PVG. The higher LAI standard deviation and range indicated a less predictable system.

The departures of succession and disturbance processes were high within the moist forest PVG. The similarity of succession/disturbance regime composition between historical and current periods was 23 and 28 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). High departures were a consequence of road and harvest systems, changes in landscape vegetation composition and structure, the invasion of blister rust on western white pine, and changes in the fire regime. These changes decreased productivity, increased the probability of severe or chaotic events, and decreased the similarity to the temporal, spatial, and habitat diversity of the native system.

Cold Forest PVG

Most (99%) of the cold forest PVG occurs above 1,200 meters elevation (table 3.18). Although the cold forest PVG dominated higher elevations, it only accounts for 10 percent of the Basin; BLM/FS lands contain most (87%) of the cold forests (maps 3.11 and 3.12). There was essentially no loss of the cold forest PVG as a result of agricultural or urban development from the historical to the current period.

The cold forest PVG is generally limited by a short growing season, and on some sites, also by low available moisture. Rates of tree growth are relatively slow. Shrub and grass productivity are variable depending on soil types. The duration of the early-seral structural stage is relatively long, often almost the same duration as the mid-seral structural stage. Nutrients are often limiting, and loss of ash, litter, surface soil, or tree foliage from the site can greatly reduce productivity. Maintenance of dead and down wood on these sites is particularly important for nutrient cycling.

Native cold forest systems generally maintained a fairly high composition of the late-seral multi-layer structure, typically in cold, wet bottoms or basins where fires rarely burned, or burned in a patchy, low-intensity gap mosaic pattern. The late-seral single-layer structure was typically maintained by underburning fires on benches and ridges that were dominated by whitebark pine and lodgepole pine. Areas on moist to wet, steep slopes typically burned with lethal crown fires at intervals that generally only allowed the development of early- to mid-seral structures. These fires varied in intensity leaving scattered, large, residual trees; small patches of green trees in seep areas; and dead-standing snags. On occasion, fires reburned within a short period of time, producing open grass and shrub

structures that could persist for relatively long periods before regenerating into forests. Tree mortality from stress, insects, and disease generally thinned the communities and accelerated the growth of surviving trees. Minor amounts of early- and mid-seral riparian woodlands developed along narrow stream courses. The composition of the native cold forest PVG typically comprised the late-seral single-layer (6-8%), late-seral multi-layer (15-24%), early-seral (23-25%), and mid-seral (44-53%) physiognomic types (table 3.36).

Historically, fire intervals in the cold forest PVG were highly variable and correlated with landforms. The non-lethal underburning regime that maintained the late-seral single-layer and some mid-seral physiognomic types, generally comprised approximately 10 percent of these landscapes, and typically occurred on ridges and flat benches. The fire-return interval on these landforms varied from 30 to 100 years. The lethal crown-fire regime generally occurred across 25 to 30 percent of the cold forest PVG, and had a fire-return interval which varied from 25 to 300 years. Shorter intervals generally occurred on steeper slopes recycling mid-seral to early-seral physiognomic types. Longer intervals occurred in wet bottoms and basins, which typically supported the late-seral multi-layer physiognomic type. The mixed-fire regime was most common and occurred throughout 60 percent of the PVG; mixed-fire return intervals varied from 25 to 300 years. The mixed-fire regime was often intermingled with the other regimes, either during one fire event or through a series of fire events. The cold forest PVG had a relatively short fire season, generally only lasting for the month of August. Most fires were very small, but a few occasionally grew very large.

The similarity of physiognomic type composition between the historical and current periods was 81 percent for the Basin as a whole and for BLM/FS lands (table 3.31). In the historical system, the early-seral physiognomic type was dominated by shade-intolerant species that composed 16 to 21 percent of the PVG, whereas shade-tolerant species in this type composed approximately 5 percent of the PVG (table 3.37). Shade-intolerant species in the mid-seral physiognomic type dominated about 30 percent of the PVG, as compared to a 15 to 21 percent composition of shade-tolerant species. The late-seral single-layer physiognomic type was dominated by shade-intolerant species (5-6%) relative to shade-tolerant species (≤ 2%).

The late-seral multi-layer physiognomic type had a different composition. Shade-tolerant species composed 8 to 15 percent of the late-seral multi-layer physiognomic type, whereas shade-intolerant species composed 7 to 9 percent. The above-mentioned relationship was consistent with the long fire intervals and landforms where the late-seral multi-layer physiognomic type occurred. The lack of frequent disturbance events allowed succession to proceed and shade-tolerant species to become established.

The cold forest PVG changed substantially as a result of fire suppression and traditional silvicultural activities (table 3.36). In general, the cold forests that had the highest departure from the unaltered biophysical template were those that had been roaded and harvested with clearcuts, other traditional even-age harvest prescriptions, or partial cuts. Much of the late-seral multi-layer forest type had been harvested between the historical and current periods, reducing its areal extent to approximately 10 percent of the PVG. Although the areal extent of the late-seral single-layer physiognomic type did not change substantially, we believe that the composition of many of these types was altered by the loss of whitebark pine due to blister rust infestation. The areal extent of the early-seral physiognomic type increased to approximately 30 percent of the cold forest PVG, generally as a result of timber harvest. Essentially, much of the early-seral stage was created by harvesting the high volume, late-seral multi-layer physiognomic type. In addition, timber harvest removed most of the snag component that occurred historically. The current period abundance of the mid-seral type (45%) was within its historical range. However, many areas that had been harvested with

Table 3.36—Percentage of area of current and historical period physiognomic types in the cold forest potential vegetation group (PVG) by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	Percent			
BLM/FS Ownerships				
Early-seral Forest	33	22	25	24
Early-seral Riparian Woodland	2	+[3]	+	+
Late-seral Multi-layer Forest	9	15	19	24
Late-seral Single-layer Forest	9	9	7	6
Mid-seral Forest	44	53	47	44
Mid-seral Riparian Woodland	3	+	1	2
Other Ownerships				
Early-seral Forest	32	27	26	23
Early-seral Riparian Woodland	3	+	+	+
Late-seral Multi-layer Forest	6	17	20	23
Late-seral Single-layer Forest	6	6	5	5
Mid-seral Forest	51	49	47	47
Mid-seral Riparian Woodland	2	1	2	2
All Ownerships				
Early-seral Forest	33	23	25	24
Early-seral Riparian Woodland	2	+	+	+
Late-seral Multi-layer Forest	9	15	19	24
Late-seral Single-layer Forest	8	8	7	6
Mid-seral Forest	45	53	47	44
Mid-seral Riparian Woodland	3	1	1	2

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

partial or selective cuts did not retain the large, scattered, residual trees that were common in the historical mid-seral physiognomic type.

The ratio of shade-tolerant to shade-intolerant tree species changed greatly within the cold forest PVG between the historical and current periods (table 3.37). Since the historical period, the amount of early-seral shade-tolerant forests has nearly doubled. Similarly, the areal extent of mid-seral shade-tolerant forests is also substantially higher than their historical range, whereas the amount of shade-intolerant mid-seral forests has declined substantially. The ratio of shade-tolerant to shade-intolerant species dominating the late-seral single-layer and multi-layer physiognomic types has not changed substantially, given the overall areal decline of both types.

Table 3.37—Percentage of area of current and historical period physiognomic types in the cold forest potential vegetation group (PVG) for shade-intolerance and shade-tolerance by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	..... Percent			
BLM/FS Ownerships				
Early-seral Shade-intolerant Forest	17	15	21	21
Early-seral Shade-tolerant Forest	16	7	4	4
Late-seral Shade-intolerant Multi-layer Forest	5	7	7	9
Late-seral Shade-intolerant Single-layer Forest	9	7	6	5
Late-seral Shade-tolerant Multi-layer Forest	4	8	12	15
Late-seral Shade-tolerant Single-layer Forest	+[3]	2	1	1
Mid-seral Shade-intolerant Forest	20	31	27	29
Mid-seral Shade-tolerant Forest	24	22	21	15
Riparian Woodland	6	1	2	2
Other Ownerships				
Early-seral Shade-intolerant Forest	23	21	23	19
Early-seral Shade-tolerant Forest	9	5	4	4
Late-seral Shade-intolerant Multi-layer Forest	4	9	8	8
Late-seral Shade-intolerant Single-layer Forest	6	3	3	4
Late-seral Shade-tolerant Multi-layer Forest	2	9	11	15
Late-seral Shade-tolerant Single-layer Forest	+	3	1	1
Mid-seral Shade-intolerant Forest	24	33	27	32
Mid-seral Shade-tolerant Forest	28	16	19	16
Riparian Woodland	5	1	2	2
All Ownerships				
Early-seral Shade-intolerant Forest	18	16	21	20
Early-seral Shade-tolerant Forest	15	7	4	4
Late-seral Shade-intolerant Multi-layer Forest	5	7	8	9
Late-seral Shade-intolerant Single-layer Forest	8	6	6	5
Late-seral Shade-tolerant Multi-layer Forest	3	8	12	15
Late-seral Shade-tolerant Single-layer Forest	+	2	1	1
Mid-seral Shade-intolerant Forest	20	31	27	29
Mid-seral Shade-tolerant Forest	24	21	21	15
Riparian Woodland	6	1	2	2

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

The cold forest PVG evolved with shade-intolerant species dominating the early-seral and mid-seral physiognomic types. In the current period, early- and mid-seral structures were dominated by either a mixture of shade-tolerant and shade-intolerant species, or shade-tolerant species alone. This was particularly true in areas that had been logged, and where fire suppression had been effective. Much of the current period cold forest PVG appeared highly susceptible to tree mortality from fires, insects, disease, and stress.

The similarity of fire regime composition between historical and current periods was nearly 65 percent, regardless of land ownership strata (table 3.31). In most areas of the cold forest PVG, tree densities and fuel loads increased substantially as a result of fire suppression. Historically, the mixed-fire regime in the cold forest PVG reduced fuels and thinned tree densities, thereby accelerating the growth rate of survivors. Under existing fire suppression programs, the fire interval had increased from 75 to 300 years. Although the change in fire interval was substantial, as in the dry forest and moist forest PVGs, the changes in landscape structure and composition in the cold forest PVG typically resulted in higher fuel loads and fire intensities. When fires did occur, in what was historically a more frequent fire interval, they tended to be large, lethal, crown-fire events of high intensity (particularly on upland slope environments).

The LAI within the cold forest PVG did not change substantially between the historical and current periods. Historically, the LAI averaged approximately 9.0 (range = 3.1 to 24.3; sd = 3.2). In the current period, the LAI had a mean of 8.3 (range = 0.2 to 43.6; sd = 8.3). The observed trend was consistent with the general indication that biomass decreased as a result of past timber harvest patterns and declines in whitebark pine. The increased standard deviation and range suggested a less predictable system.

The similarity of succession/disturbance regime composition between historical and current periods was approximately 26 percent, regardless of land ownership strata (table 3.31). Succession and disturbance departure ratings in the cold forest PVG were moderate. Moderate departures were a consequence of changes in broad-scale vegetation composition and structure, which resulted from timber harvest, blister rust impacts on whitebark pine, and changes in the fire regime. Relative to the moist forest PVG, the cold forest PVG had experienced less of a departure, primarily because the above-listed effects occurred more slowly in these cold environments. However, long-term projected outcomes would be similar — namely, lower productivity, higher probability of severe or chaotic events, and lower similarity to the temporal, spatial, and habitat diversity of the native system.

Dry Grass PVG

During the current period, 42 percent of the dry grass PVG occurred below 1,200 meters elevation; 58 percent occurred above 1,200 meters (table 3.18). The current period dry grass PVG composed 4 percent of the Basin. Historically, however, this PVG was more extensive, occurring across 9 percent of the Basin. Agricultural and urban development was responsible for the 56 percent areal decline of the dry grass PVG. The distribution of the dry grass PVG has also changed greatly (maps 3.11 and 3.12). Historically, 69 percent of this type occurred below 1,200 meters elevation and 31 percent occurred above 1,200 meters. Current period BLM/FS lands contained 44 percent of the remaining dry grass PVG (table 3.18). Much of the dry grasslands were converted to dryland agricultural croplands or pastures. In general, on Other lands, we believe that most of the dry grasslands having agricultural potential have already been converted. Consequently, we expect little loss of this dry grass PVG to future agricultural development. However, given the current trend of increased rural development on private lands within this PVG, it was assumed that the overall decrease in the dry grass PVG would continue into the future, but at a slower rate.

The dry grass PVG is limited by available moisture, either due to low rainfall or to shallow, rocky, or clay soils. Native communities are very diverse with various grasses, forbs, and sedges, and have fair production in years of good fall or winter moisture. Historically, the dry grass PVG existed primarily in north-central Oregon, southeast Washington, and north-central Idaho (map 3.11). Approximately 29 to 34 centimeters of precipitation was received during the fall-winter or winter-spring periods in these areas (table 3.38; climate divisions: Oregon North Central, Washington Palouse-Blue Mountains, and Idaho North Central Prairies). Drought years in which less than 75 percent of the fall-winter or winter-spring precipitation was received occurred between 7 and 17 percent of the time. Conversely, relatively wet periods, characterized by two or more successive years of greater than 110 percent of the fall-winter or winter-spring precipitation, have been documented only 3 to 6 times in the 100-year period (1895-1994). Thus, drought was a frequent occurrence, whereas successive wet years, believed to be critical for perennial plant recruitment, were somewhat less frequent.

Most of the dominant grass and forb species within the dry grass PVG have adapted to a cool-season moisture regime where moisture arrived primarily in the fall, winter, and spring, followed by a dry summer. These species were highly dependent upon soil moisture storage from cool-season precipitation, and conducted most of their growth and reproductive activities during the spring and early summer. In general, shrubs that are able put down deeper root systems for stored winter moisture attainment are more competitive on dry grasslands experiencing the absence of fire. Cool-season species typically become dormant in the summer and early fall, however, adequate fall moisture can stimulate an additional growing period.

In the eastern portion of the Basin, more plant species have adapted to the warm-season moisture that occurs primarily in the spring and summer. Warm-season species have adapted to take advantage of available moisture throughout the growing season. In general, grasses are more competitive than shrubs in environments where moisture is available throughout the growing season. The dry grass type is much more common in areas that have high numbers of cloudy days during the winter and spring. Sagebrush species can photosynthesize during the winter period, but in areas that receive relatively little winter sunlight this adaptation is not conducive to sagebrush establishment or to its ability to compete successfully with herbaceous species.

In the absence of fire, shrubs and trees eventually invade much of the dry grass PVG area that lies adjacent to the dry shrub, woodland, or dry forest PVGs. Soil characteristics of the dry grass PVG generally indicate that they developed in conjunction with grassland potential vegetation. When these sites are invaded by shrubs and/or trees, nutrient regimes often change.

Woody species tie up nitrogen and other trace nutrients causing a decline of site productivity. Subsequently, foliage cover, basal cover, and litter from the grasses and forbs decline, causing exposure of the surface soil to erosion. Erosion potentials in these areas can be aggravated by excessive grazing pressure from livestock and wild ungulates. Once the surface soil becomes eroded and the subsoil is exposed, the environment becomes more conducive to the woody species that better compete for subsoil moisture.

In general, the historical system of the dry grass PVG was dominated by an upland herbland physiognomic type which was, in turn, dominated by grasses and forbs (table 3.39). The upland herbland physiognomic type typically burned with non-lethal fires; non-lethal fires stimulated existing forbs the year following the fire event, and eventually caused the vegetation to revert to dominance by existing grasses. Small vegetation patches with decadent grasses and high accumulations of litter were killed, creating small openings for early-seral forbs. Regeneration from shrubs or tree seeds were generally killed by drought or fire. Historically, the early-, mid-, and late-seral woodland

Table 3.38—Selected precipitation data[1] for the 1895 to 1994 period for climate divisions existing in the Basin.

State Climate Division	Median Precipitation Fall-Winter[2] (cm)	Median Precipitation Winter-Spring[3] (cm)	Median Precipitation Spring-Summer[4] (cm)	Years < 75%[5]	Periods > 110% 2+ Years[6]
Washington					
East Slope Cascades	59.06	NA[7]	NA	17	9
Okanogan - Big Bend	19.41	NA	NA	13	6
Central Basin	16.43	NA	NA	17	6
Northeast	31.57	NA	NA	10	5
Palouse - Blue Mountains	29.16	NA	NA	16	6
Oregon					
High Plateau	53.95	NA	NA	17	8
North Central	29.24	NA	NA	17	4
South Central	19.96	NA	NA	18	7
Northeast	27.84	NA	NA	12	5
Southeast	15.60	NA	NA	17	8
Idaho					
Panhandle	44.60	NA	NA	10	8
North Central Prairies	NA	33.73	NA	7	3
Canyons	NA	33.38	NA	9	2
Central Mountains	45.09	NA	NA	15	7
Southwest Valleys	20.73	NA	NA	16	7
Southwest Highlands	NA	17.25	NA	20	9
Central Plains	NA	15.57	NA	17	6
Northeast Valleys	NA	NA	15.29	20	9
Upper Snake River Plains	NA	16.51	NA	15	7
East Highlands	NA	22.81	NA	15	5
Montana					
West	NA	26.59	NA	6	7
Wyoming					
Snake Drainage	NA	33.02	NA	12	9

[1]Unpublished data. 1995. Kelly Redmond, Climatologist, Western Regional Climate Center, Atmospheric Sciences Center, Desert Research Institute, PO Box 60220, Sage Building, 5625 Fox Avenue, Reno, NV 89506.

[2]Either the October through March, or November through April, 6-month period.

[3]Either the December through May, or January through June, 6-month period.

[4]April through September 6-month period.

[5]Less than 75 percent of the median 6-month precipitation.

[6]Exceeding 110 percent of the median 6-month precipitation for 2 or more years in succession.

[7]NA = Not Applicable; period of maximum median precipitation did not occur during these seasons.

Table 3.39—Percentage of area of current and historical period physiognomic types in the dry grass potential vegetation group (PVG) by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	..... Percent			
BLM/FS Ownerships				
Early-seral Woodland	1	6	2	2
Exotic Herbland	7	0	0	0
Late-seral Multi-layer Woodland	1	8	25	24
Mid-seral Woodland	2	23	8	7
Upland Herbland	89	64	65	67
Other Ownerships				
Early-seral Woodland	2	1	1	1
Exotic Herbland	1	0	0	0
Late-seral Multi-layer Woodland	13	+[3]	4	5
Mid-seral Woodland	4	2	4	3
Upland Herbland	80	97	92	91
All Ownerships				
Early-seral Woodland	2	2	1	1
Exotic Herbland	3	0	0	0
Late-seral Multi-layer Woodland	8	2	8	9
Mid-seral Woodland	3	6	4	4
Upland Herbland	84	91	87	87

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

physiognomic types constituted about 5 to 10 percent of the dry grass PVG (table 3.39), typically along the ecotones with the dry shrub, woodland, and dry forest PVGs. When these types burned, they usually exhibited mixed-fire behaviors.

The native grazing regime appears to have varied between relatively high- intensity short-duration grazing, to extensive low-intensity grazing, to seasonally-moderate levels of grazing by ungulates. Grazing patterns were strongly influenced by seasonal weather, greenness of foliage during the growing season, or the palatability of foliage in the winter season. The majority of fires in the dry grass PVG were non-lethal and occurred at intervals ranging from 5 to 75 years throughout 90 percent of the PVG. Mixed-fire events typically occurred in dry grass types that had developed into shrub or woodland physiognomic types, but also in herb-dominated areas with high accumulations of litter and decadent plants. Mixed-fire regimes occurred in approximately 10 percent of the dry grass PVG. The fire season was relatively long in dry grasslands; it generally started in April or May and lasted into October.

The dry grass PVG changed due to fire suppression, livestock grazing, invasion of exotics, and conversion to agricultural and urban land uses (table 3.39). The similarity of physiognomic type composition between historical and current periods was 61 and 69 percent for the Basin as a whole and BLM/FS lands, respectively (table 3.31).

Exotic herblands, particularly those containing annual grasses and knapweeds (*Centaurea* spp.), dominated at least 5 percent of dry grasslands during the current period. Exotic species were common components of most communities of the dry grass PVG. With the exception of the agricultural PVG, the dry grass PVG was the most susceptible to exotic plant invasion of all the PVGs in the Basin (see fig. 3.14).

The early-seral and mid-seral woodland physiognomic types did not increase substantially, but the current period late-seral woodland physiognomic type was at the upper end of its historical range. The composition and structure within upland herbland physiognomic types changed as a result of heavy early-season or season-long livestock grazing, and seeding to perennial exotic grasses such as crested wheatgrass (*Agropyron cristatum*). Large dominant bunchgrasses that occurred historically were generally replaced by smaller bunchgrasses, forbs, annual exotic grasses, exotic forbs, and seeded exotic grasses. Seeded exotic grass ranges were similar in structure to native bunchgrass ranges, but plant diversity was often lower in the seeded exotic grass ranges.

In general, the highest departures from the unaltered biophysical template within the dry grass PVG occurred in areas that had been subjected to high levels of continuous season-long or early-season grazing, and were extensively roaded (improving the efficiency of fire suppression, while also providing a conduit for the dispersal of exotics). The similarity of fire regime composition between historical and current periods was 44 and 65 percent for the Basin as a whole and BLM/FS lands, respectively (table 3.31). Current period fire regimes were approximately 50 percent non-lethal and 50 percent mixed. Due to fire suppression, the fire intervals have increased from approximately 25 to 75 years. Fuels generally did not increase on the upland herbland physiognomic types since they were typically grazed. However, vigor of the dominant grasses and forbs decreased in these types due to the continued absence of fire.

Fuels accumulate when shrubland and woodland encroachment occurs. During drought years, very intense fire events can occur in areas of woody encroachment, often causing relatively severe effects to the soil surface and mortality to the understory grasses and forbs.

The LAI within the dry grass PVG did not change substantially between the historical and current periods. Historically, the LAI averaged 2.4 (range = 1.9 to 7.8; sd = 0.8). The mean LAI of the current period was also 2.4 (range = 0.2 to 51.9; sd = 1.9). The current system LAI standard deviation and range suggested that the current system was less predictable than the historical system.

The departure of succession and disturbance processes were rated high for the dry grass PVG. The similarity of succession/disturbance regimes between historical and current periods was 6 and 21 percent for the Basin as a whole and BLM/FS lands, respectively (table 3.31). This was a consequence of agricultural and urban development, and altered grazing and fire regimes that differed from the disturbance regimes of the unaltered biophysical template. There was a subsequent decrease of productivity, increase in probability of severe or chaotic events, and decreased similarity to the temporal, spatial, and habitat diversity of the native system.

Dry Shrub PVG

The majority (71%) of the current period dry shrub PVG occurred above 1,200 meters elevation; 29 percent occurred below 1,200 meters (table 3.18). Since the historical period, the areal extent of the dry shrub PVG decreased by approximately 30 percent as a result of agricultural and urban

development. Historically, a greater proportion of the dry shrub PVG (40%) occurred below 1,200 meters elevation. In the current period, BLM/FS lands contained 55 percent of the remaining dry shrublands. A large proportion of this type was converted to dryland or irrigated agricultural croplands, haylands, or pastures (maps 3.11 and 3.12). Given the current trend of increased rural development on the private lands within the dry shrub PVG, we conclude that the declining trend would likely continue into the future, but at a slower rate.

In general, the dry shrub PVG is limited by moisture availability, either due to low rainfall or to shallow, rocky, or clay soils. Native communities are very diverse and have many species of shrubs, grasses, forbs, and sedges. Production is fair in years of good fall, winter, or spring moisture. The dry shrub PVG historically existed primarily in eastern Washington, southeastern Oregon, and southern Idaho (map 3.11). In these areas, approximately 15 to 21 centimeters of precipitation was received during the fall-winter or winter-spring periods (table 3.38; climate divisions: Washington Central Basin, Oregon South Central, Oregon Southeast, Idaho Southwest Valleys, Idaho Central Plains, and Idaho Upper Snake River Plains). Drought years, in which less than 75 percent of the fall-winter or winter-spring precipitation was received, occurred approximately 15 to 18 percent of the time in these areas. Conversely, relatively wet periods were documented only 6 to 8 times in the 100-year period (1895-1994). Thus, drought frequency, and above-normal precipitation frequency, are greater for the dry shrub PVG compared with the dry grass PVG. The dry shrub PVG is more arid than the dry grass PVG, but along with the greater aridity is a greater variability of precipitation received.

Most of the dominant shrub, grass, and forb species found within the dry shrub PVG have adapted to a cool-season moisture regime, when moisture arrives primarily in the fall, winter, and spring and is followed by a dry summer. The herb and shrub species are highly dependent upon soil moisture stored in the soils from fall, winter, and spring precipitation. Most of their growth and reproduction occurs during the spring and early summer. The cool-season species typically become dormant in the summer and early fall, but can become active again in the fall with adequate moisture. There are a greater number of plant species in the eastern portion of the Basin that have adapted to warm-season moisture — moisture that comes proportionately more in the spring and summer. These species have adapted to take advantage of available moisture throughout the growing season. In general, grasses become more competitive toward the eastern edge of the Basin.

Historically, the dry shrub PVG moved through fairly short cycles of dominance by upland herbland or upland shrubland physiognomic types due to the relatively short-fire intervals. In the absence of fire, trees can invade dry shrub PVGs that lie adjacent to woodland or dry forest PVGs. Soil characteristics of the dry shrub PVG generally indicate that they developed with mixed shrub and grassland potential vegetation. Shallow soils are typically dominated by low shrubs, whereas deep soils are potentially dominated by mid to tall shrubs. Tree establishment in the dry shrubland PVG disrupts the established nutrient regime. Tree species tie up nitrogen and other trace nutrients, thereby decreasing overall site productivity. Subsequently, foliage cover, basal cover, and litter from the shrubs, grasses, and forbs decline, thereby exposing the surface soil and increasing erosion potential. Erosion is potentially aggravated by excessive grazing pressure from livestock and wild ungulates. Once the surface soil is eroded and the subsoil exposed, the environment is more conducive to tree species that are more competitive for subsoil moisture.

In general, the native system was dominated by a mosaic of upland shrubland and upland herbland physiognomic types, depending on the interval between fire disturbances. The dry shrub PVG typically burned with a mixture of non-lethal fires

in areas dominated by upland herbs, and lethal fires in areas dominated by shrubs. Most fires in the dry shrub PVG that were lethal occurred at intervals from 15 to 100 years, and dominated about 90 percent of the PVG. Non-lethal fires occurred across 10 percent of the PVG at intervals of 5 to 10 years, and generally reburned upland herbland physiognomic types. The fire season was relatively long in the dry shrub PVG, generally starting in April or May and extending into October.

Fires in the dry shrub PVG typically kill the shrubs and stimulated established forb species during the year following a disturbance. Succession on these burned sites results in the dominance of established grass species. In small patches with high amounts of decadent or dead shrubs, decadent grasses, and high accumulations of litter, fire often kills the existing perennial grasses and forbs, making small openings for early-seral forbs. Regeneration of shrubs and trees are generally killed by drought or fire.

Historically, the early-, mid-, and late-seral woodland physiognomic types were never able to persist, due to the relatively high intensity and continuity of fire within the shrubland types. The upland herbland physiognomic type constituted 10 to 60 percent of the native dry shrub PVG, depending on the temporal period of the fire cycle. Similarly, the upland shrubland physiognomic type occurred across 40 to 90 percent of the PVG. Areas with mosaic patterns of upland herbs and upland shrubs typically occurred in rough terrain or rocky areas. Areas with continuous patterns of upland herbs or upland shrubs were usually located on more uniform terrains. The native grazing regime was similar to that of the dry grass PVG.

The similarity of physiognomic type composition between historical and current periods was 79 and 93 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). The dry shrub PVG changed from the historic to the current period in much the same manner as the dry grass PVG (table 3.40). The only exception in similarity was that woodland physiognomic types did not greatly increase in the dry shrub PVG. As with the dry grass PVG, the highest departures from the biophysical template within the dry shrub PVG occurred in areas subjected to high levels of continuous season-long or early-season grazing with extensive roading.

The similarity of fire regime composition within the dry shrub PVG between historical and current periods was 29 and 35 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). The current period fire regime within dry shrublands was dominated by lethal fires, which typically occurred at 3 to 15 year intervals. Areas experiencing more frequent fire intervals often had a high component of annual exotic grasses that dried early in the season and became flash fuels for fast-moving summer fires. The additional abundance of fine, flash-type fuels, combined with sagebrush fuels, creates intense fires. Most perennial vegetation in the dry shrub PVG is not adapted to these more frequent, high-intensity fires; the eventual result is mortality of perennial species and prevention of their recruitment. We expect an expansion of this shift in fire regimes over the next 50 years, which will convert even more of the dry shrub PVG to annual exotic grasses.

When woodland encroachment occurs, fuels accumulate and communities exhibit high stress and low foliage moisture. During drought years, very intense fire events can occur in areas of woody encroachment, often causing relatively severe effects to the soil surface and mortality to the understory grasses and forbs.

We did not detect a change in the LAI for the dry shrub PVG between the historical and current periods. Historically, the LAI averaged approximately 1.6 (range = 1.1 to 15.1; sd = 0.3). During the current period, the LAI also averaged 1.6 (range = 0.2 to 51.9; sd = 0.9); however, the increased standard deviation and range of the current period suggested that the system was less predictable than it was historically.

Table 3.40—Percentage of area of current and historical period physiognomic types in the dry shrub potential vegetation group (PVG) by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	Percent			
BLM/FS Ownerships				
Early-seral Woodland	+[3]	+	0	0
Exotic Herbland	6	0	0	0
Late-seral Multi-layer Woodland	0	0	0	0
Late-seral Single-layer Woodland	0	+	0	0
Mid-seral Woodland	+	+	+	+
Upland Herbland	4	3	61	61
Upland Shrubland	90	96	39	39
Other Ownerships				
Early-seral Woodland	1	+	0	+
Exotic Herbland	3	0	0	0
Late-seral Multi-layer Woodland	0	0	0	0
Late-seral Single-layer Woodland	0	+	+	+
Mid-seral Woodland	+	0	+	+
Upland Herbland	5	15	63	62
Upland Shrubland	92	85	37	38
All Ownerships				
Early-seral Woodland	+	+	0	0
Exotic Herbland	5	0	0	0
Late-seral Multi-layer Woodland	0	0	0	0
Late-seral Single-layer Woodland	0	+	+	+
Mid-seral Woodland	+	+	+	+
Upland Herbland	4	9	62	61
Upland Shrubland	91	90	38	39

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

The departures and subsequent effects of succession and disturbance processes of the dry shrub PVG were similar to those identified for the dry grass PVG. The similarity of succession/disturbance regimes between historical and current periods was 10 and 19 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31).

Cool Shrub PVG

Most (75%) of the current period cool shrub PVG occurred above 1,200 meters elevation, whereas historically, 69 percent of the PVG occurred above 1,200 meters elevation (table 3.18). Since the historical period, the areal extent of the cool shrub PVG decreased by approximately 11 percent as a result of agricultural and urban development (maps 3.11 and 3.12). The BLM/FS lands contained most (66%) of the cool shrub PVG. We expected that there would be little loss of cool shrublands to agricultural or urban development in the future. The current trend of rural development on private lands appeared to be low within the cool shrub PVG. Consequently, we conclude that the abundance of the cool shrub PVG will remain relatively constant in the future.

Productivity within the cool shrub PVG is limited by short growing seasons and by low available soil moisture, due to either low rainfall or shallow, rocky, or clay soils. Native communities are very diverse, containing many species of shrubs, grasses, forbs, and sedges. Production is good in years with high winter or spring moisture.

Historically, the cool shrub PVG existed primarily in east-central and extreme southeast Oregon, southwest Idaho, and extreme northeast Nevada (map 3.11). Comparable areas listed in table 3.38 are climate divisions Oregon South Central, Oregon Southeast, Idaho Southwest Highlands, and Nevada Northeast, of which the cool shrub PVG constitutes a high percentage of only the Idaho Southwest Highlands climate division. For this climate division, about 17 centimeters of precipitation is received during the winter-spring period. Drought years, in which less than 75 percent of the winter-spring precipitation is received, occurred 20 percent of the time in this area. Conversely, relatively wet periods, characterized by two or more successive years of greater than 110 percent of the winter-spring precipitation, were documented nine times in the 100-year period from 1895-1994. In general then, drought frequency and above-normal precipitation frequency were similar for the cool shrub and dry shrub PVGs.

Most of the dominant shrub, grass, and forb species have adapted to a cool-season moisture regime. The herb and shrub species are highly dependent upon soil moisture stored from spring rains and winter precipitation. The majority of their growth and reproduction occurs during the spring and summer. The cool-season species typically become dormant in the late summer and early fall, but also can become active in response to fall rains or early snow melts.

Soil characteristics of the cool shrub PVG generally indicate that they developed with mixed-shrub and grassland potential vegetation. When these sites are invaded by trees, the trees often become very dense and therefore, highly stressed during the summer. Stressed trees are commonly attacked by defoliators or beetles, creating areas with high fuel loadings of decadent wood and fine-flammable foliage. Trees generally tie up nitrogen and other trace nutrients, decreasing the overall site productivity. Foliage cover and basal cover of shrubs, grasses, and forbs eventually all but disappear from these sites. Deep litter and duff layers from conifer foliage then accumulate. Fires in these cool shrub PVGs can be of very high intensity during drought years, leaving few post-burn perennials to revegetate the site.

In general, the native system was dominated by a mosaic of upland shrubland and upland herbland physiognomic types (table 3.41). During some temporal cycles, sites could have been dominated by extensive areas of either upland shrubland or upland herbland physiognomic types, depending on the length of the fire-return interval. Areas dominated by uniform distributions of upland shrubs or trees (75% of the cool shrub PVG area) typically burned with lethal fires. Lethal fires typically killed the shrubs or trees and stimulated established forbs during the year following a disturbance. Burned sites were then dominated by established grasses. In small patches containing high amounts of decadent or dead shrubs, decadent grasses, and high accumulations of litter, fires often killed the existing perennial grasses and forbs, creating small openings for early-seral forbs. Regeneration of shrubs or trees was generally killed by drought or fire. Lethal fires had intervals of about 25 to 75 years. Approximately 10 percent of the cool shrub PVG burned with a mixed-fire regime that created a mosaic of upland herbland and upland shrubland structures. The mixed-fire intervals were similar to those of lethal fires. Approximately 10 to 15 percent of the cool shrub PVG burned with non-lethal fires, generally as reburns of the upland herbland physiognomic type. Non-lethal fire intervals were generally 15 to 25 years. The fire season was long, generally starting in April or May and extending into October.

Historically, the early-, mid-, and late-seral woodland physiognomic types generally occupied from 3 to 10 percent of the cool shrub PVG. The upland herbland physiognomic type ranged from 10 to 40 percent, depending on the temporal period of the fire cycle. Conversely, the composition of the upland shrubland physiognomic type ranged from 60 to 80 percent. We believe that exotic species would eventually dominate at least 2 percent of the PVG. The cool shrub PVG is susceptible to invasion by exotic weed species such as knapweed, leafy spurge (*Euphorbia esula*), and perennial grasses such as Kentucky bluegrass (*Poa pratensis*).

The native grazing regime within the cool shrub PVG was similar to regimes in the dry grass and dry shrub PVGs. However, cool shrublands were generally not strongly influenced by winter grazing in the historical period.

The composition of physiognomic types within the cool shrub PVG has changed since the implementation of fire suppression and livestock grazing, the invasion of exotics, and the conversion to agricultural uses (table 3.41). The similarity of physiognomic type composition between historical and current periods was 76 and 89 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). The current period areal extent of woodland physiognomic types increased to 25 to 30 percent of this PVG, and the upland herbland physiognomic type was nearly eliminated. Two-thirds of the current period PVG was dominated by upland shrubland physiognomic type. Exotics plants were common components of the upland shrubland physiognomic type. Species composition and structure within the upland shrubland stage changed as a result of heavy, early-season or season-long livestock grazing. Large dominant bunchgrasses were generally replaced by smaller bunchgrasses, Kentucky bluegrass, native forbs, exotic forbs, and seeded exotic grasses such as bromes and timothy (*Phleum pratense*).

As with the dry grass and dry shrub PVGs, the highest departures from the biophysical template occurred in those areas subjected to high levels of continuous season-long or early-season grazing that were also heavily roaded. Due to a high component of decadent upland shrubland and woodland physiognomic types in the cool shrub PVG, the current period fire regime was dominated by lethal fires occurring at 25- to 75-year intervals. When woodland encroachment occurred, fuels accumulated and communities exhibited high stress and low foliage moisture. During drought years, very intense fire events had the potential to occur in woodland physiognomic types, and often caused relatively severe effects to the soil surface and mortality to the understory grasses and forbs. Approximately 30 percent of

Table 3.41—Percentage of area of current and historical period physiognomic types in the cool shrub potential vegetation group (PVG) by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	..... Percent			
BLM/FS Ownerships				
Exotic Herbland	3	0	0	0
Upland Herbland	4	12	37	37
Upland Shrubland	75	78	58	59
Upland Woodland	18	10	4	4
Other Ownerships				
Exotic Herbland	+[3]	0	0	0
Upland Herbland	4	16	37	37
Upland Shrubland	49	74	55	56
Upland Woodland	48	10	8	7
All Ownerships				
Exotic Herbland	2	0	0	0
Upland Herbland	4	13	37	37
Upland Shrubland	66	77	57	58
Upland Woodland	28	10	6	6

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

the cool shrub PVG had a mixed-fire regime, which was probably a result of its rough terrain and moderate fuel moisture conditions.

The LAI of the cool shrub PVG did not change substantially between the historical and current periods. Historically, the LAI averaged approximately 2.1 (range = 1.1 to 4.8; sd = 0.4), whereas during the current period, the LAI had a mean of 2.3 (range = 0.2 to 54.9; sd = 2.8). However, the high standard deviation in comparison to the mean for the current period, and the wide range of the values, indicates that the mean could be substantially different from the historical. In addition, the current system could be much less predictable than the historical system.

The effects of departures of succession and disturbance processes in the cool shrub PVG were similar to those reported for the dry grass and dry shrub PVGs. The similarity of fire regime composition between historical and current periods was 62 and 69 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). The similarity of succession/disturbance regimes was comparable with the dry grass and dry shrub PVGs.

Riparian Shrub PVG

Agricultural and urban development were responsible for an 80 percent areal decline of the riparian shrub PVG. Although it was always a relatively minor component of the Basin, the areal extent declined from 2 to 0.5 percent between the historical and current periods (maps 3.11 and 3.12). The distribution of the riparian shrub PVG shifted to higher elevations. Historically, 38 percent occurred above 1,200 meters; whereas in the current period, 79 percent of the riparian shrublands occurred above 1,200 meters (table 3.18). BLM/FS lands contained 55 percent of the current period riparian shrub PVG. We do not anticipate that a substantial amount of riparian shrublands will be converted by agricultural or urban development on Other lands in the future. Consequently, we assume that the areal extent of the riparian shrub PVG will remain relatively constant into the future.

The riparian shrub PVG is not generally limited by moisture, except during late summer and drought years. Water tables are typically too high and soils not adequately aerated to allow tree establishment. Native communities are usually the most diverse of any PVG with a broad mixture of shrub, grass, forb, and sedge species. Production of biomass is high.

Historically, the native system was generally dominated by a mixture of riparian shrubland (60%) and riparian herbland physiognomic types (40%) (table 3.42), depending on the disturbance cycles. Disturbance regimes were dominated by floods, fires, and to a lesser degree, grazing. Flood cycles typically occurred at 20- to 30-year intervals. The fire regime was dominated by non-lethal and mixed fires that occurred at 25- to 50-year intervals. The fire season was relatively short in the riparian shrub PVG, generally starting in August and ending in early September during drought years. Grazing by native ungulates was probably widely scattered during drought years.

The riparian shrub PVG changed between historical and current periods due to fire suppression, livestock grazing, invasion of exotics, and agricultural and urban developments (table 3.42). The similarity of physiognomic type composition between historical and current periods was 47 percent for the Basin as a whole and for BLM/FS lands (table 3.31). Exotic species, such as Canada thistle (*Cirsium arvense*), were common components of most communities within the riparian shrub PVG. In the current period, Kentucky bluegrass dominated at least 1 percent of this PVG. The riparian shrubland physiognomic type had become less dominant, occupying 59 percent of the PVG in the current period. The current period riparian herbland physiognomic type contained a relatively large proportion of exotic plants, and was less productive than it was historically.

Disturbance regimes within the riparian shrub PVG also changed from the historical to the current period. Flood events on larger streams had largely been controlled by dams. Fires also occurred less frequently than they had historically. The similarity of fire regime composition between historical and current periods was 34 and 43 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). We speculate that grazing changed from an extensive, low-intensity regime, to a greater intensity regime in the riparian shrub PVG.

We did not detect a substantial change in the LAI between the historical and current periods. Historically, the LAI averaged approximately 1.5 (range = 1.0 to 7.7; sd = 1.2), whereas during the current period, the LAI averaged 2.2 (range = 0.2 to 13.6; sd = 2.4). The current period high standard deviation relative to the mean and wide range of values indicates a more variable and less predictable system than the historic system.

As with most of the rangeland PVGs, the highest departures from the unaltered biophysical template occurred in those areas subjected to excessive livestock grazing pressure, and were also heavily roaded. The overall departure of

Table 3.42—Percentage of area of current and historical period physiognomic types in the riparian shrub potential vegetation group (PVG) by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	..... Percent			
BLM/FS Ownerships				
Exotic Herbland	2	0	0	0
Riparian Herbland	36	4	49	57
Riparian Shrubland	62	42	38	28
Upland Herbland	0	0	0	0
Upland Shrubland	+[3]	54	13	15
Other Ownerships				
Exotic Herbland	+	0	0	0
Riparian Herbland	42	20	52	59
Riparian Shrubland	57	38	33	26
Upland Herbland	0	0	0	0
Upland Shrubland	1	42	15	16
All Ownerships				
Exotic Herbland	1	0	0	0
Riparian Herbland	39	18	52	58
Riparian Shrubland	59	39	34	26
Upland Herbland	0	0	0	0
Upland Shrubland	1	44	15	16

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

succession and disturbance processes in the riparian shrub PVG was high, primarily due to agricultural and urban development, changes in grazing and flooding regimes, and the introduction of exotics. The similarity of succession/disturbance regime composition between historical and current periods was 3 and 12 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). The subsequent effects were similar to those described for most other rangeland PVGs.

Riparian Woodland PVG

The riparian woodland PVG is a relatively rare component of the Basin (1%; maps 3.11 and 3.12). According to our broad-scale data, the riparian woodland PVG did not decline substantially between historical and current periods (table 3.18). However, fine- or mid-scale analysis would suggest that the riparian woodland PVG declined substantially between historical and current periods. This decline was attributable to agricultural

development, urbanization, and invasion by exotic plant species. Thus, our failure to detect broad-scale changes of the riparian woodland PVG warrants further investigation.

The elevational distribution of the riparian woodland PVG did not change substantially; most (98%) occurred above 1,200 meters during the current period, compared with 96 percent in the historical period. Approximately half (54%) of the current period riparian woodland PVG occurred within BLM/FS lands (map 3.12). We do not anticipate substantial future losses of this type attributable to agricultural or urban development on Other lands. Consequently, we assume that the areal extent of riparian woodlands will remain relatively constant into the future.

In general, the riparian woodland PVG is not limited by moisture, except during late summer and drought years. High water tables prevent the establishment of mature coniferous forests. Natural communities are usually highly diverse, with a broad mixture of shrub, grass, forb, and sedge species. Biomass production is relatively high.

The native system was generally dominated by a mixture of riparian shrubland, early-seral forest, and early-, mid-, and late-seral woodland physiognomic types. Historically, the riparian woodland PVG was dominated by mid-seral physiognomic types (60%), followed in dominance by early-seral (20%), riparian shrubland (20%), and late-seral (2%) physiognomic types. Disturbance regimes were historically dominated by flood and fire events, and grazing to a lesser degree. Flood cycles typically occurred on 10- to 20-year intervals. The fire regime was dominated by lethal or mixed fires that occurred on 65- to 150-year intervals. The fire season was relatively short in riparian woodlands, generally starting in August and ending in early September, but only during drought years. Grazing by native ungulates was probably widely scattered and of low intensity. However, some excessive grazing pressure was probably exerted on riparian woodland PVGs during drought years.

Since the historical period, the structure and composition of the riparian woodland PVG has changed due to intensive livestock grazing, the invasion of exotics, and agricultural and urban development (table 3.43). The similarity of physiognomic type composition between historical and current periods was 74 and 85 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). Exotic plants (for example spotted knapweed, Canada thistle, and leafy spurge), were common components of most current period communities within the riparian woodland PVG, and dominated 1 percent of its areal extent. Mid-seral riparian woodland physiognomic types greatly increased and came to dominate approximately 90 percent of the PVG. The areas of all other physiognomic types generally declined from their historical levels. Current period flood events of larger streams were largely controlled by dams. Fires burned less frequently, but more intensively than they did historically. The similarity of fire regime composition between historical and current periods was 71 and 85 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31).

The LAI for the riparian woodland PVG changed substantially between historical and current periods. Historically, the LAI averaged approximately 6.8 (range = 1.0 to 14.4; sd = 2.5), whereas in the current period, the LAI had a mean of 8.4 (range = 0.2 to 32.2; sd = 2.1). The LAI probably increased because, historically, the riparian woodland PVG comprised a larger array of structural stages; whereas, most of the current period PVG comprised mid-seral woodland types. Although the standard deviation did not change appreciably, the increased range indicated a somewhat less predictable system.

As with most other rangeland PVGs, the highest departures from the unaltered biophysical template occurred in those areas subjected to excessive livestock grazing pressure and extensive roading. The overall departure of succession and disturbance processes in the riparian woodland PVG

Table 3.43—Percentage of area of current and historical period physiognomic types in the riparian woodland potential vegetation group (PVG) by land ownership group[1].

Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
	..... Percent			
BLM/FS Ownerships				
Early-seral Forest	+[3]	6	7	14
Early-seral Riparian Woodland	11	44	7	13
Exotic Herbland	+	0	0	0
Late-seral Multi-layer Forest	0	0	+	0
Late-seral Multi-layer Riparian Woodland	0	+	+	+
Late-seral Single-layer Forest	0	0	0	+
Mid-seral Forest	0	0	0	+
Mid-seral Riparian Woodland	88	40	74	62
Riparian Shrub	+	+	+	+
Upland Herbland	+	10	11	11
Other Ownerships				
Early-seral Forest	+	12	12	10
Early-seral Riparian Woodland	3	16	13	11
Exotic Herbland	2	0	0	0
Late-seral Multi-layer Forest	0	+	1	1
Late-seral Multi-layer Riparian Woodland	1	1	1	1
Late-seral Single-layer Forest	1	0	+	1
Mid-seral Forest	+	1	1	1
Mid-seral Riparian Woodland	89	33	56	64
Riparian Shrubland	1	6	1	1
Upland Herbland	4	31	15	11
All Ownerships				
Early-seral Forest	+	9	10	12
Early-seral Riparian Woodland	7	31	10	12
Exotic Herbland	1	0	0	0
Late-seral Multi-layer Forest	0	+	+	1
Late-seral Multi-layer Riparian Woodland	+	+	+	+
Late-seral Single-layer Forest	+	0	+	+
Mid-seral Forest	+	+	+	+
Mid-seral Riparian Woodland	89	37	66	63
Riparian Shrubland	+	3	1	+
Upland Herbland	2	20	13	11

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

was high due to the changes of grazing and flood regimes, and the introduction of exotic vegetation. The similarity of succession/disturbance regime composition between historical and current periods was 12 and 15 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31). The subsequent effects of these changes were similar to those reported for most other rangeland PVGs.

Alpine PVG

The alpine PVG occurs above 1,200 meters elevation. The areal extent of the alpine PVG did not change substantially between historical and current periods (table 3.18). Most (83%) of the alpine PVG occurred on BLM/FS lands (maps 3.11 and 3.12).

The alpine PVG is limited by a short growing season. The moisture regime ranges from dry to wet. Native communities are very diverse with a large set of low shrubs, sedges, forbs, and grasses that are adapted to alpine environments.

The alpine PVG rarely burns. When fires do occur, they are usually limited to small patches and are generally non-lethal. Fire-return intervals are long. The native grazing regime probably is characterized by scattered low-intensity, seasonal use by native ungulates.

We did not detect any major broad-scale changes of physiognomic types within the alpine PVG between the historical and current periods (table 3.31), possibly due to the resolution of our broad-scale data. Similarly, no substantial changes of fire regime occurred within the alpine PVG. Based on review of finer-scale information, we suspect that excessive grazing pressure by domestic sheep caused changes in plant communities and soil conditions.

Broad-scale departures of succession and disturbance processes in the alpine PVG were low. Those effects that we suspect had occurred should be evaluated with a fine-scale assessment in a future investigation. The similarity of succession/disturbance regime composition between historical and current periods was 11 and 14 percent for the Basin as a whole and for BLM/FS lands, respectively (table 3.31).

Water PVG

The water PVG is nearly evenly distributed above (48%) and below (52%) 1,200 meters elevation. We did not detect any measurable changes in the water PVG between historical and current periods (table 3.18), largely because of the resolution of our data. Although, we know that many large impoundments were developed within the Basin, we also suspect that many large water bodies declined in size due to anthropogenic uses. However, finer resolution data are necessary to evaluate such changes. Approximately 18 percent of the water PVG occurred on BLM/FS lands.

Rock PVG

Most of the rock PVG occurs above 1,200 meters elevation. We did not detect any changeof the areal extent of the rock PVG between the historical and current periods (table 3.18). Nearly all of the rock PVG (96%) occurred on BLM/FS lands.

Agricultural PVG

Most (75%) of the agricultural PVG occurs below 1,200 meters, and virtually all of it occurs on Other lands (table 3.18). The agricultural PVG is not native to the Basin and did not exist historically. Its development resulted in the decline of many of the native PVGs, particularly the dry grass, dry shrub, and riparian shrub PVGs (maps 3.11 and 3.12).

In general, the LAI of the agricultural PVG was relatively high (mean = 2.3; range = 1.0 to 3.4; sd = 0.5). The LAI was similar to the LAIs of the dry grass and dry shrub PVGs. Although structures of agricultural hayland and pasture were similar to some of the native systems that they replaced, the grazing and haying disturbance regimes generally displaced most native species.

Urban PVG

Most (81%) of the urban PVG was developed at elevations below 1,200 meters elevation, and was derived primarily from the dry grass, dry shrub, and riparian shrub PVGs (table 3.18). The urban PVG is located entirely within Other lands.

Road PVG

The road PVG is an extensive cultural development and occurs as linear features. Although roads are designed to function as connective linkages for humans, they also serve as travel ways for other animals, and have facilitated the dispersal of exotic plants. In addition, they have functioned as conduits for water flow (in ditches) and sediment transport. Well-maintained roads (fitted to the land), with minimal cut and fill slopes, good drainage features, and vegetation cover in ditches and on cut/fill slopes are generally not a problem in terms of bare soil, erosion, and sediment transport. However, many of the forest and rangeland roads located in the Basin were not well maintained, had large cut and fill slopes, poor drainage features, and lacked vegetation cover in ditches and on cut/fill slopes. Many of the roads were surfaced with fine aggregate or native materials that are easily eroded. Their high erosion potential, in conjunction with their ability to capture and transport water, has created an effective sediment transport systems. In addition, the higher densities of roads often occur in watersheds that are sensitive to soil erosion.

The current road PVG exists on approximately 1.9 percent of the Basin (table 3.19). The distribution of the road PVG is slightly skewed towards Other land ownerships (2.1%) as compared to BLM/FS lands (1.7%). Approximately 39 percent of all roads in the Basin are located in highly sensitive watersheds in terms of their susceptibility to erosion and sediment transport. Another 22 and 39 percent of all roads are located in watersheds that have moderate or low erosion, and sediment transport sensitivity, respectively. There is little doubt that problems relative to sedimentation in streams are highly correlated to the large proportion of roads that occur in high sensitivity watersheds.

Many opportunities exist to restore or redesign existing roads and to avoid the development of new roads in moderate and high sensitivity watersheds. In addition, finer-resolution data could be used to (1) orient transportation systems to the less-sensitive land types within watersheds, (2) reduce cut/fill slopes, (3) improve the selection of surfacing material, and (4) better design drainage systems.

Comparison of Biogeochemical Processes and Succession/ Disturbance Regimes

Each PVG has a unique combination of biogeochemical processes, seasonal climates, and topoedaphic conditions that produce a complex of succession and disturbance regimes (table 3.44). The NPP, NAI, CSI, and WSI values shown in table 3.44 are historical values without the influence of management actions except for agriculture and roads, which were new PVGs developed by humans. The seasonal climate gradient index (SCI) and topoedaphic index (TEI) did not change unless climate or land-forming changes occurred. The SCI and TEI also accounted for landscape continuity that influences disturbances across space. As discussed previously in the "Relationships to succession/disturbance regimes" subsection of this "Results and Discussion" section, the NPP, NAI, CSI, and WSI have changed as a result of changed succession and disturbance regimes.

We determined that current succession/disturbance regimes could be spatially predicted based on PVGs, native succession/disturbance regimes, and recent management and disturbance histories. Thus, this information provides a way of stratifying

Table 3.44—Trends of relativized biogeochemical characteristics of potential vegetation groups (PVGs) and relationships with succession / disturbance regimes (SDR[1]).

PVG	Net Primary Production	Nutrient Availability Index	Carbon Stress Index	Water Stress Index	Seasonal Climate Gradient[2]	Topoedaphic Index[3]	SDR - Historical[4]	SDR - Current
Agriculture[5]	1.0	1.0	0.7	1.0	0.8	0.2	NA	SC
Trend[6]	+[7]	–[8]	+	+				
Alpine	0.3	0.2	0.5	0.3	1.0	1.0	LC	VC-LC
Trend	–	–	–	–				
Cold Forest	0.9	0.6	0.9	0.7	1.0	0.8	AC-IM	LC-RC
Trend	+	+	–	NC[9]				
Cool Shrub	0.7	0.9	0.6	0.9	0.9	0.6	MC-FM	RC-LC
Trend	–	–	+	NC				
Dry Forest	0.8	0.7	1.0	0.9	0.8	0.6	FM-MC	LC-RC
Trend	–	–	+	+				
Dry Grass	0.7	0.8	0.7	1.0	0.7	0.4	FM-MC	RC-LC
Trend	–	–	+	+				
Dry Shrub	0.6	1.0	0.6	1.0	0.9	0.5	MC-FM	RC-MC
Trend	–	–	+	NC				
Moist Forest	1.0	0.8	1.0	0.7	0.9	0.7	AC-IM	MC-RC
Trend	–	–	+	+				
Riparian Shrub/ Woodland	1.0	0.8	0.5	0.9	0.9	0.3	LC-MC	RC-LC
Trend	+	–	–	+				
Road[5]	0.0	0.0	0.0	0.0	0.9	0.5	NA	SC
Trend	–	–	–	–				
Rock	0.0	0.0	0.0	0.0	0.9	1.0	LC	LC
Trend	NC	NC	NC	NC				
Woodland	0.7	1.0	0.8	1.0	0.8	0.9	MC-IM	RC-LC
Trend	+	+	–	+				

[1]See table 3.6 for description of succession/disturbance regime cycles.

[2]Seasonal climate gradient—index of spring-to-summer evapotranspiration gradient. High values indicate steep gradients that result in high stress, and high risk of very dry fuels.

[3]Topoedaphic index—index of topographic and soil complexity. High values indicate complex terrain and potential for complex fire weather and fuel conditions.

[4]NA = Not Applicable; AC = Accelerated cycle; LC = Long cycle; SC = Short cycle; VC = Very long cycle; FM = Frequent maintenance; IM = Irregular maintenance; MC = Moderate cycle; RC = Retrogressive cycle.

[5]Not present historically—calculated for current.

[6]Trend—trend from historical to current: +=increase; -=decrease; NC=no change.

[7]+ = Increasing trend from historical to current period conditions.

[8] – = Decreasing trend from historical to current period conditions.

[9]NC = No trend from historical to current period conditions.

environments and disturbances at multiple-spatial and temporal scales, without requiring a current period vegetation map that would require continual updating. Management prescriptions designed to achieve a desired succession/disturbance regime for a given PVG-succession/disturbance regime condition could then be developed to meet management objectives. This set of prescriptions could be used for project planning or implementation that would contribute to coarser-scale, desired conditions, as well as meeting finer-scale objectives. The PVG, succession/disturbance regimes and prescriptions provide a template that is useful for the long term, as compared to current period vegetation maps which would change every few years as a result of succession and disturbance. In addition, this information provides an ecological and landscape systems approach to understanding vegetation and disturbance processes and potential response. Another valuable asset of knowing the PVG, succession regime, and management and disturbance histories is that the current vegetation could be predicted with much higher precision from satellite imagery, photo interpretation, or ground-truth extrapolation.

The woodland PVG had high NPP and NAI, and moderate WSI. This was combined with a steep seasonal gradient (from moist winter to dry summer conditions) on typically rocky upland foothills that produced a complex of succession/disturbance regimes dominated by moderate cycle- and irregular-maintenance regimes (table 3.6). Fire exclusion, excessive livestock grazing pressure, and invasion of exotics, in conjunction with succession to later vegetation stages, altered the composition of succession/disturbance regimes to one dominated by retrogressive and long-cycle regimes. Associated changes of biogeochemical characteristics included increased NPP and NAI, decreased CSI, and increased WSI. Fire exclusion, as a result of fire-control efforts plus grazing of fine fuels, resulted in an increase of woodland trees and shrubs compared to herbs. The tree and shrub species had higher leaf area and thus, the associated increase of NPP. However, in these moisture-limited environments, the higher leaf area caused increased water stress. Increased temperatures in the understory resulted in increased decomposition and nutrient availability, and susceptibility to erosion. Total loading of carbon relative to growth potential, as indicated by the CSI, decreased as a result of herbaceous cover loss.

The dry forest had high NPP, moderate NAI, and high carbon and water stresses. The seasonal gradient from moist winter to dry summer conditions was steep and topoedaphic conditions were generally moderate on plains, break, foothill, and some mountain landforms. These conditions produced an inherent succession/disturbance regime that was dominated by a complex of frequent-maintenance and moderate-cycle regimes. Fire exclusion and timber harvest of large, shade-intolerant, and fire-, insect-, and disease-resistant trees shifted the dry forest succession regime to one dominated by a complex of long- and retrogressive-cycle regimes. These changes caused an increase in NPP and NAI with associated increases in carbon and water stresses.

The moist and cold forest PVGs had similar biogeochemical relationships. Both had high NPP and CSI with moderate WSI. They differed in that NAI was moderate in the cold forest, while it was high in the moist forest. Both PVGs had high seasonal gradients from moist-to-wet winters, to dry summers. Both generally occurred on moderate topoedaphic conditions. However, the cold forest PVG generally occurred in mountain landforms, while the moist forest PVG occurred across both foothill and mountain landforms. The dominant environmental difference between the two PVGs

was a shorter growing season and colder temperatures in the cold forest, which affected nutrient availability and precluded growth of many moist forest tree, shrub, and herb species because they are ill-adapted to cold temperatures.

The moist and cold forest PVGs had inherent succession/disturbance systems that were dominated by a complex of accelerated-cycle and irregular-maintenance regimes. Both were substantially affected by the introduction of blister rust, which nearly eliminated the dominant seral tree species from each system (that is, the western white pine in the moist forest, and whitebark pine in the cold forest). Both were also affected by fire exclusion, although the temporal effects occurred much faster in the moist forest than in the cold forest. However, the trends were very similar. The moist forest PVG was substantially affected by traditional timber-harvest activities that did not simulate the native succession/disturbance regime. Timber harvest affected the cold forest to some extent in the Cascade Mountains, but not substantially in the Rocky Mountains. Blister rust, fire exclusion, and timber harvests changed the composition of succession/disturbance regimes to a complex dominated by moderate- and retrogressive-cycles in the moist forest, and long- and retrogressive-cycles in the cold forest.

The trends in biogeochemical variables for the cold forest were quite different with an increase in NPP and NAI, as compared to a decrease in the moist forest. The increase in NPP and NAI was due to the transition to shade-tolerant species in the cold forest [such as subalpine fir (*Abies lasiocarpa*)] that tended to photosynthesize at higher rates; an increase in dead wood and nutrient release in areas of high whitebark pine mortality; and increased levels of finer woody fuels that were more rapidly cycled into nutrients. Carbon stress declined due to the lack of late-seral stage development, which in turn was the result of the decline in shade-intolerant species. In contrast, NPP and NAI declined in the moist forest PVG. Tree and shrub species that dominated this type in the current period generally had lower NPP, and nutrients were cycled at slower rates. As a result of higher accumulations of biomass in mid-seral stages, carbon and water stress increased.

The dry grass, dry shrub, and cool shrub PVGs had a similar set of biogeochemical characteristics. These non-forest (rangeland) PVGs differed from forest PVGs (for example, woodland, dry forest, moist forest, and cold forest) in that they had high water stress, moderate carbon stress, high nutrient availability, and moderate net primary productivity. In contrast, the forest PVGs had lower water stress, higher carbon stress, lower nutrient availability, and higher net primary productivity. The woodland and dry forest PVGs were transitional, falling between the non-forest and moist forest PVGs. The primary factor distinguishing the woodland PVG from non-forest PVGs was its higher carbon stress and topoedaphic conditions. The primary factors distinguishing the woodland PVG from the dry forest PVG were its lower NPP, lower carbon stress, and topoedaphic conditions. The dry forest PVG had higher NPP, lower NAI, and higher CSI, relative to the non-forest PVGs.

The primary difference between the dry grass, and dry or cool shrub PVGs was the seasonal climate gradient, which was higher for the dry and cool shrub PVGs, than the dry grass PVG. The dry grass PVG generally occurred in climates with little winter and spring sunlight, and relatively lower spring evaporation and winter sublimation rates relative to the shrub PVG. Available moisture was often influenced by topoedaphic conditions, such as those found on the Columbia Plateau, where deep loess soils retain winter moisture in the surface horizon that is critical for summer growth.

The dry grass, dry shrub, and cool shrub PVGs had an inherent succession/disturbance system that was dominated by a complex of moderate-cycle and frequent-maintenance regimes. This was substantially changed by a history of fire exclusion, (late 1800s through current) excessive growing-season grazing by livestock that selectively grazed the dominant perennial grasses, and the invasion of exotic forbs and annual grasses. The composition of the succession/disturbance regime shifted to a system dominated by retrogressive-, and moderate- to long-cycle regimes, with substantial amounts of the short-cycle regime in areas that had an understory of, or were dominated by, exotic annual grasses.

The riparian system was complex and dynamic with variations from herb, to shrub, to woodland-dominated systems. The riparian system could be distinguished from the forest and non-forest PVGs because of its topoedaphic conditions, which maintained higher levels of moisture in the growing season. Higher moisture levels promoted high levels of NPP and NAI, while maintaining fairly low carbon stress, in environments that normally had steep winter-to-summer moisture gradients. This resulted in a brief period of high WSI during summer drought. The native succession/disturbance regime was dominated by a complex of long- and moderate-cycle regimes. As a result of fire exclusion, extensive growing-season grazing by livestock that selectively grazed the woody plants and perennial grasses, and the invasion of exotic forbs and grasses, the composition of the succession/disturbance regime shifted to one dominated by a complex of retrogressive- and long-cycle regimes. Our simulations of NPP indicated a decrease in the shrub types due to the loss of shrub cover, and an increase in the riparian woodland types due to a shift from broadleaf to conifer and an increase in tree density. In association, carbon and water stress increased, while nutrient availability declined in the shrub type. In contrast, carbon stress declined in the woodland types as a result of an overall reduction of total biomass, while water stress and nutrient availability increased.

The alpine PVG differed substantially from all other PVGs. As a consequence of low temperature and high precipitation levels, the alpine PVG had a relatively low NPP, NAI, CSI, and WSI. Historically, this system was dominated by a long-cycle regime. Due to fire exclusion, this system shifted to a complex of very long- and long-cycling regimes.

Agricultural lands were not present in the native system, but there were inherent biogeochemical processes based on the changed conditions. Because of inputs of water, fertilizer, crop species, tillage, and weed control, the NPP and NAI could be maintained at relatively high levels with moderate carbon stress and high water stress. The succession/disturbance regime was dominated by the short-cycle regime due to tillage and production of annual crops, or perennial crops that lasted 3 to 5 years. In comparison to the original potentials the trends of NPP, CSI, and WSI increased, while NAI declined.

The road PVG shifted from the succession/disturbance regime of the original PVG to a short-cycle system. NPP, NAI, CSI, and WSI all declined as the result of loss of vegetation cover.

Continue

Previous

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Ecological Reporting Units

This subsection provides a description by ERU of the trends in potential vegetation group composition, vegetation succession, and disturbance dynamics from the historical to the current period. Furthermore, we highlighted the abiotic factors such as geology, hydrology, climate, and soil, that affected trends. The data for this subsection were derived from the assessment of current conditions and the 100-year simulation of historical conditions used to estimate historical range of variability (HRV). The PVGs, vegetation, succession, and disturbance dynamics of the ERUs were associated with differences in geomorphology, landform, soil, climate, and history of human use. The geologic, hydrologic, climatic, and soil features associated with each ERU have been described in Chapter 2, Biophysical Environments. In following subsections of this "Results and Discussion" section, descriptions and discussions of each ERU are oriented around the dominant PVGs, their compositional changes of physiognomic types in relation to their HRV, and the associated implications to succession/disturbance regimes. Dominant PVGs were selected based on those that composed at least 5 percent of the BLM/FS lands during the current period. In the final part of this subsection, we provide a comparison among ERUs relative to biogeochemical processes and succession/disturbance regimes.

There were substantial differences among ERUs in the composition of the PVGs. We summarized the areal extent of woodland, dry forest, moist forest, cold forest, dry grass, dry shrub, and cool shrub PVGs in the ERUs by All land ownerships, BLM/FS land ownerships, and Other land ownerships (table 3.45).

Blue Mountains ERU

The Blue Mountains ERU is located primarily in northeastern Oregon and southeastern Washington. A small portion of this ERU also occurs in central Idaho (map 3.3). This ERU has relatively low relief (160 to 2,900 m), and exists as a complex of foothills and mountains resulting from the erosion of volcanic parent material (map 3.17). Extensive areas of soils in this ERU were susceptible to erosion by wind, and shrinking and swelling from drying or wetting (table 3.46; maps 3.18, 3.19, and 3.20). Landforms include a mix of foothills, breaks, mountains, and valleys that form a complex of headwater and downstream (mainstem) watersheds (map 3.21). The number of headwater watersheds found in an ERU, compared to the number of downstream watersheds, is important because ERUs with more area in headwater systems are less subject to invasion by exotic plants and animals, in both terrestrial and aquatic environments. The Blue Mountains ERU is primarily situated in ecoregion section M332G (map 3.1).

Precipitation in the Blue Mountain ERU averages 55 centimeters per year (range = 29 to 120 cm). Climate was strongly influenced by oceanic storms from the west. Most of the precipitation occurred in the form of winter snows or spring rains. A steep moisture gradient existed between the relatively moist spring conditions and the very dry summer and fall conditions. The growing season was relatively long, vegetation was diverse, and the biogeochemical energy relationships were dynamic. Consequently, the Blue Mountains ERU had an inherently high rate of NPP and nutrient cycling, which was associated with high carbon and water stress in the upland areas.

Table 3.45—Dominant current potential vegetation groups (PVGs) by Ecological Reporting Unit (ERU) and land ownership group.

ERU/ Land Ownership Group[1]	Potential Vegetation Group						
	Cold Forest	Cool Shrub	Dry Forest	Dry Grass	Dry Shrub	Moist Forest	Wood-land
	Percent						
Blue Mountains							
All lands	4	8	46	8	8	6	1
BLM/FS lands	4	4	31	5	4	5	1
Other lands	+[2]	4	15	4	4	1	+
Central Idaho Mountains							
All lands	25	8	27	7	8	16	1
BLM/FS lands	25	7	22	6	6	15	1
Other lands	+	1	5	1	2	1	+
Columbia Plateau							
All lands	+	9	10	5	23	4	1
BLM/FS lands	+	3	3	+	3	2	+
Other lands	+	6	7	5	20	2	1
Lower Clark Fork							
All lands	3	0	14	+	0	78	0
BLM/FS lands	3	0	6	+	0	57	0
Other lands	+	0	8	+	0	21	0
Northern Cascades							
All lands	25	1	12	2	1	49	+
BLM/FS lands	21	+	6	1	+	26	0
Other lands	4	1	6	1	2	23	+
Northern Glaciated Mountains							
All lands	7	1	16	2	+	58	0
BLM/FS lands	5	+	3	+	0	31	0
Other lands	2	1	13	2	1	27	0
Northern Great Basin							
All lands	+	5	9	+	75	1	+
BLM/FS lands	+	3	7	+	60	1	+
Other lands	+	2	3	+	14	+	+

Table 3.45 (continued).

ERU/ Land Ownership Group[1]	Potential Vegetation Group						
	Cold Forest	Cool Shrub	Dry Forest	Dry Grass	Dry Shrub	Moist Forest	Wood-land
	Percent						
Owyhee Uplands							
All lands	+	23	2	1	59	+	2
BLM/FS lands	+	19	1	1	47	+	1
Other lands	+	4	1	1	13	+	1
Snake Headwaters							
All lands	45	+	17	5	2	+	+
BLM/FS lands	36	+	11	2	1	+	+
Other lands	9	+	6	3	1	+	+
Southern Cascades							
All lands	12	5	33	2	2	37	+
BLM/FS lands	10	3	18	+	1	23	0
Other lands	2	2	15	2	1	14	+
Upper Clark Fork							
All lands	34	1	26	6	+	19	+
BLM/FS lands	28	+	9	1	+	12	0
Other lands	6	1	17	5	+	7	+
Upper Klamath							
All lands	3	5	64	4	4	7	+
BLM/FS lands	2	2	35	1	1	5	+
Other lands	1	3	29	3	3	2	+
Upper Snake							
All lands	1	7	+	2	48	+	1
BLM/FS lands	1	4	+	1	35	+	+
Other lands	+	3	+	1	13	+	1

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]+ = < 0.5%.

Note: values shown are a percentage of the ERU. Not all PVGs are displayed; hence the values for each PVG do not total 100 percent.

Map 3.17—Topographic map of the Interior Columbia Basin and portions of the Klamath and Great Basins (referred to as "the Basin"). Topographic relief is one of the key variables that produces the high diversity of biophysical conditions and disturbance processes found within the Basin.

Table 3.46—Ecological Reporting Units (ERUs) and the percent of each ERU by land ownership category that is of high, moderate, and moderate-low susceptibility of rangeland health to management-induced disturbance stresses, as indicated by climate and soil property indicators.

ERU	Climate Indicators (precipitation zones)[1] Suscept -ibility Rating	Percent of ERU	Soil Property Indicators SEW[2]	SEW & SAL	SEW & SAL & WE	SEW & SSP & WE	WE	WE & SEW	SAL	SAL & WE	SAL & SSP	SAL & SAR	SAL & SAR & SSP & WE	SSP	SSP & WE
BLM / FS Lands															
			Percent												
Blue Mountains	H	T[3]	-[4]	T	-	-	T	-	-	-	T	-	-	-	T
	M	2	-	-	-	-	1	-	T	T	-	-	-	T	T
	M-L	50	-	-	-	-	18	-	T	T	-	-	-	T	3
Central Idaho Mountains	H	1	-	-	-	-	T	-	T	T	-	-	-	-	-
	M	2	-	-	-	-	T	T	1	T	-	-	-	T	-
	M-L	78	T	-	-	-	18	-	1	1	-	-	-	T	-
Columbia Plateau	H	1	T	-	T	-	T	T	T	T	-	-	-	T	T
	M	4	T	-	-	-	2	T	T	T	-	-	-	T	T
	M-L	7	T	-	-	-	3	T	T	-	-	-	-	T	T
Lower Clark Fork	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M-L	64	T	-	-	-	36	T	-	-	-	-	-	-	-
Northern Cascades	H	T	-	-	-	-	T	-	-	-	-	-	-	-	-
	M	T	T	-	-	-	T	T	-	-	-	-	-	-	-
	M-L	54	T	-	-	-	6	T	-	-	-	-	-	-	-
Northern Glaciated Mtns.	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M	T	-	-	-	-	T	-	-	-	-	-	-	-	-
	M-L	39	T	-	-	-	17	T	-	-	-	-	-	-	-
Northern Great Basin	H	8	-	1	-	-	3	-	1	1	T	-	-	T	T
	M	22	-	1	-	-	15	-	T	1	T	-	-	T	1
	M-L	43	-	1	-	-	23	-	T	1	-	-	-	T	7
Owyhee Uplands	H	15	1	T	T	-	4	2	1	3	-	-	T	T	2
	M	20	1	T	T	T	7	2	T	1	-	-	T	T	3
	M-L	31	T	T	T	T	18	1	T	1	-	-	-	T	4

Table 3.46 (continued).

ERU	Climate Indicators (precipitation zones)[1] Susceptibility Rating	Percent of ERU	Soil Property Indicators SEW[2]	SEW & SAL	SEW & SAL & WE	SEW & SSP & WE	WE	WE & SEW	SAL	SAL & WE	SAL & SSP	SAL & SAR	SAL & SAR & SSP & WE	SSP	SSP & WE
			Percent												
Snake Headwaters[5]	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M-L	59	2	T	-	-	23	T	T	T	-	-	-	T	-
Southern Cascades	H	T	-	-	-	-	T	-	-	-	-	-	-	-	-
	M	2	-	-	-	-	2	-	-	-	-	-	-	-	-
	M-L	55	T	-	-	-	3	-	-	-	-	-	-	-	-
Upper Clark Fork	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M	T	-	-	-	-	-	-	-	-	-	-	-	-	-
	M-L	54	T	-	-	-	31	-	-	-	-	-	-	T	-
Upper Klamath	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M	T	-	-	-	-	T	-	-	-	-	-	-	-	T
	M-L	46	-	-	-	-	10	-	T	-	-	-	-	-	3
Upper Snake	H	6	T	1	T	-	T	T	T	T	T	-	-	-	-
	M	16	T	1	-	-	4	T	1	1	T	-	-	T	-
	M-L	19	1	T	-	-	8	-	1	2	-	-	-	1	T
Other Lands															
Blue Mountains	H	1	T	T	-	-	T	-	-	-	T	-	-	-	T
	M	3	T	T	-	-	1	T	T	T	T	-	-	T	T
	M-L	45	4	T	-	-	16	T	1	T	-	-	-	1	6
Central Idaho Mountains	H	2	-	T	-	-	T	-	T	1	T	-	-	-	-
	M	1	-	T	-	-	T	-	T	T	-	-	-	T	-
	M-L	15	1	T	-	-	5	-	T	T	-	-	-	T	-
Columbia Plateau	H	25	11	T	T	-	5	2	4	T	-	-	-	T	T
	M	17	6	T	T	-	6	1	T	-	-	-	-	1	T
	M-L	47	10	T	-	-	15	2	T	-	-	-	-	2	T
Lower Clark Fork	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M-L	36	1	-	-	-	19	2	-	-	-	-	-	-	-

Table 3.46 (continued).

ERU	Climate Indicators (precipitation zones)[1] Susceptibility Rating	Percent of ERU	Soil Property Indicators SEW[2]	SEW & SAL	SEW & SAL & WE	SEW & SSP & WE	WE	WE & SEW	SAL	SAL & WE	SAL & SSP	SAL & SAR	SAL & SAR & SSP & WE	SSP	SSP & WE
			Percent												
Northern Cascades	H	1	T	-	T	-	T	T	-	-	-	-	-	-	-
	M	2	T	-	-	-	1	T	-	-	-	-	-	-	-
	M-L	43	1	-	-	-	9	3	T	-	-	-	-	-	-
Northern Glaciated Mtns.	H	T	T	-	-	-	T	-	-	-	-	-	-	-	-
	M	4	T	-	-	-	2	T	-	-	-	-	-	-	-
	M-L	57	3	T	-	-	25	1	-	-	-	-	-	-	-
Northern Great Basin	H	5	-	T	-	-	1	-	1	T	1	-	-	T	T
	M	9	-	T	-	-	3	-	T	T	1	-	-	T	T
	M-L	13	-	T	-	-	4	-	T	T	T	-	-	T	3
Owyhee Uplands	H	9	1	1	T	-	2	T	2	1	-	-	T	-	1
	M	11	1	1	T	T	3	1	1	T	-	-	T	T	1
	M-L	14	T	T	T	T	6	T	T	T	-	-	-	T	2
Snake Headwaters	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M	T	T	-	-	-	-	-	T	-	-	-	-	-	-
	M-L	39	7	T	-	-	12	1	T	T	-	-	-	T	-
Southern Cascades	H	1	-	-	-	-	1	-	-	-	-	-	-	-	-
	M	2	-	-	-	-	2	-	-	-	-	-	-	-	-
	M-L	40	2	-	-	-	9	-	-	-	-	-	-	T	T
Upper Clark Fork	H	1	-	-	-	-	T	-	-	-	-	-	-	-	-
	M	2	T	-	-	-	T	-	-	-	-	-	-	-	-
	M-L	44	7	-	-	-	27	T	-	-	-	-	-	T	-
Upper Klamath	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M	1	-	-	-	-	-	-	1	-	-	-	-	-	T
	M-L	53	-	-	-	-	8	-	6	-	-	-	-	-	3
Upper Snake	H	10	T	3	1	-	T	T	1	1	1	T	-	-	-
	M	17	T	4	-	-	1	T	4	3	T	T	-	-	-
	M-L	32	12	3	-	-	4	T	3	2	-	T	-	T	-

Table 3.46 (continued).

ERU	Climate Indicators (precipitation zones)[1] Suscept -ibility Rating	Percent of ERU	Soil Property Indicators SEW[2]	SEW & SAL	SEW & SAL & WE	SEW & SSP & WE	WE	WE & SEW	SAL	SAL & WE	SAL & SSP	SAL & SAR	SAL & SAR & SSP & WE	SSP	SSP & WE
All Lands															
			Percent												
Blue Mountains	H	1[6]	T	T	-	-	T	-	-	-	T	-	-	-	T
	M	5	T	T	-	-	1	T	T	T	T	-	-	T	T
	M-L	95	4	T	-	-	34	T	1	T	-	-	-	2	9
Central Idaho Mountains	H	3	-	T	-	-	T	-	1	1	T	-	-	-	-
	M	3	-	T	-	-	T	T	1	T	-	-	-	T	-
	M-L	93	1	T	-	-	23	-	1	1	-	-	-	T	-
Columbia Plateau	H	26	11	T	T	-	6	2	4	T	-	-	-	T	T
	M	20	6	T	T	-	8	1	T	T	-	-	-	1	T
	M-L	54	10	T	-	-	18	2	T	-	-	-	-	3	1
Lower Clark Fork	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	M-L	100	2	-	-	-	55	2	-	-	-	-	-	-	-
Northern Cascades	H	1	T	-	T	-	T	T	-	-	-	-	-	-	-
	M	2	T	-	-	-	1	T	-	-	-	-	-	-	-
	M-L	97	1	-	-	-	15	3	T	-	-	-	-	-	-
Northern Glaciated Mtns.	H	T	T	-	-	-	T	-	-	-	-	-	-	-	-
	M	4	T	-	-	-	2	T	-	-	-	-	-	-	-
	M-L	96	3	T	-	-	41	1	-	-	-	-	-	-	-
Northern Great Basin	H	13	-	1	-	-	3	-	2	2	1	-	-	T	T
	M	31	-	1	-	-	18	-	T	1	1	-	-	1	1
	M-L	56	-	1	-	-	28	-	T	1	T	-	-	T	10
Owyhee Uplands	H	24	1	1	T	-	5	2	3	4	-	-	T	T	2
	M	31	2	1	T	T	10	2	1	1	-	-	T	T	4
	M-L	45	T	T	T	T	24	1	T	1	-	-	-	1	6

Table 3.46 (continued).

ERU	Climate Indicators (precipitation zones)[1] Suscept -ibility Rating	Percent of ERU	Soil Property Indicators SEW[2]	SEW & SAL	SEW & SAL & WE	SEW & SSP & WE	WE	WE & SEW	SAL	SAL & WE	SAL & SSP	SAL & SAR	SAL & SAR & SSP & WE	SSP	SSP & WE
			Percent												
Snake	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Headwaters[5]	M	T	T	-	-	-	-	-	T	-	-	-	-	-	-
	M-L	98	9	T	-	-	35	1	T	T	-	-	-	T	-
Southern	H	1	-	-	-	-	1	-	-	-	-	-	-	-	-
Cascades	M	4	-	-	-	-	4	-	-	-	-	-	-	-	-
	M-L	95	2	-	-	-	12	-	-	-	-	-	-	T	T
Upper Clark	H	1	-	-	-	-	T	-	-	-	-	-	-	-	-
Fork	M	2	T	-	-	-	T	-	-	-	-	-	-	-	-
	M-L	97	7	-	-	-	58	T	-	-	-	-	-	T	-
Upper	H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Klamath	M	1	-	-	-	-	T	-	1	-	-	-	-	-	T
	M-L	99	-	-	-	-	18	-	6	-	-	-	-	-	5
Upper Snake	H	16	T	4	1	-	T	T	1	1	1	T	-	-	-
	M	33	T	5	-	-	5	1	5	3	T	T	-	T	-
	M-L	51	13	4	-	-	13	T	4	4	-	T	-	1	T

[1]Climate indicators include: (H) high susceptibility to management-induced disturbance stress = less than 25 centimeters annual precipitation zone; (M) moderate susceptibility to management-induced disturbance stresses = 25 to 30 centimeters annual precipitation zone; and (M-L) moderate to low susceptibility to management-induced disturbance stresses) = greater than 30 centimeters annual precipitation zone. The amounts indicated represent the percent of the ERU found within each of those climate zones depending on land ownership category.

[2]Soil property indicator codes and definitions: SEW = Soil erodibility to water; SAL = Soil salinity; WE = Soil erodibility to wind; SSP = Potential for soil to shrink or swell from drying or wetting; and SAR = Soil sodicity. Percent of ERU in each soil property indicator, when summed across a row [that is, across the 13 individual or combination soil property indicator(s)], will be less than or equal to the percent of ERU in the climate (precipitation zone) indicator.

[3]T = Trace; less than or equal to 0.50%.

[4] - = Not Applicable. Soil map units that contained 75 percent or greater areal extent of soils characterized by individual or combination soil property indicator(s) did not exist in this ERU in the precipitation zone associated with the susceptibility rating.

[5]Climate (precipitation) data for the Snake Headwaters ERU were not available for approximately 2 percent of the ERU. Some of the lands without available precipitation data included soil map units that were characterized by soil erodibility to wind (approximately 1 percent of the ERU).

[6] In the All Lands ownership category, the percent of ERU found in the 3 climate (precipitation) zones should sum to 100, with only slight deviations due to rounding error.

Map 3.18—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to wind. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils that are characterized by wind erodibility Groups 1 through 3; none of the other four, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Map 3.19—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with potential for soil to shrink or swell from drying or wetting, and soil erodibility to wind. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having these specific soil-property indicators: a high shrink-swell potential (SSP), and wind erodibility Groups 1 through 3; none of the other three, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Map 3.20—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with potential for soil to shrink or swell from drying or wetting. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having a high shrink-swell potential (SSP); none of the other four, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Map 3.21—Headwater and downstream general landforms. This map shows the dominant landforms for subwatersheds that lie at headwaters, or are in down-river or downstream locations within the Basin. Headwater and mountainous subwatersheds are often less vulnerable to the detrimental effects associated with the spread of exotic biota and anthropogenic-induced erosion. In contrast, they are often more vulnerable to upslope spread of wildfire.

Substantial changes in fire regimes occurred in the Blue Mountains ERU as a result of fire exclusion, timber harvest practices, and the invasion of annual grasses in the dry shrub and dry grass PVGs (maps 3.22 and 3.23) Fire severity generally shifted from non-lethal and mixed, to lethal in the forest PVGs due to longer fire intervals and harvest activities, which did not simulate the composition and structure of the native systems. In the non-forest (rangeland) PVGs, fire severity generally shifted from non-lethal to lethal, and intervals between fires increased due to fire exclusion, closure of shrub canopies, and conifer encroachment.

From a regional-scale perspective, although the Blue Mountains ERU has a negligible amount of area that received less than 30 centimeters of annual precipitation (map 3.24), drought years were documented 12 percent of the time between 1895 and 1994 (table 3.38; climate division: Oregon Northeast). This level of drought is less than other ERUs that have higher arid, non-forest PVG dominance. Consequently, most of the non-forest PVGs that have been affected by the invasion of exotics or by excessive livestock grazing pressure have a fairly high potential for restoration. However, at the landscape scale 16 percent of the area consists of steep break and valley landforms with southerly exposures and microclimates that are conducive to droughts.

There has been a long history of livestock grazing on public lands in the Blue Mountains ERU (map 3.25). Most of the public land has been grazed since the 1860s (Skovlin and Thomas 1995). Improvements in range conditions and associated watershed conditions has occurred since the mid-1900s. However, native vegetation diversity in the non-forest PVGs and the dry forest PVG, which together composed 82 percent of the BLM/FS lands, has been threatened by the invasion of annual grasses and other exotic plants. Cheatgrass, medusahead (*Taeniatherum caput-medusae*), and yellow starthistle (*Centaurea solstitialis*), for example, were three problematic exotic plant species in the Blue Mountains ERU. Approximately 32 and 6 percent of the BLM/FS lands were highly susceptible to invasion by cheatgrass and yellow starthistle, respectively. Roughly 34 and 22 percent of All lands in the Blue Mountains ERU were of high susceptibility to invasion by cheatgrass and yellow starthistle, respectively (table 3.47; maps 3.26 and 3.27). In addition, the prevalence of soils that will shrink or swell from drying or wetting (maps 3.19 and 3.20) enhance the establishment of medusahead, because medusahead shows an affinity for soils with a high clay content.

Road densities in the Blue Mountains ERU are relatively high (map 3.28). At the regional scale, the high road densities typically occur on watersheds with higher sensitivity to disruption of the hydrologic regime (map 3.29). Relative to non-forest watersheds, forested watersheds are generally steeper with less developed soils, and hence are more susceptible to erosion and sediment transport via road networks. Where forested watersheds have been developed for timber harvest, road densities are commonly high. Roads in forested watersheds are typically surfaced with gravel or native materials that are susceptible to sediment transport. Annual grading of these roads maintains a high component of fine material on the road surface, and grades materials into the ditches. Due to continual disturbance, ditches commonly do not develop a vegetation cover capable of filtering sediment.

The ownership pattern of BLM/FS and Other lands is relatively fragmented in the Blue Mountains ERU (map 3.30, see glossary for description of land ownership classes). Only the inner core of mountain ridges contain uniform BLM/FS land ownership. Most of the area is mixed, or a mosaic of BLM/FS and Other land ownerships interspersed with uniform BLM/FS ownerships. Much of the BLM/FS lands have high or moderate risk of fire occurrence and associated high-intensity wildfires that would be difficult to suppress (map 3.31). The risk is related to high wildfire occurrence

from both lightning and human-caused ignitions, generally dry summer and fall conditions, and a large component of woody fuels that create the potential for severe fire behavior. The high rate of human-caused fires has generally been associated with high recreational use in areas of higher road densities.

The Blue Mountains ERU also has a substantial component of forests with high fuel accumulations, and higher potential for crown fires, forest insects, diseases, and stress-related mortalities (map 3.32). These forests have an inherently higher rate of NPP, high potentials for carbon and water stress, and witnessed historical timber harvest practices that removed most of the large, stress-resistant, shade-intolerant trees. These large, shade-intolerant trees have generally been replaced by smaller, shade-tolerant tree species that are more susceptible to the above-mentioned mortality agents.

There are substantial fire risks related to the rural/wildland interface on BLM/FS lands (map 3.33). At the landscape scale, high-risk areas often occur at the edge of the steep foothill and break environments. Rural developments are typically associated with the bench landforms that are on the edge of, or interspersed with, the steep, complex topography of the lower foothill and break landforms. The lower foothill and break landforms typically occur on the BLM/FS lands.

The composition of PVGs changed substantially between the historical and current periods in the Blue Mountains ERU, primarily as a result of agricultural and urban development (maps 3.11 and 3.12). We compared the historical PVG composition to the current period PVG composition for BLM/FS, Other, and All land ownerships (table 3.48). Across All ownerships, the historical and current compositions were dominated by the dry forest PVG (47 and 46%, respectively), with fairly even amounts of moist forest, cold forest, dry shrub, and cool shrub PVGs. The historical dry grass PVG areal extent was twice that of the current period on All lands. A substantial amount of the ERU (18%) had been developed for agricultural use. Most agricultural lands were converted from the dry grass, dry shrub, and cool shrub PVGs, with a minor amount from the dry forest PVG. Approximately 2.8 percent of the Blue Mountains ERU was converted to roads.

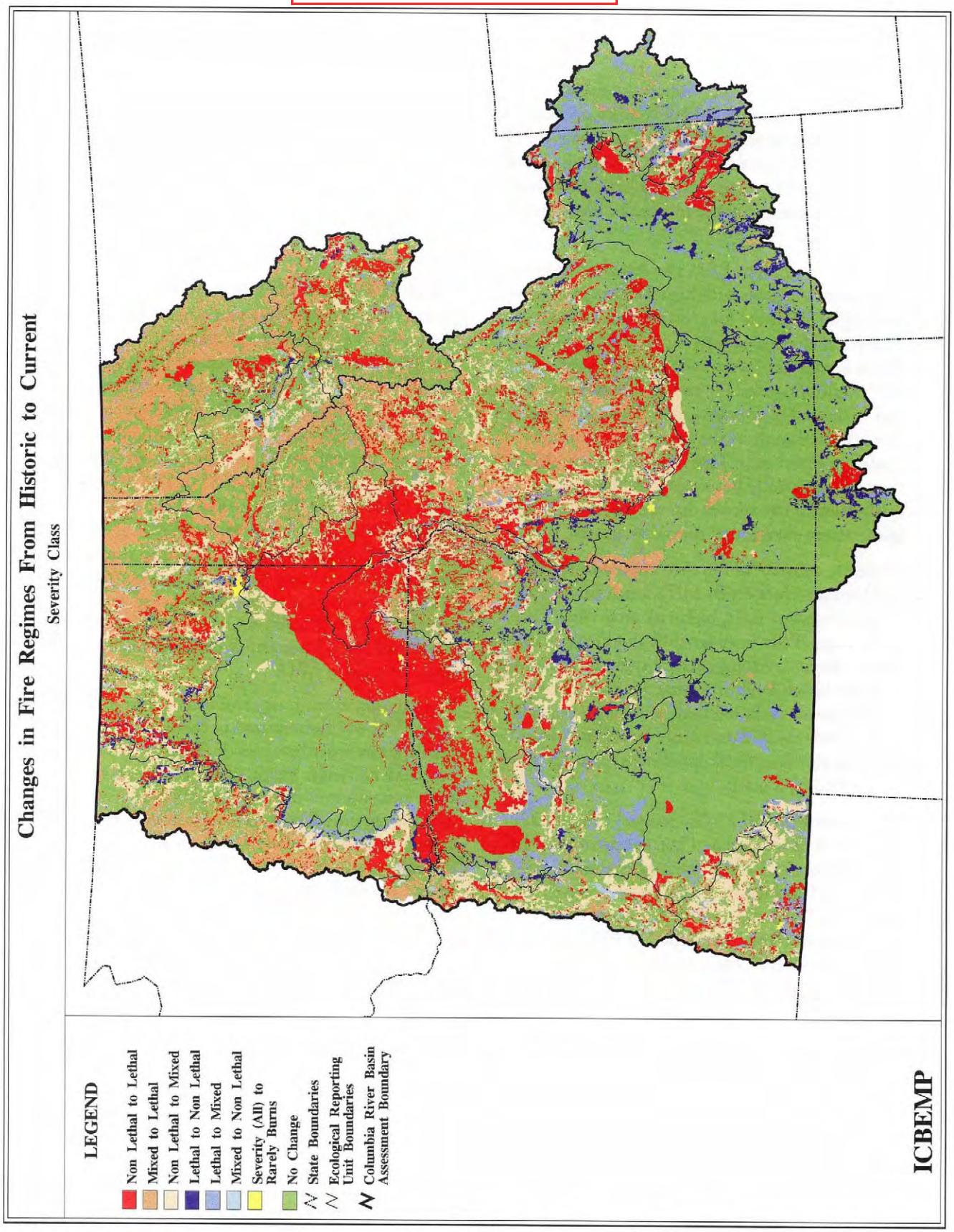
For BLM/FS lands, the historical and current period compositions were also dominated by the dry forest PVG (31%), with even amounts of moist forest, cold forest, dry grass, dry shrub, and cool shrub PVGs (4-5% each). During the current period, BLM/FS roads constituted 1.6 percent of the Blue Mountains ERU. For Other land ownerships, the current period composition was dominated by agricultural lands (18%). The dry forest PVG made up a substantial area of the Other ownerships (16 and 15% for the historical and current periods, respectively). The areal extent of the dry shrub and cool shrub PVGs declined by nearly 50 percent between the historical and current periods. Roads on Other land ownerships accounted for 1.3 percent of the land area in the Blue Mountains ERU.

The physiognomic type composition of the dry grass PVG was summarized in table 3.49. Exotic herblands were furthest outside the HRV, especially on BLM/FS lands. Exotic plants that were especially invasive into the dry grass PVG within the Blue Mountains ERU included yellow starthistle and cheatgrass. As with all PVGs and all ERUs, the areal extent of exotic herblands in the current period was underestimated, particularly on Other lands. Most other physiognomic types in the current dry grass PVG had areas that were within or close to the simulated HRV. However, woodland development in the current period appeared to be below the HRV on BLM/FS ownerships, and above the HRV on Other ownerships.

Continue

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Map 3.22—Changes in fire regime severity class from the historical to the current period. Fire severity classes include (1) the lethal regimes, which remove (cycle) the upper vegetation layer, (2) the non-lethal regimes, which maintain the vegetation structure, and (3) the mixed regimes, which are a fine-scale mosaic of lethal and non-lethal. Fire severity class changes were used as indicators for ecological integrity, landscape patterns, and succession/disturbance regimes.

Map 3.23—Changes in fire regime frequency class from the historical to the current period. A change to a less-frequent fire class in forests infers higher levels of fuel accumulation and is usually caused by fire exclusion. A change to a less-frequent fire class in rangelands is often caused by grazing of fine fuels and fire exclusion. Fire frequency class changes were used as indicators for ecological integrity, landscape patterns, and succession/disturbance regimes.

Map 3.24—Annual average precipitation in the Basin, from PRISM data, showing areas (typically rangelands) that receive various increments of precipitation less than 12 inches (<305 mm) and areas that receive greater than 12 inches (>305 mm). Precipitation data were used in the development of the maps showing susceptibility status of the Basin to invasion by exotic plants, and the rangeland health susceptibility to management-induced disturbance stresses.

Map 3.25—The extent of grazing allotments on most public (BLM/FS, State, and other Federal) lands in the Basin. Grazing allotment distributions and associated information were used as a general indicator of potential for excessive livestock grazing pressure effects during the early historical period and subsequent trends in the recent historical and current periods.

Table. 3.47—Percent of each Ecological Reporting Unit (ERU) in the context of All land ownerships, and percent of BLM/FS land ownerships in each ERU, which are contained within the high, moderate, low, and none susceptibility to invasion categories (that is, for five problematic exotic plants within the Basin). Percentages in the high, moderate, and low susceptibility to invasion categories are derived from a Susceptibility to Invasion Index of 38 broad-scale cover types in the Basin (see table 3.174) that lie within the known precipitation range of the exotic plant species. Percentages in the none susceptibility category represent lands that (1) lie outside the known precipitation range of the exotic plant species, (2) are cover types with unknown susceptibility, or (3) are cover types not included in this analysis (that is, the barren, water, and urban cover types).

ERU	Susceptibility to Invasion Category			
	High	Moderate	Low	None
	All / BLM-FS	All / BLM-FS	All / BLM-FS	All / BLM-FS
			Cheatgrass	
Blue Mountains	33.9 / 32.0	25.1 / 8.6	NA[1] / NA	41.0 / 59.4
Central Idaho Mountains	20.9 / 19.4	9.2 / 4.3	0.1 / 0.1	69.8 / 76.2
Columbia Plateau	34.3 / 44.9	50.0 / 32.5	T[2] / T	15.7 / 22.6
Lower Clark Fork	2.8 / 0.9	1.5 / 0.1	NA / NA	95.7 / 99.0
Northern Cascades	11.8 / 5.2	7.3 / 0.7	T / T	80.9 / 94.1
Northern Glaciated Mountains	17.6 / 3.3	16.1 / 3.9	0.1 / 0.1	66.2 / 92.7
Northern Great Basin	64.1 / 66.4	22.7 / 19.6	NA / NA	13.2 / 14.0
Owyhee Uplands	66.7 / 73.0	28.6 / 17.8	T / T	4.7 / 9.2
Snake Headwaters	10.3 / 5.7	14.4 / 3.5	NA / NA	75.3 / 90.8
Southern Cascades	20.1 / 18.2	13.1 / 7.7	T / T	66.9 / 74.1
Upper Clark Fork	26.6 / 12.3	16.9 / 4.0	NA / NA	56.5 / 83.7
Upper Klamath	28.3 / 26.0	16.2 / 11.0	NA / NA	55.6 / 63.0
Upper Snake	46.3 / 75.3	44.9 / 10.5	T / T	8.8 / 14.2
			Diffuse Knapweed	
Blue Mountains	24.0 / 24.7	63.8 / 52.8	0.6 / 1.0	11.6 / 21.5
Central Idaho Mountains	17.7 / 16.8	47.0 / 40.3	2.7 / 2.8	32.6 / 40.1
Columbia Plateau	13.2 / 19.7	82.2 / 72.8	T / 0.1	4.6 / 7.5
Lower Clark Fork	6.8 / 2.6	23.6 / 12.6	T / T	69.6 / 84.8
Northern Cascades	17.9 / 11.0	32.3 / 23.0	0.1 / 0.2	50.1 / 65.8
Northern Glaciated Mountains	15.2 / 3.4	49.1 / 33.6	0.1 / 0.2	35.5 / 62.8
Northern Great Basin	6.8 / 6.5	79.6 / 77.4	10.5 / 11.3	3.1 / 4.8
Owyhee Uplands	4.5 / 4.6	90.7 / 84.8	4.3 / 5.5	0.6 / 5.1
Snake Headwaters	6.1 / 3.6	60.9 / 56.9	T / T	33.2 / 39.6

Table. 3.47 (continued).

ERU	Susceptibility to Invasion Category			
	High	Moderate	Low	None
	All / BLM-FS	All / BLM-FS	All / BLM-FS	All / BLM-FS
		Diffuse Knapweed cont'd		
Southern Cascades	23.3 / 20.8	35.2 / 26.0	T / 0.1	43.1 / 53.2
Upper Clark Fork	22.2 / 12.5	55.5 / 50.7	T / 0.1	22.4 / 36.6
Upper Klamath	37.5 / 36.3	45.5 / 44.7	0.3 / 0.6	17.1 / 18.4
Upper Snake	8.3 / 10.1	90.9 / 85.6	0.5 / 0.7	0.4 / 3.6
		Leafy Spurge		
Blue Mountains	23.7 / 6.9	75.3 / 90.8	0.6 / 1.0	0.4 / 1.3
Central Idaho Mountains	13.5 / 7.8	81.5 / 84.2	4.2 / 5.0	0.8 / 3.0
Columbia Plateau	49.2 / 3.4	49.9 / 96.6	T / 0.1	0.9 / T
Lower Clark Fork	3.9 / 0.1	94.0 / 95.9	0.1 / 0.1	2.0 / 3.9
Northern Cascades	8.2 / 2.2	76.5 / 76.7	9.7 / 14.6	5.5 / 6.5
Northern Glaciated Mountains	13.1 / 0.4	82.7 / 95.0	1.5 / 2.5	2.7 / 2.1
Northern Great Basin	3.2 / 0.5	94.3 / 95.4	0.2 / 0.2	2.2 / 3.9
Owyhee Uplands	14.5 / 2.5	85.1 / 92.6	0.1 / 0.1	0.3 / 4.8
Snake Headwaters	14.3 / 3.1	81.6 / 91.8	1.5 / 1.1	2.5 / 4.0
Southern Cascades	6.8 / 0.9	86.1 / 92.9	1.1 / 1.9	6.0 / 4.3
Upper Clark Fork	12.9 / 1.5	82.2 / 89.7	0.5 / 0.8	4.4 / 8.0
Upper Klamath	7.6 / 1.0	86.0 / 95.7	0.8 / 1.4	5.6 / 1.9
Upper Snake	39.5 / 5.6	60.4 / 91.0	T / 0.1	T / 3.3
		Spotted Knapweed		
Blue Mountains	48.1 / 35.1	28.4 / 29.4	T / T	23.4 / 35.5
Central Idaho Mountains	22.2 / 16.8	23.2 / 23.4	1.2 / 1.5	53.3 / 58.3
Columbia Plateau	35.4 / 19.0	14.2 / 30.3	T / T	50.5 / 50.7
Lower Clark Fork	9.9 / 3.1	8.8 / 3.9	NA / NA	81.3 / 93.0
Northern Cascades	26.8 / 15.4	7.8 / 5.4	T / T	65.3 / 79.2
Northern Glaciated Mountains	33.1 / 6.8	16.3 / 13.4	0.1 / 0.2	50.5 / 79.6
Northern Great Basin	9.6 / 8.3	40.5 / 42.8	3.1 / 3.4	46.8 / 45.5
Owyhee Uplands	5.5 / 3.6	38.2 / 39.1	1.3 / 1.6	55.0 / 55.7
Snake Headwaters	30.6 / 18.4	21.3 / 20.9	T / T	48.1 / 60.7

Table. 3.47 (continued).

ERU	Susceptibility to Invasion Category			
	High	Moderate	Low	None
	All / BLM-FS	All / BLM-FS	All / BLM-FS	All / BLM-FS
		Spotted Knapweed cont'd		
Southern Cascades	32.9 / 23.7	11.4 / 12.2	T / 0.1	55.7 / 64.0
Upper Clark Fork	38.9 / 19.4	27.1 / 28.9	NA / NA	34.1 / 51.7
Upper Klamath	56.4 / 52.6	17.3 / 19.7	T / T	26.2 / 27.7
Upper Snake	25.2 / 9.2	26.1 / 34.9	0.1 / 0.1	48.7 / 55.8
		Yellow Starthistle		
Blue Mountains	21.9 / 6.1	42.1 / 41.3	T / T	35.9 / 52.6
Central Idaho Mountains	11.4 / 7.1	22.0 / 21.2	0.3 / 0.4	66.3 / 71.3
Columbia Plateau	26.6 / 1.9	18.6 / 42.8	T / T	54.8 / 55.3
Lower Clark Fork	1.5 / T	6.7 / 2.4	NA / NA	91.8 / 97.6
Northern Cascades	5.2 / 1.0	17.9 / 9.5	T / T	76.9 / 89.5
Northern Glaciated Mountains	10.7 / 0.2	27.0 / 10.3	0.1 / 0.2	62.2 / 89.3
Northern Great Basin	2.5 / 1.8	45.4 / 47.4	3.1 / 3.4	49.0 / 47.4
Owyhee Uplands	6.2 / 3.9	38.2 / 39.6	1.2 / 1.6	54.4 / 54.9
Snake Headwaters	14.5 / 2.8	21.6 / 17.4	NA / NA	63.9 / 79.8
Southern Cascades	5.6 / 0.2	31.3 / 29.7	T / 0.1	63.1 / 70.0
Upper Clark Fork	14.0 / 1.8	38.5 / 27.3	NA / NA	47.6 / 70.9
Upper Klamath	6.5 / 0.9	51.9 / 55.6	T / T	41.6 / 43.5
Upper Snake	28.7 / 14.0	19.9 / 26.6	0.1 / 0.1	51.3 / 59.3

[1]NA = Not Applicable; no lands in this susceptibility category were detected at the broadscale.

[2]T = Trace amount < 0.05 percent.

Note: The percent of each ERU, when summed by susceptibility category, should total 100 percent for All land ownerships and should total 100 percent for BLM- and FS-administered lands.

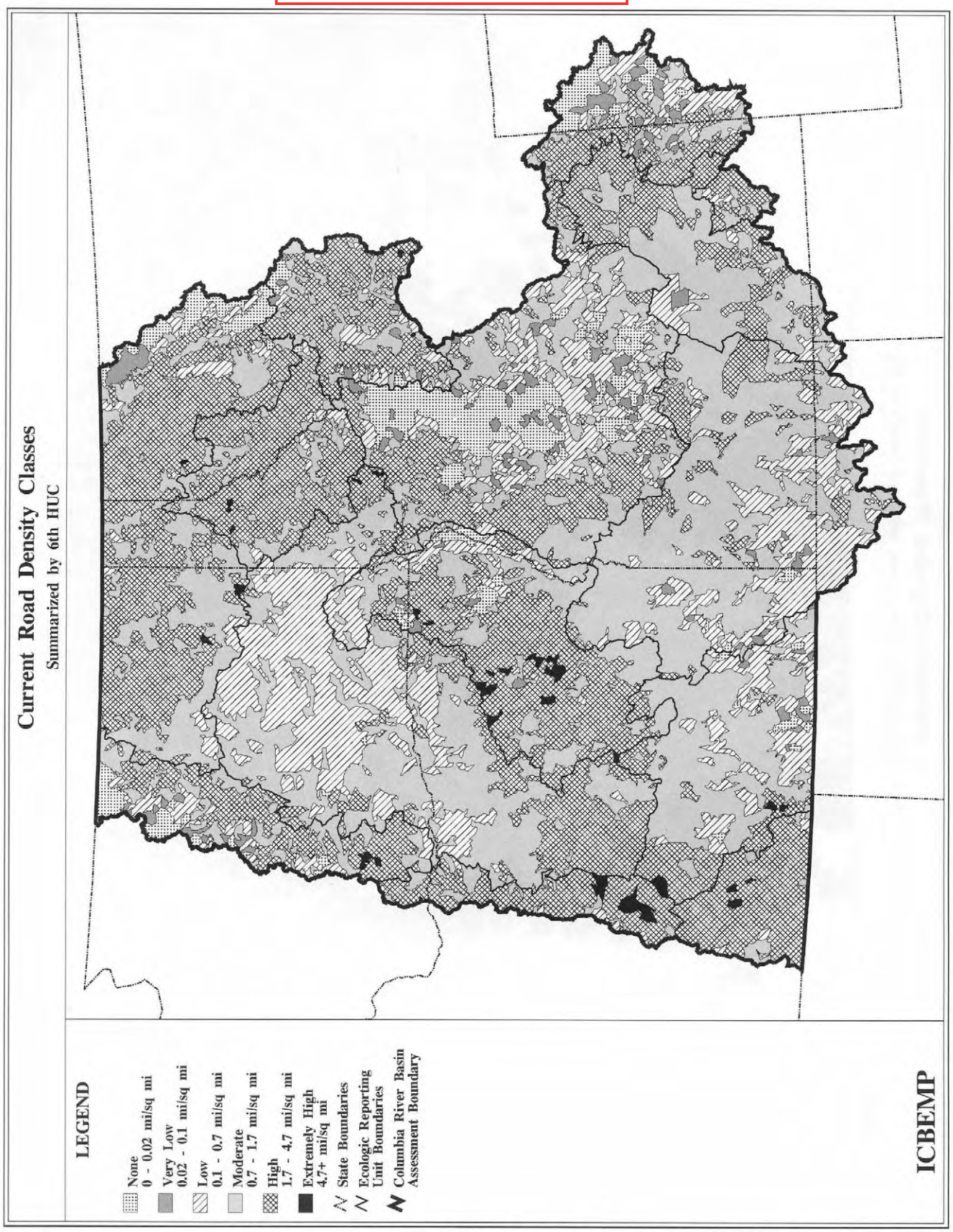
Map 3.26—Susceptibility status of the Basin to invasion by cheatgrass, an exotic annual grass. Each shaded area (that is, susceptibility category) represents a grouping of cover types that were rated the same for susceptibility, and lie within the precipitation range (150-560 mm) of cheatgrass. Susceptibility ratings originate from the Susceptibility to Invasion Index.

Map 3.27—Susceptibility status of the Basin to invasion by yellow starthistle, an exotic annual forb. Each shaded area (that is, susceptibility category) represents a grouping of cover types that were rated the same for susceptibility, and lie within the precipitation range (300-635 mm) of yellow starthistle. Susceptibility ratings originate from the Susceptibility to Invasion Index.

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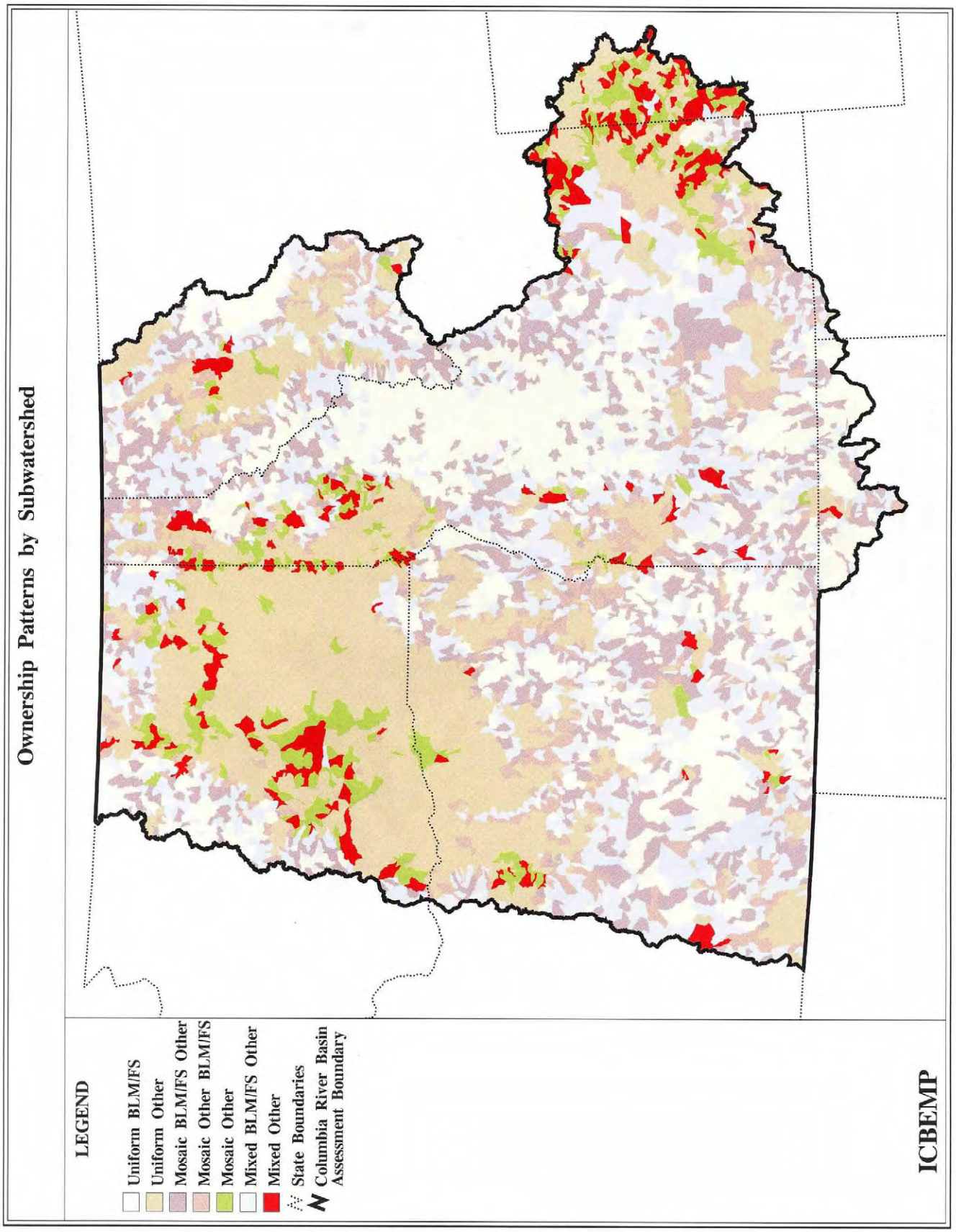
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Map 3.28—Current road density classes summarized by subwatershed (6th field hydrologic unit codes). Data used to formulate these classes was statistically extrapolated from sampled subwatershed road data. Because of the coarse scale of the data and the limited area that was sampled, this extrapolation is only applicable for broad-scale trends, subbasin summaries, or coarser analyses.

Map 3.29—Potentially degraded watersheds in the Basin. This map illustrates the relative hydrologic sensitivity of watersheds to acute, moderate, and high severity disturbance effects (such as roads, fire, harvest, and associated erosion and sediment transport potentials) combined with high and very-high road densities. High and very-high road densities were used as correlates of severity of disturbance. This map does not reflect susceptibility to soil disturbance due to the lack of vegetation cover or cumulative severe effects from chronic, low-severity disturbance (such as excessive livestock grazing pressure).



Map 3.30—Land ownership patterns within the Basin by subwatershed (6th field hydrologic unit codes).

Map 3.31—Wildfire occurrence/intensity risk on BLM- and Forest Service-administered lands. Wildfire occurrence is based on recent (1980s) wildfire ignitions. Risk of intense fire events is based on the potential for high amounts of contiguous fuels. The combined relative index indicates areas with combined risks of intense wildfire.

Map 3.32—High potential fuels, crown fire, and insect and disease mortalities. This map is limited to the dry forest PVG because of high relative risk of contiguous fuels, wildfire ignitions, severe fire-weather conditions, stressed environments, and fuel ladders that exacerbate crown fire potential in these environments.

Map 3.33—Rural population/wildland interface fire risk areas on Forest Service- and BLM-administered lands. This map is a combination of (1) the wildfire occurrence/intensity risk (map 3.30), and (2) current period estimates of areas in the urban and rural/wildland interface. The combination is therefore, the risk of wildfire damage to dwellings.

Continue

Table 3.48—Historical and current potential vegetation groups (PVGs) for the Blue Mountains Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	18 / 39	0 / 0	18 / 18
Alpine	+[4]	+	0 / 0	0 / 0	+	+
Cold Forest	4 / 7	4 / 7	+	+	4 / 4	4 / 4
Cool Shrub	4 / 7	4 / 7	8 / 17	4 / 9	12 / 12	8 / 8
Dry Forest	31 / 57	31 / 57	16 / 33	15 / 33	47 / 16	46 / 46
Dry Grass	5 / 9	5 / 9	13 / 24	4 / 9	18 / 18	9 / 9
Dry Shrub	4 / 7	4 / 7	8 / 17	4 / 9	12 / 12	8 / 8
Moist Forest	5 / 9	5 / 9	1 / 2	1 / 2	6 / 6	6 / 6
Riparian Shrub	+	+	2 / 4	+	2 / 2	+
Riparian Woodland	+	+	+	0 / 0	+	+
Road	NA[5] / NA	1.6 / NA	NA	1.3 / NA	NA	2.8 / NA
Rock	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Urban	0 / 0	0 / 0	0 / 0	+	0 / 0	+
Water	+	+	+	+	+	+
Woodland	1 / 2	1 / 2	+	+	1 / 1	1/1
Total[6]	54 / 98	54 / 98	48 / 100	46 / 101	102 / 101	100 / 100

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes. Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes.
For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

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Table 3.49—Current and historical physiognomic types for the dry grass potential vegetation group (PVG) for Blue Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Woodland	2	2	2	2
	Exotic Herbland	15	0	0	0
	Late-seral Multi-layer Woodland	3	21	30	26
	Mid-seral Woodland	3	9	8	7
	Upland Herbland	77	68	60	65
Other	Early-seral Woodland	2	+[3]	1	1
	Exotic Herbland	1	0	0	0
	Late-seral Multi-layer Woodland	11	1	5	7
	Mid-seral Woodland	5	+	5	4
	Upland Herbland	82	99	89	88
All	Early-seral Woodland	2	1	2	1
	Exotic Herbland	9	0	0	0
	Late-seral Multi-layer Woodland	6	6	12	12
	Mid-seral Woodland	3	3	6	5
	Upland Herbland	79	91	81	82

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Within the dry shrub PVG, exotic herblands were furthest outside the HRV, especially on BLM/FS lands (table 3.50). Several exotic plants were invasive into the dry shrub PVG within the Blue Mountains ERU, but cheatgrass, medusahead, and whitetop (*Cardaria draba*) were particularly extensive in land coverage. The upland herbland physiognomic type was substantially below the HRV on All ownerships, and especially within Other ownerships.

However, the historical area of the upland herbland physiognomic type on All ownerships may have been underestimated because of misclassification into the upland shrubland type. The areal extent of the upland shrubland type was generally higher than the HRV for All ownerships, primarily due to its extent in Other ownerships. The area of the upland shrubland on BLM/FS ownerships was at the upper end of the HRV. However, the historical area of the

Table 3.50—Current and historical period physiognomic types for the dry shrub potential vegetation group (PVG) for Blue Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Exotic Herbland	8	0	0	0
	Upland Herbland	5	4	42	46
	Upland Shrubland	87	96	58	55
Other	Exotic Herbland	0	0	0	0
	Upland Herbland	1	26	63	61
	Upland Shrubland	99	74	37	39
All	Exotic Herbland	4	0	0	0
	Upland Herbland	2	20	57	56
	Upland Shrubland	94	81	43	44

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

upland shrubland physiognomic type on All ownerships may have been overestimated, due to misclassification of upland herbland into upland shrubland.

The physiognomic type composition of the cool shrub PVG is summarized in table 3.51. Exotic herblands were far outside the HRV, especially on BLM/FS lands. Of the weeds we considered, cheatgrass, medusahead, and whitetop probably had the most extensive coverage within the cool shrub PVG of the Blue Mountains ERU. The area of the upland herbland physiognomic type was substantially lower than the HRV, the area of the upland shrubland physiognomic type was on the high end of the HRV, and the area of the early-seral woodland physiognomic type was substantially above the HRV for All ownerships. The abundance of the early-seral woodland was primarily due to the encroachment of conifers as a result of fire exclusion. Similar trends were detected for BLM/FS and Other land ownerships, although more substantial changes occurred on Other ownerships.

The physiognomic type composition of the dry forest PVG in the Blue Mountains ERU is summarized in tables 3.52 and 3.53. The amount of exotic herbland was substantially underestimated because of aerial photo or satellite image obstructions by forest overstory cover. Cheatgrass and yellow starthistle were problematic exotic plants in the dry forest PVG of this ERU, especially within the fescue-bunchgrass, interior ponderosa pine, and shrub or herb/tree regeneration cover types. Areal extent of the upland herbland and upland shrubland physiognomic types were generally less than the HRV on All ownerships. The areal extent of the early-seral forest physiognomic type was generally at the upper range of HRV, whereas the areal extent of the mid-seral forest physiognomic type was nearly double the HRV.

Table 3.51—Current and historical period physiognomic types for the cool shrub potential vegetation group (PVG) for Blue Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		..... Percent			
BLM/FS	Early-seral Woodland	6	3	1	2
	Exotic Herbland	4	0	0	0
	Late-seral Single-layer Woodland	0	+[3]	0	0
	Mid-seral Woodland	1	11	2	1
	Upland Herbland	8	10	54	54
	Upland Shrubland	81	77	42	43
Other	Early-seral Woodland	42	6	3	2
	Exotic Herbland	0	0	0	0
	Late-seral Single-layer Woodland	0	1	+	0
	Mid-seral Woodland	2	1	2	2
	Upland Herbland	0	12	47	48
	Upland Shrubland	56	80	48	48
All	Early-seral Woodland	25	5	2	2
	Exotic Herbland	2	0	0	0
	Late-seral Single-layer Woodland	0	+	+	0
	Mid-seral Woodland	1	4	2	2
	Upland Herbland	4	12	50	50
	Upland Shrubland	68	79	46	46

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.52—Current and historical period physiognomic types for the dry forest potential vegetation group (PVG) for Blue Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	21	15	16	7
	Exotic Herbland	+[3]	0	0	0
	Late-seral Multi-layer Forest	31	12	15	19
	Late-seral Single-layer Forest	1	36	47	54
	Mid-seral Forest	47	29	22	20
	Upland Herbland	+	7	+	0
	Upland Shrubland	0	2	+	0
Other	Early-seral Forest	25	28	34	10
	Exotic Herbland	0	0	0	0
	Late-seral Multi-layer Forest	9	6	7	10
	Late-seral Single-layer Forest	2	21	30	45
	Mid-seral Forest	65	15	29	35
	Upland Herbland	0	22	+	0
	Upland Shrubland	0	7	+	+
All	Early-seral Forest	23	20	22	8
	Exotic Herbland	+	0	0	0
	Late-seral Multi-layer Forest	23	10	13	16
	Late-seral Single-layer Forest	2	31	41	51
	Mid-seral Forest	53	24	24	25
	Upland Herbland	+	12	+	0
	Upland Shrubland	0	4	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.53—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Blue Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	19	14	14	6
	Early-seral Shade-tolerant Forest	3	1	2	2
	Exotic Herbland	+[3]	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	8	9	11	13
	Late-seral Shade-intolerant Single-layer Forest	1	35	45	52
	Late-seral Shade-tolerant Multi-layer Forest	22	3	4	5
	Late-seral Shade-tolerant Single-layer Forest	1	1	2	2
	Mid-seral Shade-intolerant Forest	25	24	15	12
	Mid-seral Shade-tolerant Forest	22	5	7	9
	Upland Herbland	+	7	+	0
	Upland Shrubland	0	2	+	0
Other	Early-seral Shade-intolerant Forest	24	28	32	8
	Early-seral Shade-tolerant Forest	+	+	2	2
	Exotic Herbland	0	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	5	5	6	7
	Late-seral Shade-intolerant Single-layer Forest	2	21	29	45
	Late-seral Shade-tolerant Multi-layer Forest	4	1	2	3
	Late-seral Shade-tolerant Single-layer Forest	+	+	+	1
	Mid-seral Shade-intolerant Forest	45	13	20	22
	Mid-seral Shade-tolerant Forest	19	2	9	13
	Upland Herbland	0	22	+	0
	Upland Shrubland	0	7	+	+
All	Early-seral Shade-intolerant Forest	21	19	20	6
	Early-seral Shade-tolerant Forest	2	1	2	2
	Exotic Herbland	+	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	7	8	9	11
	Late-seral Shade-intolerant Single-layer Forest	1	30	40	49
	Late-seral Shade-tolerant Multi-layer Forest	16	2	3	4
	Late-seral Shade-tolerant Single-layer Forest	1	1	1	2
	Mid-seral Shade-intolerant Forest	32	20	16	15
	Mid-seral Shade-tolerant Forest	21	4	8	10
	Upland Herbland	+	12	+	0
	Upland Shrubland	0	4	0	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

The late-seral single-layer forest type was almost nonexistent in the current period, whereas the late-seral multi-layer forest type was substantially above the HRV. These trends were similar for both BLM/FS and Other lands, although the late-seral multi-layer physiognomic type on Other lands was within the HRV. The cause of these trends was primarily due to the synergistic effect of fire exclusion and timber harvest practices.

Fire exclusion of lethal fires in the mid- and late-seral multi-layer physiognomic types resulted in an areal decline of the early-seral physiognomic type. Exclusion of fire permitted the succession of early-seral into mid-seral types. Fire exclusion also eliminated the non-lethal and mixed fires that maintained the late-seral single-layer physiognomic type, and thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer physiognomic types. Timber harvest practices selectively removed the larger, shade-intolerant tree species that were more resistant to insects, disease, and stress mortality. Clearcutting and seed-tree timber-harvest activities commonly created small early-seral patches that contained no dead-standing trees, no scattered live trees, and high down fuel accumulations. This combination of factors, combined with a climatic trend (commencing in the 1980s) that seemed to produce drier spring, summer, and fall periods, resulted in changed conditions and higher risks of wildfire.

Current period dry forests, dominated by shade-tolerant tree species, were generally two to four times the HRV (table 3.53). Conversely, the late-seral shade-intolerant multi-layer forests on BLM/FS lands were below the HRV.

The composition of physiognomic types within the moist forest PVG varied among ownership strata in the Blue Mountains ERU (table 3.54). Although the areal extent of the early-seral physiognomic type in the current period occurred above the HRV for All ownerships, it was substantially above the HRV for BLM/FS ownerships, and substantially below the HRV for Other ownerships. This apparent contradiction was due to the lack of even-age harvest treatments (that is, clearcut or seed tree) and wildfire on Other lands, whereas these disturbances had been extensive on BLM/FS lands. The areal extent of the mid-seral forest type was within the HRV on All land ownerships, well below the HRV on BLM/FS lands, and well above the HRV on Other ownerships. Evidently, selective timber harvests on Other ownerships converted a substantial proportion of the late-seral single-layer forest type into the mid-seral forest type. The area of late-seral single-layer forest type occurred within the HRV on All and BLM/FS ownerships, whereas it occurred well below the HRV on Other ownerships. The late-seral multi-layer forest type occurred within the HRV for all ownership strata.

The moist forest PVG, dominated by shade-tolerant tree species in the mid-seral types, was well above the HRV on All ownerships, primarily due to selective harvests of large, shade-intolerant trees on Other lands (table 3.55). Shade-tolerant species were well above the HRV in late-seral multi- and single-layer physiognomic types on All ownerships, which was most likely the result of fire exclusion.

In response to the changes in regional and landscape conditions on forest and rangelands in the Blue Mountains ERU, the succession/disturbance regimes shifted substantially from maintenance regimes to long-cycle and retrogressive regimes (see table 3.6 for a description of succession/disturbance regimes). Consequently, the effects associated with wildfire, timber harvest, and grazing tended to be more severe in the current period. Without restoration of landscape structure and fuel conditions, the probability of returning to the succession/disturbance regimes that existed historically (that is, in the native system) was determined to be low.

Table 3.54—Current and historical period physiognomic types for the moist forest potential vegetation group (PVG) for Blue Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	34	20	20	21
	Late-seral Multi-layer Forest	24	15	25	28
	Late-seral Single-layer Forest	14	24	16	11
	Mid-seral Forest	28	42	39	41
Other	Early-seral Forest	6	46	18	18
	Late-seral Multi-layer Forest	21	8	18	20
	Late-seral Single-layer Forest	4	26	20	16
	Mid-seral Forest	69	20	45	47
All	Early-seral Forest	29	24	19	20
	Late-seral Multi-layer Forest	23	14	24	26
	Late-seral Single-layer Forest	12	24	17	12
	Mid-seral Forest	35	38	40	42

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

Central Idaho Mountains ERU

The Central Idaho Mountains ERU has a high relief (300 to 3,700 m) complex of narrow valleys, breaks, and mountains (maps 3.3 and 3.17). Its topography is complex as a result of erosional processes and mountain glaciation. Landforms include a complex mix of foothills, breaks, mountains, and narrow valleys, with varied combinations of headwater and downstream subwatersheds (map 3.21). The ERU primarily occurs within ecoregion sections M332A, M332F, M332E, and M332G (map 3.1).

Precipitation averaged 68 centimeters per year within the Central Idaho Mountains ERU (range = 25 to 105 cm). The steep gradient in precipitation combined with the complex topography has resulted in very diverse vegetation in the Central Idaho Mountains ERU. Climate is strongly influenced by both oceanic storms from the west and the continental climates to the east. The rain-shadow effect of the Seven Devils Mountains to the west strongly affects this ERU. Precipitation primarily comes in the form of winter snows or spring rains. There is a moderately steep gradient from relatively moist spring conditions, to dry summer and fall conditions with a moderately long growing season. The moisture gradient results in vegetation and disturbance regimes that have high environmental diversity and dynamic biogeochemical energy relationships.

Table 3.55—Current and historical period moist forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Blue Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	26	18	16	17
	Early-seral Shade-tolerant Forest	8	2	4	4
	Late-seral Shade-intolerant Multi-layer Forest	6	10	12	13
	Late-seral Shade-intolerant Single-layer Forest	3	23	15	10
	Late-seral Shade-tolerant Multi-layer Forest	18	5	13	15
	Late-seral Shade-tolerant Single-layer Forest	11	1	1	1
	Mid-seral Shade-intolerant Forest	12	27	27	28
	Mid-seral Shade-tolerant Forest	16	14	13	13
Other	Early-seral Shade-intolerant Forest	5	46	15	15
	Early-seral Shade-tolerant Forest	1	0	3	2
	Late-seral Shade-intolerant Multi-layer Forest	2	6	8	8
	Late-seral Shade-intolerant Single-layer Forest	1	26	19	15
	Late-seral Shade-tolerant Multi-layer Forest	19	3	10	11
	Late-seral Shade-tolerant Single-layer Forest	3	0	1	1
	Mid-seral Shade-intolerant Forest	4	15	36	38
	Mid-seral Shade-tolerant Forest	66	5	8	9
All	Early-seral Shade-intolerant Forest	22	23	16	17
	Early-seral Shade-tolerant Forest	7	1	4	4
	Late-seral Shade-intolerant Multi-layer Forest	5	10	11	12
	Late-seral Shade-intolerant Single-layer Forest	3	24	16	11
	Late-seral Shade-tolerant Multi-layer Forest	18	4	13	14
	Late-seral Shade-tolerant Single-layer Forest	10	+[3]	1	1
	Mid-seral Shade-intolerant Forest	11	25	28	30
	Mid-seral Shade-tolerant Forest	25	13	12	12

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Consequently, the Central Idaho Mountains ERU has moderately high rates of inherent NPP and nutrient cycling, with associated moderate carbon and water stresses in upland areas.

There have been substantial changes in the Central Idaho Mountains ERU fire regimes primarily as a result of fire exclusion (maps 3.22 and 3.23). Fire severity generally shifted from non-lethal or mixed to lethal, and non-lethal to mixed in the forest PVGs. This shift was caused by longer fire-return intervals. In the non-forest PVGs, fire severity generally shifted from mixed to lethal, and fire intervals increased due to fire exclusion, the removal of fine fuels by livestock grazing, and conifer encroachment.

From a regional-scale perspective, although the Central Idaho Mountains ERU has little area that receives less than 30 centimeters of annual precipitation (map 3.24), 15 percent of the years between 1895 and 1994 were drought years (table 3.38; climate division: Idaho Central Mountains). This level of drought frequency was nearly indistinguishable from other ERUs that are more dominated by arid, non-forest PVGs. Consequently, although the Central Idaho Mountains ERU received more precipitation in the fall-winter period compared with the ERUs dominated by arid, non-forest PVGs (45 cm; table 3.38), drought frequently affected both the forested and non-forested PVGs. At the landscape scale, the break landforms have a high component of areas that are steep with southerly exposures. These areas have high drought risks. Many of the steep breaklands are in nearly pristine condition at present because they are relatively inaccessible. Consequently, the steep breaklands may provide reference condition of native, or near-native, vegetation composition of grasslands and shrublands.

There has been a long history of livestock grazing of public lands along the outer perimeter of the Central Idaho Mountains ERU, but little livestock grazing has taken place in the central part of the ERU that became wilderness (map 3.25). Since the late-1800s, sheep and cattle have grazed on allotments on much of the public-ownership land. Improvements in range conditions and associated watershed conditions have occurred since the mid-1900s. However, the recovery process has been slowed to some degree because soils that are susceptible to erosion by wind are prevalent in this ERU (maps 3.18 and 3.34). In addition, slow recovery rates were evident in many of the high-elevation sheep allotments that lost soil cover and were subjected to extensive erosion. During the current period, many of these areas were dominated by early-seral forbs such as alpine knotweed (*Polygonum phytolaccifolium*), which provided very poor soil cover and had low productivity. Even though many of these allotments have been closed or have had their stocking rates substantially reduced, there are areas where soil cover or dominance by later-seral native species have not recovered. The non-forest and dry forest PVGs in the southwest and southeast portions of the Central Idaho Mountains ERU are particularly susceptible to invasion by exotic plants, particularly spotted knapweed and leafy spurge. In addition, the Selway-Bitterroot Wilderness in the northeast portion of this ERU currently has extensive infestations of spotted knapweed. In the current period, approximately 17 and 8 percent of the BLM/FS lands were of high susceptibility to invasion by spotted knapweed and leafy spurge, respectively. Similarly, approximately 22 and 14 percent of All lands in this ERU were of high susceptibility to invasion by spotted knapweed and leafy spurge, respectively (table 3.47; maps 3.35 and 3.36). Rangeland riparian areas, although commonly highly altered, have been recovering relatively quickly as a result of improved riparian management strategies.

In general, roads are virtually absent from the central portion of the ERU, but moderate to high road densities dominated the periphery of the ERU (map 3.28). Much of the Central Idaho Mountains ERU had sensitive watersheds because of the steep topography and highly-erosive granitic soils. Some of the sensitive subwatersheds on the outer edges of the ERU were affected by moderate to high road densities (map 3.29).

Map 3.34—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil salinity and soil erodibility to wind. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having these specific soil-property indicators: salinity of 8 to 16 millihmos per centimeter (mmhos/cm), and wind erodibility Groups 1 through 3; none of the other three, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Map 3.35—Susceptibility status of the Basin to invasion by spotted knapweed, an exotic biennial-perennial forb. Each shaded area (that is, susceptibility category) represents a grouping of cover types that were rated the same for susceptibility, and lie within the precipitation range (300-760 mm) of spotted knapweed. Susceptibility ratings originate from the Susceptibility to Invasion Index.

Map 3.36—Susceptibility status of the Basin to invasion by leafy spurge, an exotic perennial forb. Each shaded area (that is, susceptibility category) represents a grouping of cover types that were rated the same for susceptibility. Susceptibility ratings originate from the Susceptibility to Invasion Index.

The pattern of BLM/FS and Other land ownerships is relatively contiguous, occurring in large, unfragmented blocks in the Central Idaho Mountains ERU (map 3.30). Only the outer portions of the ERU have mixed BLM/FS and Other ownerships. Much of the BLM/FS lands have a moderate risk of fire occurrence and high-intensity wildfires, which would be difficult to suppress (map 3.31). Some of the area, particularly the break and narrow valley landforms, have high fire risks. Moderate and high fire risks have primarily been attributed to high wildfire occurrence from lightning ignition; dry summer and fall conditions; very complex and steep terrain; and a mosaic of woody and grass fuels that create the potential for severe fire behavior.

The outer periphery of the Central Idaho Mountains ERU is largely composed of dry forests that have high carbon and water stress, high fuel accumulations, and high potential for crown fires, forest insects, diseases, and stress-related mortalities (map 3.32). Historical timber-harvest practices often removed most of the large, shade-intolerant trees that are generally more resistant to these mortality agents. These large, shade-intolerant trees have largely been replaced by smaller, shade-tolerant tree species that are more susceptible to these types of mortality. We detected moderate fire risks within the rural/wildland interface on BLM/FS lands adjacent to other ownerships (map 3.33). Large wildfires or prescribed natural fires that have burned in the core of the ERU (which is mostly wilderness) have, on occasion, expanded out into the periphery of the ERU, particularly when late summer or early fall wind events occurred. If the fire fronts were sufficiently large, these fires became uncontainable. At the landscape scale, the high-risk areas often occur at the edge of the steep breakland environments. Rural developments are also typically associated with the bench or narrow valley landforms that lie on the edge of, or are interspersed within, the steep, complex topography of the break landforms. The break landforms typically occur on BLM/FS lands.

The PVG composition did not change substantially from the historical to the current period in the Central Idaho Mountains ERU (table 3.56, maps 3.11 and 3.12). Only 6 percent of the area was converted to agriculture, and a lesser amount to urban developments. Agricultural and urban development occurred primarily in the cool shrub, dry shrub, and dry grass PVGs. Across All current period ownerships, dry forest and cold forest PVGs dominated the ERU (27 and 25%, respectively), with lesser amounts of moist forest, cool shrub, dry shrub, and dry grass PVGs (16, 8, 8, and 7%, respectively). Approximately 1.5 percent of the ERU was converted into roads.

The PVG composition of BLM/FS lands was very similar to the composition of the ERU as a whole. For Other land ownerships, the current period composition was dominated by the agricultural and dry forest PVGs (6% and 5%, respectively).

The composition of physiognomic types within the dry grass PVG did not change substantially across ownership strata in the Central Idaho Mountains ERU (table 3.57). Not surprisingly, the areal extent of exotic herblands were far outside the HRV because this type was not present in the native system. However, the areal extent of exotic herbland was underestimated for the current period, especially on BLM/FS lands. The upland herbland physiognomic type was at the upper limit or above the HRV for all ownership strata. The woodland types did not occur across a substantial proportion of the dry grass PVG during the current period, although they were more common within the historical system (approximately 30%). However, the mid-scale assessment (Hessburg and others 1996a) did detect a measurable amount of conifer encroachment within the dry grass PVG in the Central Idaho Mountains ERU. These physiognomic types in the dry grass PVG normally occurred in relatively small patches, and consequently, were probably not detectable by broad-scale remote sensing.

In the dry shrub PVG of the Central Idaho Mountains ERU, the composition of physiognomic types did not vary across ownership strata.

Table 3.56—Historical and current period potential vegetation groups (PVGs) for the Central Idaho Mountains Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	6 / 37	0 / 0	6 / 6
Alpine	+[4]	+	0 / 0	0 / 0	+	+
Cold Forest	25 / 30	25 / 30	+	+	25 / 25	25 / 25
Cool Shrub	7 / 8	7 / 8	3 / 19	1 / 6	10 / 10	8 / 8
Dry Forest	22 / 26	22 / 26	5 / 31	5 / 30	27 / 27	27 / 27
Dry Grass	6 / 7	6 / 7	3 / 19	1 / 6	9 / 9	7 / 7
Dry Shrub	6 / 7	6 / 7	3 / 19	2 / 12	9 / 9	8 / 8
Moist Forest	15 / 18	15 / 18	1 / 6	1 / 6	16 / 16	16 / 16
Riparian Shrub	+	+	1 / 6	+	1 / 1	+
Riparian Woodland	+	+	+	+	+	+
Road	NA[5] / NA	1.1 / 1	NA / NA	0.4 / 2	NA	1.5 / 1.5
Rock	1 / 1	1 / 1	0 / 0	0 / 0	1 / 1	1 / 1
Urban	0 / 0	0 / 0	0 / 0	+	0 / 0	+
Water	+	+	+	+	+	+
Woodland	1 / 1	1 / 1	+	+	1 / 1	1 / 1
Total[6]	83 / 98	84.1 / 99	16 / 100	16.4 / 99	99 / 99	100.5 / 100.5

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes. Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes.

For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

Table 3.57—Current and historical period physiognomic types for the dry grass potential vegetation group (PVG) for Central Idaho Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Woodland	+[3]	8	2	2
	Exotic Herbland	2	0	0	0
	Late-seral Multi-layer Woodland	+	1	26	26
	Mid-seral Woodland	+	35	10	8
	Upland Herbland	97	56	62	64
Other	Early-seral Woodland	+	1	1	1
	Exotic Herbland	0	0	0	0
	Late-seral Multi-layer Woodland	2	+	17	16
	Mid-seral Woodland	+	2	6	4
	Upland Herbland	97	97	76	78
All	Early-seral Woodland	+	6	2	2
	Exotic Herbland	2	0	0	0
	Late-seral Multi-layer Woodland	1	1	23	23
	Mid-seral Woodland	+	24	9	7
	Upland Herbland	97	70	67	69

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

(table 3.58). The areal extent of exotic herblands was furthest outside the HRV because this type was not present in the native system. However, as with the dry grass PVG, the areal extent of exotic herblands on BLM/FS lands was underestimated for the current condition, and greatly underestimated on Other lands for the current period. The upland herbland physiognomic type was well below the HRV on BLM/FS lands and Other lands, most likely as a result of the invasion of exotic vegetation and the development of shrub types due to fire exclusion. Conversely, the upland shrubland physiognomic type was substantially above the HRV on BLM/FS lands and Other lands as a result of succession from the upland herbland type caused by fire exclusion.

The physiognomic type of the cool shrub PVG in the Central Idaho Mountains ERU is summarized in table 3.59. As expected, the areal extent of the exotic herbland physiognomic type was furthest outside the HRV, especially on BLM/FS lands.

Table 3.58—Current and historical period physiognomic types for the dry shrub potential vegetation group (PVG) for Central Idaho Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Exotic Herbland	10	0	0	0
	Upland Herbland	8	38	24	23
	Upland Shrubland	82	62	76	77
Other	Exotic Herbland	+[3]	0	0	0
	Upland Herbland	3	15	40	42
	Upland Shrubland	97	85	60	58
All	Exotic Herbland	8	0	0	0
	Upland Herbland	7	30	29	30
	Upland Shrubland	86	70	71	70

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3] + = < 0.5%.

The area of the upland herbland type was well below the HRV, regardless of the ownership strata. The areal decline of upland herbland types was primarily a result of fire exclusion, which allowed the successional development into the upland shrubland type.

The ownership distribution of physiognomic types in the dry forest PVG is summarized in tables 3.60 and 3.61. The amount of exotic herbland was substantially underestimated because of forest overstory cover. The areal extent of the upland herbland and upland shrubland physiognomic types was generally below the HRV for the Central Idaho Mountains ERU as a whole. The amount of the early-seral and mid-seral forest types occurred toward the upper end or above the HRV. The late-seral single-layer forest type was well below the HRV, whereas the late-seral multi-layer forest type occurred at the upper limit of the HRV. The late-seral single-layer forest type largely converted into the mid-seral forest type because of insect, disease, and stress mortalities in the overstory layer, and growth of shade-tolerant layers in the understory. These trends were similar for BLM/FS and Other ownerships.

The aforementioned transitions occurred primarily as a result of fire exclusion. Fire exclusion substantially reduced the extent of the non-lethal and mixed fire regimes that maintained late-seral single-layer types, and that thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer types. Timber harvest activities largely occurred in the peripheral areas of the ERU, where the larger, shade-intolerant tree species were those primarily selected for harvest. These trees were more resistant to insect, disease, and stress mortality. Clearcutting and seed tree timber harvest activities commonly created small patches of early-seral structures containing few live or dead-standing trees, and high down fuel accumulations.

Table 3.59—Current and historical period physiognomic types for the cool shrub potential vegetation group (PVG) for Central Idaho Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		..... Percent			
BLM/FS	Early-seral Woodland	1	+[3]	+	1
	Exotic Herbland	9	0	0	0
	Late-seral Single-layer Woodland	0	1	0	0
	Mid-seral Woodland	1	+	+	+
	Upland Herbland	10	43	59	57
	Upland Shrubland	79	56	41	42
Other	Early-seral Woodland	2	0	+	+
	Exotic Herbland	1	0	0	0
	Late-seral Single-layer Woodland	0	0	0	0
	Mid-seral Woodland	5	0	+	+
	Upland Herbland	1	38	58	57
	Upland Shrubland	91	62	42	42
All	Early-seral Woodland	1	+	+	1
	Exotic Herbland	8	0	0	0
	Late-seral Single-layer Woodland	0	+	0	0
	Mid-seral Woodland	2	+	+	+
	Upland Herbland	9	41	59	57
	Upland Shrubland	81	58	41	42

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.60—Current and historical period physiognomic types for the dry forest potential vegetation group (PVG) for Central Idaho Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	32	22	20	10
	Exotic Herbland	+[3]	0	0	0
	Late-seral Multi-layer Forest	19	12	11	17
	Late-seral Single-layer Forest	2	13	31	43
	Mid-seral Forest	46	41	38	30
	Upland Herbland	1	12	+	0
	Upland Shrubland	+	1	+	+
Other	Early-seral Forest	27	21	35	12
	Exotic Herbland	0	0	0	0
	Late-seral Multi-layer Forest	11	11	8	11
	Late-seral Single-layer Forest	4	13	26	42
	Mid-seral Forest	57	21	31	36
	Upland Herbland	0	31	0	0
	Upland Shrubland	+	3	+	+
All	Early-seral Forest	31	21	23	10
	Exotic Herbland	+	0	0	0
	Late-seral Multi-layer Forest	17	12	10	16
	Late-seral Single-layer Forest	2	13	30	43
	Mid-seral Forest	48	37	37	31
	Upland Herbland	1	15	+	0
	Upland Shrubland	+	1	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.61—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Central Idaho Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	24	13	16	8
	Early-seral Shade-tolerant Forest	9	9	4	2
	Exotic Herbland	+[3]	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	8	7	5	9
	Late-seral Shade-intolerant Single-layer Forest	1	10	27	40
	Late-seral Shade-tolerant Multi-layer Forest	11	5	6	8
	Late-seral Shade-tolerant Single-layer Forest	1	4	4	4
	Mid-seral Shade-intolerant Forest	27	19	22	17
	Mid-seral Shade-tolerant Forest	18	21	17	13
	Upland Herbland	1	12	+	0
	Upland Shrubland	+	1	+	+
Other	Early-seral Shade-intolerant Forest	25	19	31	10
	Early-seral Shade-tolerant Forest	3	2	3	2
	Exotic Herbland	0	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	4	10	5	7
	Late-seral Shade-intolerant Single-layer Forest	3	13	25	40
	Late-seral Shade-tolerant Multi-layer Forest	8	1	3	4
	Late-seral Shade-tolerant Single-layer Forest	2	1	1	2
	Mid-seral Shade-intolerant Forest	39	15	23	25
	Mid-seral Shade-tolerant Forest	18	5	8	10
	Upland Herbland	0	31	0	0
	Upland Shrubland	+	3	+	+
All	Early-seral Shade-intolerant Forest	24	14	19	8
	Early-seral Shade-tolerant Forest	8	8	4	2
	Exotic Herbland	+	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	7	8	5	9
	Late-seral Shade-intolerant Single-layer Forest	1	10	27	40
	Late-seral Shade-tolerant Multi-layer Forest	10	4	5	7
	Late-seral Shade-tolerant Single-layer Forest	1	3	3	3
	Mid-seral Shade-intolerant Forest	30	19	22	18
	Mid-seral Shade-tolerant Forest	18	18	15	13
	Upland Herbland	1	15	+	0
	Upland Shrubland	+	1	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Altered composition and structure, in conjunction with a climatic trend (commencing in the 1980s) that seemed to produce drier spring, summer, and fall periods, resulted in changed conditions and higher risks of wildfire.

The areal extent of the dry forest PVG dominated by shade-tolerant tree species was generally at the upper limit of the HRV. The conversion to dominance by shade-tolerant species was not as dramatic in the Central Idaho Mountains ERU as compared with the Blue Mountains ERU, because there had been less selective harvest of the large shade-intolerant trees in the Central Idaho Mountains ERU.

The composition of physiognomic types within the moist forest PVG is summarized in tables 3.62 and 3.63. The areal extent of the early-seral forest type was within the HRV for the Central Idaho Mountains ERU as a whole and BLM/FS ownerships within the ERU. However, it was below the HRV on Other ownerships. The area of mid-seral forest type was at the high end of the HRV in the ERU as a whole and in BLM/FS ownerships, whereas it was well above the HRV on Other ownerships. The late-seral single-layer forest physiognomic type was below the HRV for all ownership strata, whereas the late-seral multi-layer forest physiognomic type occurred at the low end of the HRV for BLM/FS and Other ownerships. Physiognomic types dominated by shade-tolerant tree species were generally at the upper limit of, or slightly above the HRV.

The physiognomic type composition of the cold forest PVG in the Central Idaho Mountains ERU is summarized in tables 3.64 and 3.65. The areal extent of the early-seral physiognomic type was substantially higher than the HRV for the ERU as a whole, as well as for BLM/FS ownerships. On Other ownerships, the area of the early-seral physiognomic type occurred within the HRV. The mid-seral forest physiognomic type was below its HRV for all ownership strata. The areal extent of the late-seral multi-layer forest types occurred within their HRV for all ownership strata, whereas the areal extent of the late-seral single-layer forest types occurred below the HRV for Other ownerships and above the HRV for BLM/FS and All ownerships. A general shift from mid- and late-seral to early-seral types appeared to be related primarily to the mortality of whitebark pine caused by blister rust. In addition, there was a lack of successful regeneration of whitebark pine and subalpine larch (*Larix lyallii*) in many areas as a result of fire exclusion. Whitebark pine and subalpine larch both require fire for seedbed preparation.

Physiognomic types within the cold forest PVG, dominated by shade-tolerant and shade-intolerant species, is summarized in table 3.65. The amount of the early-seral shade-tolerant forest type was substantially above the HRV for All ownerships and BLM/FS lands, whereas in Other ownerships it occurred at the lower end of the HRV. The areal extent of late-seral and mid-seral shade-intolerant forest types were well below HRV, which supported our interpretation that shade-intolerant whitebark pine had declined due to fire exclusion and mortality from blister rust, and was being replaced by shade-tolerant subalpine fir. The areal extent of shade-intolerant subalpine larch also declined as a result of fire exclusion, and had been replaced by subalpine fir.

In response to the changes in regional and landscape conditions on forest and rangelands, the primary change in succession/disturbance regimes appeared to be a shift from moderate and accelerated cycles to long and retrogressive cycles. Most of the areas within the wilderness and roadless areas had low probability for re-establishment of these regimes given the limitations of prescribed fire and the effects of blister rust on whitebark pine. The existing prescribed natural-fire program has had a limited number of ignitions, as well as a limited number of fires that have been allowed to burn as prescribed natural fires. The small number of ignitions were

Table 3.62—Current and historical period physiognomic types for the moist forest potential vegetation group (PVG) for Central Idaho Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	25	30	19	20
	Late-seral Multi-layer Forest	16	13	21	29
	Late-seral Single-layer Forest	3	6	6	6
	Mid-seral Forest	55	51	54	45
Other	Early-seral Forest	15	45	24	19
	Late-seral Multi-layer Forest	14	12	16	24
	Late-seral Single-layer Forest	10	16	13	11
	Mid-seral Forest	62	28	48	47
All	Early-seral Forest	24	31	19	20
	Late-seral Multi-layer Forest	16	13	21	29
	Late-seral Single-layer Forest	4	7	7	6
	Mid-seral Forest	56	49	53	45

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

the result of efficient fire-suppression efforts. Existing wilderness and roadless areas have a high probability for restoration of historical regimes provided that implementation of a prescribed fire program has an adequate number of ignitions.

The roaded areas on the periphery of the Central Idaho Mountains ERU generally had the highest departures from the HRV regimes. There was a low probability of returning these roaded systems to the native succession/disturbance regimes without restoration of landscape structure, fuel conditions, whitebark pine, and fire.

Columbia Plateau ERU

The Columbia Plateau ERU is located primarily in Washington and Oregon, with a portion extending into northern Idaho (map 3.3). This ERU has a low relief (20 to 2,300 m) complex of wide valleys and plains with interspersed breaks, foothills, and mountains. Topography is generally gentle as a result of relatively level volcanic flows and wind-blown deposition (map 3.17). The interspersed breaklands developed from major floods during geologic glacial recessions and subsequent erosional processes. Landforms include a mix of valleys, plains, foothills, and breaks.

Table 3.63—Current and historical period moist forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Central Idaho Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	12	16	15	16
	Early-seral Shade-tolerant Forest	13	15	4	5
	Late-seral Shade-intolerant Multi-layer Forest	6	5	9	13
	Late-seral Shade-intolerant Single-layer Forest	1	5	4	4
	Late-seral Shade-tolerant Multi-layer Forest	10	9	13	16
	Late-seral Shade-tolerant Single-layer Forest	3	1	3	2
	Mid-seral Shade-intolerant Forest	18	21	32	29
	Mid-seral Shade-tolerant Forest	38	30	22	16
Other	Early-seral Shade-intolerant Forest	11	41	18	15
	Early-seral Shade-tolerant Forest	5	4	6	4
	Late-seral Shade-intolerant Multi-layer Forest	4	8	9	11
	Late-seral Shade-intolerant Single-layer Forest	2	14	9	9
	Late-seral Shade-tolerant Multi-layer Forest	10	4	7	12
	Late-seral Shade-tolerant Single-layer Forest	8	2	3	2
	Mid-seral Shade-intolerant Forest	15	16	34	34
	Mid-seral Shade-tolerant Forest	47	12	14	13
All	Early-seral Shade-intolerant Forest	12	18	15	16
	Early-seral Shade-tolerant Forest	12	14	4	5
	Late-seral Shade-intolerant Multi-layer Forest	6	5	9	13
	Late-seral Shade-intolerant Single-layer Forest	1	5	4	4
	Late-seral Shade-tolerant Multi-layer Forest	10	8	12	16
	Late-seral Shade-tolerant Single-layer Forest	3	1	3	2
	Mid-seral Shade-intolerant Forest	18	20	32	30
	Mid-seral Shade-tolerant Forest	38	29	21	16

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

Table 3.64—Current and historical period physiognomic types for the cold forest potential vegetation group (PVG) for Central Idaho Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	39	28	24	25
	Early-seral Riparian Woodland	2	0	+[3]	+
	Late-seral Multi-layer Forest	12	10	16	24
	Late-seral Single-layer Forest	14	12	10	8
	Mid-seral Forest	33	49	50	42
	Mid-seral Riparian Woodland	1	0	+	+
Other	Early-seral Forest	24	39	25	19
	Early-seral Riparian Woodland	10	0	+	1
	Late-seral Multi-layer Forest	24	15	13	24
	Late-seral Single-layer Forest	1	3	3	3
	Mid-seral Forest	41	43	57	52
	Mid-seral Riparian Woodland	+	0	1	1
All	Early-seral Forest	39	28	24	25
	Early-seral Riparian Woodland	2	0	+	+
	Late-seral Multi-layer Forest	12	10	16	24
	Late-seral Single-layer Forest	14	12	10	8
	Mid-seral Forest	33	49	50	42
	Mid-seral Riparian Woodland	1	0	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.65—Current and historical period cold forest potential period vegetation group (PVG) Shade Intolerance/Shade Tolerance for Central Idaho Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	19	19	22	22
	Early-seral Shade-tolerant Forest	20	9	2	3
	Late-seral Shade-intolerant Multi-layer Forest	7	5	6	10
	Late-seral Shade-intolerant Single-layer Forest	14	11	9	8
	Late-seral Shade-tolerant Multi-layer Forest	5	6	10	15
	Late-seral Shade-tolerant Single-layer Forest	0	1	1	1
	Mid-seral Shade-intolerant Forest	19	23	27	31
	Mid-seral Shade-tolerant Forest	13	27	23	11
	Riparian Woodland	3	0	+[3]	+
Other	Early-seral Shade-intolerant Forest	20	35	20	13
	Early-seral Shade-tolerant Forest	3	4	5	6
	Late-seral Shade-intolerant Multi-layer Forest	23	12	4	5
	Late-seral Shade-intolerant Single-layer Forest	1	+	+	2
	Late-seral Shade-tolerant Multi-layer Forest	1	3	9	19
	Late-seral Shade-tolerant Single-layer Forest	0	2	3	1
	Mid-seral Shade-intolerant Forest	26	23	33	33
	Mid-seral Shade-tolerant Forest	15	19	24	19
	Riparian Woodland	10	0	1	2
All	Early-seral Shade-intolerant Forest	19	19	22	22
	Early-seral Shade-tolerant Forest	20	9	2	3
	Late-seral Shade-intolerant Multi-layer Forest	7	5	6	10
	Late-seral Shade-intolerant Single-layer Forest	14	11	9	7
	Late-seral Shade-tolerant Multi-layer Forest	5	6	10	15
	Late-seral Shade-tolerant Single-layer Forest	0	2	1	1
	Mid-seral Shade-intolerant Forest	20	23	27	31
	Mid-seral Shade-tolerant Forest	13	27	23	11
	Riparian Woodland	3	0	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3] + = < 0.5%.

Most watersheds are oriented around mainstem streams; most headwater watersheds are located in adjacent ERUs (map 3.21). The Columbia Plateau ERU primarily falls within ecoregion sections 342I, 342G, and 342H (map 3.1).

Precipitation averages 36 centimeters per year (range = 22 to 102 cm). However, most of the Columbia Plateau ERU has a fairly low variation of precipitation. The lower and higher precipitation areas are confined to river breaklands and scattered mountains, respectively. Climate is strongly influenced by oceanic storm patterns and the rain-shadow effect of the Cascade Mountains to the west. Precipitation primarily comes in the form of rain or snow in the fall and winter, with some rain in the spring. Frequent winds and relatively high temperatures during the growing season cause high rates of evapotranspiration and soil surface moisture desiccation. There is a moderately steep gradient from moist fall, winter, and spring conditions to very dry summer and early fall conditions. The growing season is relatively long compared with other ERUs. As a result, the Columbia Plateau ERU has relatively low diversity of vegetation and disturbance regimes. However, because of the long growing season and high soil productivity, biogeochemical energy relationships are very dynamic. Consequently, the inherent rates of NPP and nutrient cycling are high, and the associated carbon and water stresses on upland sites are moderate.

Agricultural development and fire exclusion substantially changed the fire regimes of the Columbia Plateau ERU (maps 3.22 and 3.23). Agricultural development also substantially reduced the fire frequency in the grasslands, shrublands, and forests. Fire severity in the forest PVGs generally shifted from non-lethal and mixed to lethal, and from non-lethal to mixed. In the non-forest PVGs, fire severity shifted from non-lethal and mixed to lethal, and fire-return intervals decreased as a result of the invasion of flammable annual grasses.

A substantial proportion of the Columbia Plateau ERU receives less than 30 centimeters of annual precipitation (map 3.24). Drought was documented for 16 to 18 percent of the years between 1895 and 1994 (table 3.38; climate divisions: Washington Palouse-Blue Mountains, Washington Central Basin, Oregon North Central, and Oregon South Central). Conversely, relatively wet periods were documented only 4 to 7 times during that same timeframe (table 3.38). The combination of (1) inherently meager annual precipitation, (2) relatively frequent drought years, and (3) relatively infrequent periods believed to be favorable for perennial plant recruitment, has reduced the potential for non-forest PVG restoration on sites that experienced exotic plant invasions or were subject to excessive livestock grazing pressure.

The Columbia Plateau ERU has a high component of break landforms that are steep and have southerly exposures. Most of these breaklands are relatively accessible and have been invaded by exotic forbs or annual grasses. Most upland rangeland types on private lands have also been invaded by exotic forbs or annual grasses. BLM/FS lands that compose only 11 percent of the Columbia Plateau ERU, exist primarily as small parcels surrounded by agricultural land. BLM/FS lands have also been extensively invaded by exotic forb or annual grasses. Examples of exotic plants that have been problematic in this ERU are cheatgrass, yellow starthistle, diffuse knapweed, and medusahead. During the current period, approximately 45, 20, and 2 percent of the BLM/FS lands in the Columbia Plateau ERU were of high susceptibility to invasion by cheatgrass, diffuse knapweed (*Centaurea diffusa*), and yellow starthistle, respectively. Approximately 34, 13, and 27 percent of All lands in this ERU were deemed of high susceptibility to invasion by cheatgrass, diffuse knapweed, and yellow starthistle, respectively (table 3.47; maps 3.26, 3.27 and 3.37). In addition, soils that shrink or swell from drying or wetting were extensive in the southern portion of this ERU (maps 3.19 and 3.20) and thus, were susceptible to medusahead establishment.

The entire Columbia Plateau ERU has had a long history of livestock grazing on both private and public lands (map 3.25). Some improvements in rangeland conditions and associated watershed conditions have occurred since the mid-1900s. However, many stream and river banks have been downcut to the extent that they have lost their associated riparian areas.

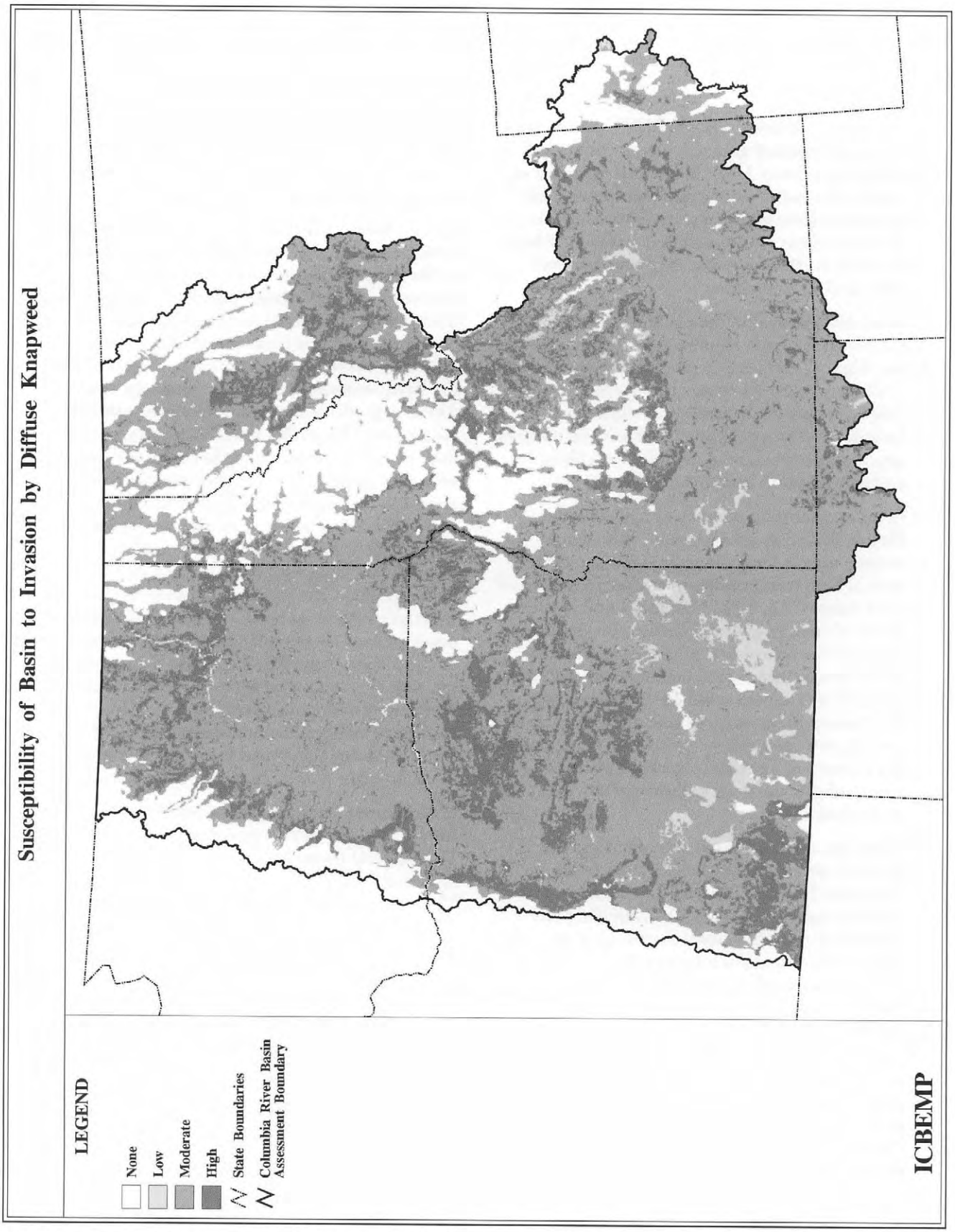
Road densities within the Columbia Plateau ERU are primarily low to moderate; few areas have very low, high, or extremely high densities, or no roads at all (map 3.28). However, because there were only a few mid-scale subbasins sampled, and because there was difficulty in identifying roads in agricultural terrain, road densities were likely underestimated (Menakis and others 1996).

In the current period, much of the Columbia Plateau ERU contained sensitive watersheds because soils lacking adequate vegetation cover were of high susceptibility to erosion by water and wind (maps 3.18, 3.38, 3.39 and 3.40). However, many of these areas were in private ownership and managed for agricultural purposes, and are thus, not evident in map 3.29. Lands in public ownership generally had adequate soil cover that minimized their susceptibility to erosion (map 3.29). Consequently, due to extensive agricultural development, the erosion risks of the Columbia Plateau ERU were probably the most extensive of any ERU in the Basin.

There are minor amounts of highly-fragmented BLM/FS and Other land ownerships in the Columbia Plateau ERU (mostly classified as "uniform other" in map 3.30). Only the outer portions of the ERU contain substantial areas of BLM/FS lands, which are generally in the mixed or mosaic ownership classes. A minor portion of the BLM/FS lands has moderate risk of fire occurrence and associated high-intensity wildfires that would be difficult to suppress (map 3.32). High-intensity wildfires have generally occurred in the peripheral areas of the ERU. At the landscape scale, there are some areas, particularly the break landforms, that have high fire risk. The moderate and high risks were related primarily to potential wildfire occurrence from human-caused ignition; dry spring, summer, and fall conditions; complex break terrain; and flammable annual-grass fuels that created the potential for severe fire behavior.

The Columbia Plateau ERU has few areas in the outer periphery that have high fuel accumulations or the potential for crown fires, forest insects, diseases, and stress-related mortalities (map 3.32). These mortality agents have been associated with dry forests that have high carbon and water stress. Historical harvest practices often removed most of the large, stress-resistant, shade-intolerant trees. These large, shade-intolerant trees have generally been replaced by smaller, shade-tolerant tree species that are more susceptible to the above-mentioned mortality agents. There are moderate fire risks related to the rural/wildland interface on the BLM/FS lands adjacent to rural development (map 3.33). However, BLM/FS ownership is minor in the Columbia Plateau ERU. At the landscape scale, the high-risk areas often occur at the edge of the steep break environments. Rural developments are typically associated with the adjacent valley and plain landforms that are on the edge or interspersed with the steep, complex topography of the break landforms. The break landforms predominantly occur on the BLM/FS lands, although substantial break landforms also occur on other public lands.

PVG composition changed substantially from the historical to the current period in the Columbia Plateau ERU (maps 3.11 and 3.12). We compared historical PVG composition to current period PVG composition by land ownership strata (table 3.66). Except for the development of roads, there was no substantial change on BLM/FS lands. On Other ownerships, 48 percent of the area was converted to agriculture, most of which came from the dry grass and dry shrub PVGs. Across All ownerships, dry grass, dry shrub, cool shrub, dry forest, and agricultural PVGs dominated the ERU, with a lesser amount of the moist forest PVG. Approximately 1.7 percent of the total area was roaded.

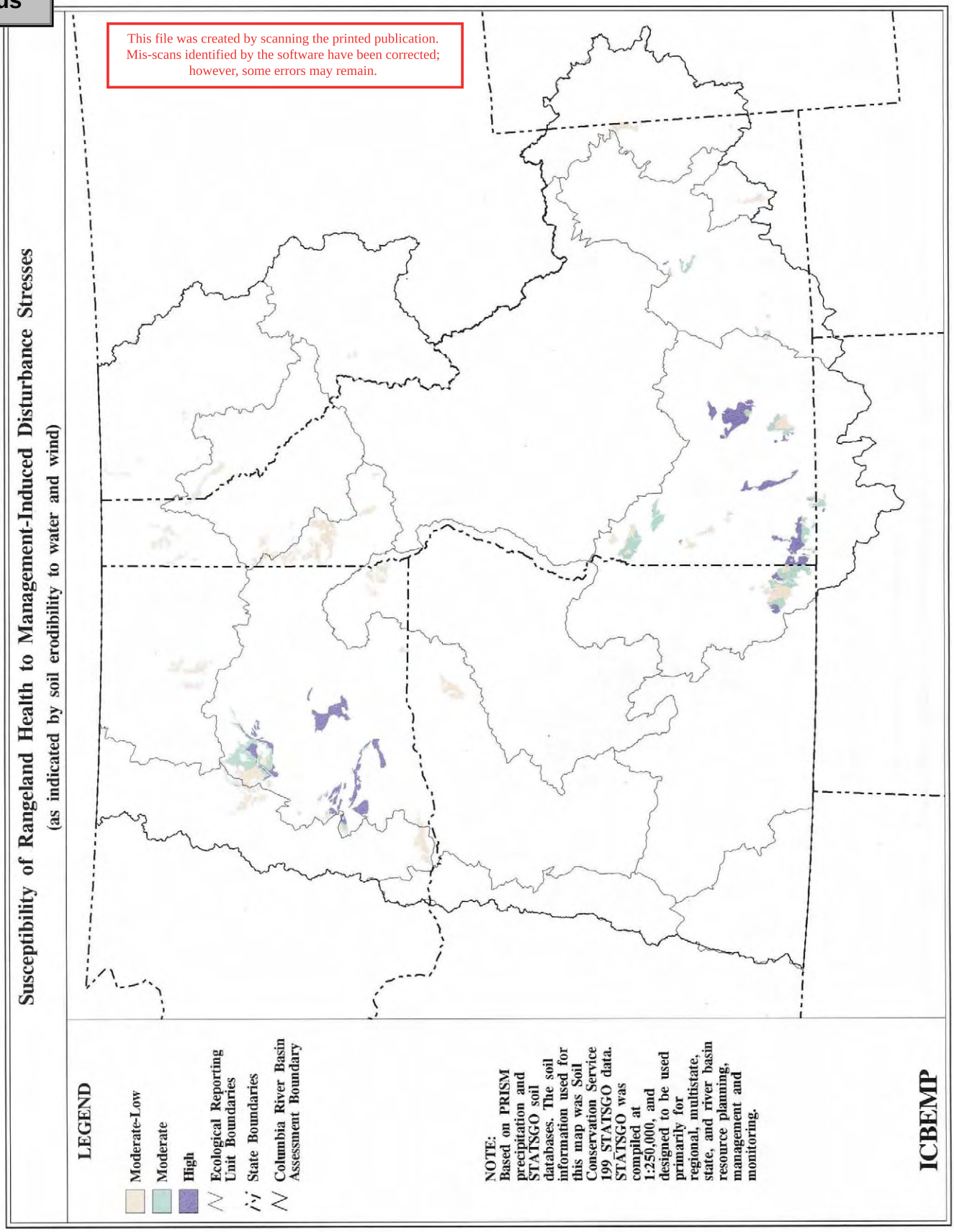


Map 3.37—Susceptibility status of the Basin to invasion by diffuse knapweed, an exotic annual or occasional perennial forb. Each shaded area (that is, susceptibility category) represents a grouping of cover types that were rated the same for susceptibility, and lie within the precipitation range (150-890 mm) of diffuse knapweed. Susceptibility ratings originate from the Susceptibility to Invasion Index.

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Map 3.38—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to water and wind. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having these specific soil-property indicators: a soil erodibility factor (K factor) exceeding 0.37, and wind erodibility Groups 1 through 3; none of the other three, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Map 3.39—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to water. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having an erodibility factor (K factor) exceeding 0.37; none of the other four, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Map 3.40—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to water and wind, and salinity. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having these specific soil-property indicators: a soil erodibility factor (K factor) exceeding 0.37, and salinity of 8 to 16 millihmos per centimeter (mmhos/cm), and wind erodibility Groups 1 through 3; neither of the other two, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Table 3.66—Historical and current period potential vegetation groups (PVGs) for the Columbia Plateau Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	48 / 53	0 / 0	48 / 47
Alpine	+[4]	+	0 / 0	0 / 0	+	+
Cold Forest	+	+	+	+	+	+
Cool Shrub	3 / 27	3 / 26	7 / 8	6 / 7	10 / 10	9 / 9
Dry Forest	3 / 27	3 / 26	8 / 9	7 / 8	11 / 11	10 / 10
Dry Grass	+	+	22 / 24	5 / 5	22 / 22	5 / 5
Dry Shrub	3 / 27	3 / 26	48 / 53	20 / 22	51 / 50	23 / 22
Moist Forest	2 / 18	2 / 17	2 / 2	2 / 2	4 / 4	4 / 4
Riparian Shrub	+	+	2 / 2	+	2 / 2	+
Riparian Woodland	+	+	+	+	+	+
Road	NA[5] / NA	0.4 / 3	NA / NA	1.3 / 1	NA / NA	1.7 / 2
Rock	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Urban	0 / 0	0 / 0	0 / 0	+	0 / 0	+
Water	+	+	1 / 1	1 / 1	1 / 1	1 / 1
Woodland	+	+	1 / 1	1 / 1	1 / 1	1 / 1
Total[6]	11 / 99	11.4 / 98	91 / 100	91.3 / 100	102 / 101	102.7 / 101

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes. Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes.

For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

BLM/FS land ownerships in the Columbia Plateau ERU were fairly evenly distributed between the dry forest, moist forest, dry shrub, and cool shrub PVGs. In the current period, BLM/FS roads accounted for 0.4 percent of the land cover. For Other ownerships, the current composition was dominated by the agricultural, dry shrub, dry forest, cool shrub, and dry grass PVGs. Roads on Other ownerships accounted for 1.3 percent of the land area.

None of the PVGs met the 5 percent BLM/FS land ownership criteria for the Columbia Plateau ERU. However, we described PVG types and succession/disturbance regimes for the dry grass, dry shrub, cool shrub, and dry forest PVGs because of their importance from a coarse-filter biodiversity perspective. The BLM/FS lands were generally the only remaining areas that were not converted to agriculture, dominated by exotic plants, or at high risk of future conversion. Consequently, these lands could play an important role in conserving some semblance of the native biota in the Columbia Plateau ERU.

The physiognomic type composition of the dry grass PVG of the Columbia Plateau ERU is summarized in table 3.67. The areal extent of the exotic herbland type was furthest outside the HRV, primarily on BLM/FS lands. However, the amount of exotic herbland type on Other and BLM/FS lands was substantially underestimated for the current period condition, by possibly as much as 50 percent in the upland herbland physiognomic type. Exotic plants that are especially problematic within the current period dry grass PVG included yellow starthistle, cheatgrass, and dalmatian toadflax (*Linaria dalmatica*). For the dry grass PVG that was not converted to agriculture, the upland herbland physiognomic type declined from the HRV for all ownerships. The mid-seral woodland physiognomic type increased substantially. This combined shift was a result of exotic plant invasions, fire exclusion in woodlands, and fire regime changes in the exotic herbland type. On All ownerships, the historical system was generally dominated by upland herbland and was maintained by frequent non-lethal fires. Composition and relationships on BLM/FS and Other ownerships generally followed the same pattern as on All ownerships.

The physiognomic type composition for the dry shrub PVG is summarized in table 3.68. The extent of exotic herblands on BLM/FS, Other, and All ownerships was substantially underestimated. For the dry shrub PVG that was not converted to agriculture, the areal extent of the upland herbland physiognomic type was extremely low and the upland shrubland physiognomic type was high compared to the HRV for BLM/FS, Other, and All land ownerships. This combined shift was a result of fire exclusion.

The exotic plants that are especially problematic in this PVG include cheatgrass, medusahead, and diffuse knapweed. Because the dry shrub PVG had such extensive exotic vegetation coverage, a return of native fire regimes would likely cause an expansion of communities dominated by exotics.

The composition of physiognomic types within the cool shrub PVG is summarized in table 3.69. For the cool shrub PVG that was not converted to agriculture, the areal extent of the upland herbland and upland shrubland physiognomic types was quite low, and the early- and mid-seral woodland physiognomic types were high compared to the HRV for All ownerships. These trends were a result of fire exclusion. The amount of the exotic herbland type was substantially underestimated, which means that the amount of the upland herbland and upland shrubland types could have been much less than our predictions indicated. The return of native fire regimes to the cool shrub PVG would likely promote the expansion of communities dominated by exotic vegetation, and further the subsequent decline of the upland herbland and upland shrubland types. The trends for BLM/FS and Other land ownerships followed similar patterns as those on All ownerships.

Tables 3.70 and 3.71 display the physiognomic type composition by ownership strata for the dry forest PVG. The amount of the exotic herbland physiognomic type was substantially underestimated because of forest overstory cover. The abundance of the early-seral forest type was generally at the lower end of the range of the HRV for All ownerships. The areal extent of the mid-seral forest type was twice

Table 3.67—Current and historical period physiognomic types for the dry grass potential vegetation group (PVG) for Columbia Plateau Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Woodland	1	3	1	2
	Exotic Herbland	14	0	0	0
	Late-seral Multi-layer Woodland	1	4	4	5
	Mid-seral Woodland	12	7	3	6
	Upland Herbland	72	87	92	87
Other	Early-seral Woodland	1	+[3]	+	+
	Exotic Herbland	+	0	0	0
	Late-seral Multi-layer Woodland	1	+	+	1
	Mid-seral Woodland	4	+	1	+
	Upland Herbland	94	100	99	99
All	Early-seral Woodland	1	+	+	+
	Exotic Herbland	1	+	+	+
	Late-seral Multi-layer Woodland	1	+	+	1
	Mid-seral Woodland	4	+	1	1
	Upland Herbland	93	99	99	99

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

as high as the HRV maximum. The areal extent of the late-seral multi-layer forest type was at the high end of the range, whereas the late-seral single-layer forest type was essentially non-existent compared with a very-high HRV level. There were similar trends for BLM/FS and Other ownerships. These conditions related primarily to the exclusion of non-lethal and mixed-underburning fires, and the harvesting of large, shade-intolerant trees. The late-seral single-layer forest types shifted to mid-seral types as a result of selective harvest practices, insects, disease, and stress mortality in the overstory layer, as well as the subsequent growth of shade-tolerant layers in the understory. Fire exclusion eliminated the non-lethal and mixed fires that maintained the late-seral single- and multi-layer types, and thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer types.

Table 3.68—Current and historical period physiognomic types for the dry shrub potential vegetation group (PVG) for Columbia Plateau Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Exotic Herbland	1	0	0	0
	Upland Herbland	1	2	68	67
	Upland Shrubland	98	98	32	33
Other	Exotic Herbland	+[3]	0	0	0
	Upland Herbland	5	21	65	64
	Upland Shrubland	95	79	35	36
All	Exotic Herbland	+	0	0	0
	Upland Herbland	4	20	65	64
	Upland Shrubland	96	80	35	36

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Clearcut, seed tree, shelterwood, and group selection timber-harvest activities commonly created a mosaic of small patches of the early-seral types with no dead-standing trees, no scattered small live trees, and high down-fuel accumulations. In the matrix areas surrounding these early-seral patches, the large trees and dead-standing trees were often selectively harvested. These practices resulted in an overall landscape forest pattern with high-risk conditions for fire, insect, disease, and stress mortality. When shade tolerance was included as a descriptor of the physiognomic type (table 3.71), it was apparent that the mid- and late-seral forests dominated by shade-tolerant tree species were substantially above or at the upper limit of the HRV.

In response to the changes in regional and landscape conditions on forest and rangelands, the succession/disturbance regimes went through a substantial shift from moderate-cycle and maintenance regimes to short-cycle and retrogressive-cycle regimes. Much of the area is roaded and succession/disturbance regimes changed due to timber harvest and fire exclusion. There was a low probability of returning the succession/disturbance regimes to their historical compositions without the restoration of perennial vegetation and landscape structures.

Lower Clark Fork ERU

The Lower Clark Fork ERU is located primarily in Idaho and Montana (map 3.3). This ERU has a high relief (300 to 2,500 m) complex of narrow valleys and steep mountains (map 3.17). Topography is generally steep and complex. Interspersed break areas are quite complex as a result of major floods during geologic glacial recessions and their subsequent erosional processes.

Table 3.69—Current and historical period physiognomic types for the cool shrub potential vegetation group (PVG) for Columbia Plateau Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Woodland	76	44	11	9
	Exotic Herbland	2	0	0	0
	Late-seral Single-layer Woodland	0	1	+[3]	+
	Mid-seral Woodland	15	1	10	10
	Upland Herbland	+	2	19	20
	Upland Shrubland	7	52	60	61
Other	Early-seral Woodland	58	17	8	7
	Exotic Herbland	+	0	0	0
	Late-seral Single-layer Woodland	0	+	0	+
	Mid-seral Woodland	16	1	6	6
	Upland Herbland	1	11	25	24
	Upland Shrubland	25	71	62	64
All	Early-seral Woodland	65	26	9	7
	Exotic Herbland	1	0	0	0
	Late-seral Single-layer Woodland	0	1	+	+
	Mid-seral Woodland	16	1	7	7
	Upland Herbland	1	8	23	23
	Upland Shrubland	18	65	61	63

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.70—Current and historical period physiognomic types for the dry forest potential vegetation group (PVG) for Columbia Plateau Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	16	14	19	9
	Exotic Herbland	+[3]	0	0	0
	Late-seral Multi-layer Forest	25	13	14	17
	Late-seral Single-layer Forest	2	32	47	54
	Mid-seral Forest	56	30	21	20
	Upland Herbland	+	10	0	0
	Upland Shrubland	+	1	+	0
Other	Early-seral Forest	8	17	24	7
	Exotic Herbland	0	0	0	0
	Late-seral Multi-layer Forest	7	7	6	9
	Late-seral Single-layer Forest	1	20	36	57
	Mid-seral Forest	84	21	33	27
	Upland Herbland	+	22	+	0
	Upland Shrubland	+	12	1	+
All	Early-seral Forest	10	17	23	7
	Exotic Herbland	+	0	0	0
	Late-seral Multi-layer Forest	12	9	8	11
	Late-seral Single-layer Forest	1	23	39	56
	Mid-seral Forest	76	24	30	25
	Upland Herbland	+	19	+	0
	Upland Shrubland	+	9	1	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.71—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Columbia Plateau Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	16	13	17	8
	Early-seral Shade-tolerant Forest	1	1	2	1
	Exotic Herbland	+[3]	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	19	10	10	13
	Late-seral Shade-intolerant Single-layer Forest	1	32	46	52
	Late-seral Shade-tolerant Multi-layer Forest	7	3	4	4
	Late-seral Shade-tolerant Single-layer Forest	+	1	1	2
	Mid-seral Shade-intolerant Forest	39	25	15	15
	Mid-seral Shade-tolerant Forest	17	5	6	6
	Upland Herbland	+	10	0	0
	Upland Shrubland	+	1	+	0
Other	Early-seral Shade-intolerant Forest	7	17	23	6
	Early-seral Shade-tolerant Forest	+	+	1	1
	Exotic Herbland	0	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	5	7	5	7
	Late-seral Shade-intolerant Single-layer Forest	1	20	35	56
	Late-seral Shade-tolerant Multi-layer Forest	2	1	1	2
	Late-seral Shade-tolerant Single-layer Forest	+	+	1	1
	Mid-seral Shade-intolerant Forest	66	20	29	22
	Mid-seral Shade-tolerant Forest	18	1	4	5
	Upland Herbland	+	22	+	0
	Upland Shrubland	+	12	1	+
All	Early-seral Shade-intolerant Forest	10	16	21	6
	Early-seral Shade-tolerant Forest	+	1	2	1
	Exotic Herbland	+	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	9	8	6	9
	Late-seral Shade-intolerant Single-layer Forest	1	23	38	55
	Late-seral Shade-tolerant Multi-layer Forest	3	1	2	3
	Late-seral Shade-tolerant Single-layer Forest	+	+	1	1
	Mid-seral Shade-intolerant Forest	59	21	25	20
	Mid-seral Shade-tolerant Forest	18	2	5	5
	Upland Herbland	+	19	+	0
	Upland Shrubland	+	9	1	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Landforms include a mix of mountains, foothills, and breaks with narrow valleys. Downstream and upstream watersheds are juxtaposed (map 3.21).

Precipitation for the Lower Clark Fork ERU averages 110 centimeters per year (range 63 to 141 cm). The Lower Clark Fork ERU is primarily in ecoregion section M333D (map 3.1).

Climate is strongly influenced by the oceanic storm patterns from the west. The Clark Fork River and the ERU itself act as a funnel for westward-moving storms. Although the mountains in this ERU are relatively high and run from north to south, they do not function as a substantial barrier to storms because of the deep cut of the Clark Fork River valley and the position of several relatively low, wide mountain passes. In addition, the foothills and mountains on the western side of the ERU provide a gradual uplift that generally does not produce a sharp rain-shadow effect, but instead a relatively uniform increase in precipitation throughout the ERU. Precipitation occurs primarily in the form of winter snows, spring rains, and summer thunder storms and showers. There is a moderately steep gradient from moist winter and spring conditions, to dry summer and fall conditions, with a moderately long growing season.

Soils in the Lower Clark Fork ERU are fairly productive as a result of volcanic ash deposition. The climate and productive soils have resulted in moderately high inherent NPP and nutrient cycling. The ERU has very dynamic disturbance regimes because of this inherent productivity combined with steep and complex topography, and associated moderate carbon and water stress on upland areas.

There were substantial changes in fire regimes from the historical to the current period in this ERU, primarily as a result of timber harvest activities combined with fire exclusion (map 3.22 and 3.23). In general, longer fire intervals caused the fire severity in the forest PVGs to shift from a mixture of classes (that is, non-lethal, mixed, and lethal) in the historical period to lethal in the current period.

From a regional perspective, the Lower Clark Fork ERU is not in a high-risk, drought climate. The ERU averaged greater than 30 centimeters annual precipitation (map 3.24). At the landscape scale, a few areas that have steep topographic settings and southerly exposures have high drought-risk environments. In the current period, these areas were typically dominated by the dry grass PVG and susceptible to exotic forb invasions, particularly spotted knapweed and sulfur cinquefoil (*Potentilla recta*). The upland herbland physiognomic type within the dry forest and moist forest PVGs was also particularly susceptible to invasion by spotted knapweed and sulfur cinquefoil. Approximately 10 percent of the entire Lower Clark Fork ERU and 3 percent of BLM/FS lands in this ERU were of high susceptibility to invasion by spotted knapweed (table 3.47; map 3.35). A relatively small portion of this ERU had a history of livestock grazing on public lands (map 3.25).

Road densities in the Lower Clark Fork ERU are generally high with lesser amounts of other categories (map 3.28). High road densities typically occur in subwatersheds that are sensitive to the disruption of hydrologic regimes (map 3.29). Relative to subwatersheds dominated by rangelands, forested subwatersheds are generally steeper, have less developed soils, and are more susceptible to erosion and sediment transport via road networks. Forested subwatersheds developed for timber harvest, typically have high road densities. As previously discussed, in contrast to hard-surface roads, roads in forested subwatersheds are commonly surfaced with gravel or native materials that are susceptible to sediment transport. Because of the narrow draws and valley bottoms of the Lower Clark Fork ERU, many roads were historically developed in close proximity to the stream network. Consequently, these roads often constrict the stream floodplain energy and have very short distances for sediment delivery.

The ownership pattern of BLM/FS and Other land is moderately fragmented in the Lower Clark Fork ERU (map 3.30). There are large areas with relatively uniform BLM/FS land ownership and

many interspersed areas with mixed and mosaic ownership patterns. A large portion of the BLM/FS lands have a moderate risk of fire occurrence and associated high-intensity wildfires that could be difficult to suppress (map 3.31). These areas generally occur on the lower elevations and steeper terrain of the dry forest PVG. At the landscape scale, there are areas, particularly the break landforms, that have high risks of fire. Moderate and high fire risks have been related to potential wildfire occurrence from lightning and human-caused ignition; dry spring, summer, and fall conditions; complex steep terrain; and high forest fuel-loadings that create the potential for severe fire behavior.

The Lower Clark Fork ERU has areas located around the outer periphery with high fuel accumulations, potential for crown fire, and forest insect-, disease-, and stress-related mortalities (map 3.32). These areas have been associated with dry forest and moist forest PVGs that have high carbon and water stress. Historical harvest practices in forest PVGs often removed most of the large, shade-intolerant trees that were generally resistant to the above-mentioned mortality agents. The large, shade-intolerant trees have generally been replaced by smaller, more susceptible, shade-tolerant tree species.

There are moderate fire risks associated with the rural/wildland interface on BLM/FS lands (map 3.33). At the landscape scale, the high-risk areas often occur at the edge of the steep foothill or mountain environments. Rural developments are typically associated with the adjacent narrow valley landforms that are on the edge of, or interspersed with, the steep foothill or mountain landforms.

With the exception of road development, PVG composition did not change substantially between the historical and current periods in the Lower Clark Fork ERU, (table 3.72; maps 3.11 and 3.12). The moist forest and dry forest PVGs dominated the ERU, regardless of ownership strata. Approximately 3.4 percent of the total area was in roads, of which BLM/FS contributed 2.2 percent and Other ownerships contributed 1.1 percent.

We summarize the composition of physiognomic types within the dry forest PVG in the Lower Clark Fork ERU (tables 3.73 and 3.74). The areal extent of the early-seral forest physiognomic type was at the lower end or below the range of the HRV for All land ownerships. The area of the mid-seral forest type was almost two to three times as high as the HRV maximum. The area of the late-seral multi-layer forest physiognomic type was very low and the late-seral single-layer forest type was non-existent in comparison to the HRV. Similar trends were found for BLM/FS and Other land ownerships.

The above trends resulted from the harvest of late-seral forests and fire exclusion. The late-seral single- and multi-layer forests physiognomic types shifted to mid-seral forest types because of harvest activities, and insect, disease, and stress mortalities in the overstory layer. When forests were harvested using clearcut and seed tree treatments and then planted, succession processes were accelerated. Consequently, mid-seral structures developed faster than was typical in native systems. Fire exclusion eliminated non-lethal and mixed fires that maintained late-seral single- and multi-layer physiognomic types, and thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer types. The shade-tolerant trees were susceptible to insects, disease, and stress mortality. Clearcut, seed tree, shelterwood, and group-selection timber-harvest activities commonly created a mosaic of small early-seral patches with no dead-standing trees, no scattered small live trees, and high down-fuel accumulations. In the matrix areas surrounding the patches, the large trees and dead-standing trees were often selectively harvested. This combination of activities commonly resulted in an overall landscape forest pattern with high risk conditions for fire, insect, disease, and stress mortality.

The areal extent of the mid-seral forest physiognomic types, dominated by shade-tolerant tree species, was five times the upper limit of the HRV on All ownerships. This system was at very high risk of substantial mortality to insects, disease, and stress, as well as large, high-intensity fires.

Table 3.72—Historical and current period potential vegetation groups (PVGs) for the Lower Clark Fork Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	4 / 11	0 / 0	4 / 4
Alpine	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Cold Forest	3 / 4	3 / 4	+[4]	+	3 / 3	3 / 3
Cool Shrub	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Dry Forest	6 / 9	6 / 9	9 / 26	8 / 23	15 / 15	14 / 13
Dry Grass	+	+	1 / 3	+	1 / 1	+
Dry Shrub	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Moist Forest	57 / 86	57 / 84	23 / 68	21 / 60	80 / 80	78 / 75
Riparian Shrub	+	+	+	0 / 0	+	+
Riparian Woodland	+	+	+	+	+	+
Road	NA[5] / NA	2.2 / 3	NA / NA	1.1 / 3	NA / NA	3.4 / 3
Rock	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Urban	0 / 0	0 / 0	0 / 0	+	0 / 0	+
Water	+	+	1 / 1	1 / 3	1 / 1	1 / 1
Woodland	0 / 0	0 / 0	0 / 0	0	0 / 0	0 / 0
Total[6]	66 / 99	68.2 / 100	34 / 100	35.1 / 100	100 / 100	103.4 / 99

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes. Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes. For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

Table 3.73—Current and historical period physiognomic types for the dry forest potential vegetation group (PVG) for Lower Clark Fork Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	16	30	11	11
	Late-seral Multi-layer Forest	2	18	14	20
	Late-seral Single-layer Forest	0	16	33	40
	Mid-seral Forest	83	36	42	28
	Upland Herbland	+[3]	0	0	0
Other	Early-seral Forest	3	24	14	10
	Late-seral Multi-layer Forest	1	17	13	20
	Late-seral Single-layer Forest	0	19	38	45
	Mid-seral Forest	96	32	36	25
	Upland Herbland	0	7	0	0
All	Early-seral Forest	8	26	13	11
	Late-seral Multi-layer Forest	1	18	13	20
	Late-seral Single-layer Forest	0	18	36	43
	Mid-seral Forest	90	34	38	26
	Upland Herbland	+	5	0	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

The physiognomic type composition is summarized for the moist forest PVG in the Lower Clark Fork ERU in tables 3.75 and 3.76. The area of the early-seral forest physiognomic type was generally at the lower end of the range of the HRV for All land ownerships. The extent of the mid-seral forest physiognomic type was almost twice as high as the HRV maximum. The abundance of the late-seral multi- and single-layer forest types was very low in comparison to the HRV. There was a similar trend for BLM/FS and Other land ownerships. These trends were a result of the harvest of late-seral forests and exclusion of fire. The late-seral single- and multi-layer forest types shifted to mid-seral because of harvest practices and insect, disease, and stress mortalities in the overstory layer. In areas where the forests were harvested using clearcut and seed tree treatments, forest succession was accelerated toward mid-seral types, at a rate faster than the HRV, through the use of advanced regeneration plantings. Fire exclusion eliminated the non-lethal and mixed fires that maintained late-seral single- and multi-layer types, and

Table 3.74—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Lower Clark Fork Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	14	17	9	9
	Early-seral Shade-tolerant Forest	2	13	3	3
	Late-seral Shade-intolerant Multi-layer Forest	0	12	7	12
	Late-seral Shade-intolerant Single-layer Forest	0	14	28	34
	Late-seral Shade-tolerant Multi-layer Forest	2	6	7	9
	Late-seral Shade-tolerant Single-layer Forest	0	2	4	6
	Mid-seral Shade-intolerant Forest	8	24	26	13
	Mid-seral Shade-tolerant Forest	75	12	16	15
	Upland Herbland	+[3]	0	0	0
Other	Early-seral Shade-intolerant Forest	2	20	11	8
	Early-seral Shade-tolerant Forest	1	4	2	2
	Late-seral Shade-intolerant Multi-layer Forest	0	15	8	13
	Late-seral Shade-intolerant Single-layer Forest	0	18	35	40
	Late-seral Shade-tolerant Multi-layer Forest	1	2	5	7
	Late-seral Shade-tolerant Single-layer Forest	0	1	4	5
	Mid-seral Shade-intolerant Forest	38	27	27	15
	Mid-seral Shade-tolerant Forest	58	5	9	10
	Upland Herbland	0	7	0	0
All	Early-seral Shade-intolerant Forest	7	19	10	9
	Early-seral Shade-tolerant Forest	1	7	2	2
	Late-seral Shade-intolerant Multi-layer Forest	0	14	7	13
	Late-seral Shade-intolerant Single-layer Forest	0	17	32	38
	Late-seral Shade-tolerant Multi-layer Forest	1	4	6	8
	Late-seral Shade-tolerant Single-layer Forest	0	2	4	5
	Mid-seral Shade-intolerant Forest	25	26	27	14
	Mid-seral Shade-tolerant Forest	66	8	12	12
	Upland Herbland	+	5	0	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.75—Current and historical period physiognomic types for the moist forest potential vegetation group (PVG) for Lower Clark Fork Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	22	41	15	18
	Late-seral Multi-layer Forest	1	16	22	30
	Late-seral Single-layer Forest	1	3	6	10
	Mid-seral Forest	76	40	57	42
Other	Early-seral Forest	10	31	17	19
	Late-seral Multi-layer Forest	1	20	24	28
	Late-seral Single-layer Forest	1	13	12	18
	Mid-seral Forest	89	36	46	35
All	Early-seral Forest	19	38	16	18
	Late-seral Multi-layer Forest	1	17	23	30
	Late-seral Single-layer Forest	1	6	8	12
	Mid-seral Forest	80	39	54	40

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer types. Clearcut, seed tree, shelterwood, and group-selection timber-harvest activities commonly created a mosaic of small early-seral patches with no dead-standing trees, no small live trees, and high down-fuel accumulations. In the matrix areas surrounding these patches, the large trees and dead-standing trees were generally harvested. This combination of factors resulted in an overall landscape forest pattern with high-risk conditions for fire, insects, disease, and stress mortality.

The areal extent of the mid-seral forest physiognomic types, dominated by shade-tolerant tree species, was three times the upper limit of the HRV (table 3.76). The amount of the shade-intolerant mid-seral forest type was at the upper limit of the HRV. The loss of western white pine from this system due to blister rust infestations resulted in the lack of a fast-growing dominant tree for moist environments. The moist forest system in the Lower Clark Fork ERU had a very high risk of substantial mortality from insects, disease, stress, and large high-intensity fire occurrences.

Much of the Lower Clark Fork ERU is roaded and has been changed by timber harvest activities and fire exclusion. Consequently, in the Lower Clark Fork ERU the succession/disturbance regimes substantially shifted from a dominance of acceleration and maintenance regimes, to moderate-cycle and retrogressive cycle regimes.

Table 3.76—Current and historical period moist forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Lower Clark Fork Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	18	32	12	15
	Early-seral Shade-tolerant Forest	4	9	3	4
	Late-seral Shade-intolerant Multi-layer Forest	1	15	15	19
	Late-seral Shade-intolerant Single-layer Forest	+[3]	3	5	9
	Late-seral Shade-tolerant Multi-layer Forest	1	1	7	11
	Late-seral Shade-tolerant Single-layer Forest	1	+	1	1
	Mid-seral Shade-intolerant Forest	41	36	46	29
	Mid-seral Shade-tolerant Forest	35	4	11	13
Other	Early-seral Shade-intolerant Forest	9	30	14	15
	Early-seral Shade-tolerant Forest	1	1	3	4
	Late-seral Shade-intolerant Multi-layer Forest	1	20	18	19
	Late-seral Shade-intolerant Single-layer Forest	+	13	12	17
	Late-seral Shade-tolerant Multi-layer Forest	+	+	6	9
	Late-seral Shade-tolerant Single-layer Forest	1	+	1	1
	Mid-seral Shade-intolerant Forest	50	36	41	26
	Mid-seral Shade-tolerant Forest	39	+	6	9
All	Early-seral Shade-intolerant Forest	15	31	13	15
	Early-seral Shade-tolerant Forest	3	7	3	4
	Late-seral Shade-intolerant Multi-layer Forest	1	17	16	19
	Late-seral Shade-intolerant Single-layer Forest	+	6	7	11
	Late-seral Shade-tolerant Multi-layer Forest	1	1	7	11
	Late-seral Shade-tolerant Single-layer Forest	1	+	1	1
	Mid-seral Shade-intolerant Forest	44	36	44	29
	Mid-seral Shade-tolerant Forest	36	3	10	12

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Northern Cascades ERU

The Northern Cascades ERU is oriented along the crest of the Cascade Mountains in central Washington (map 3.3). This ERU has a very high relief (60 to 3,400 m) complex of low elevation valleys to higher elevation narrow valleys and steep mountains (map 3.17). Topography is generally steep and complex. Landforms include a mix of broad river valleys with breaks, and mountains and foothills with narrow valleys. Watersheds are mixed between downstream and headwater systems (map 3.21). The average precipitation across the ERU is relatively high, approximately 93 centimeters per year but with a steep gradient from an average of 24 centimeters per year at low elevations to an average of 190 centimeters per year at high elevations. The complex diversity of climate and topography has resulted in high vegetation diversity and a dynamic disturbance regime. The Northern Cascades ERU is primarily in ecoregion section M242C (map 3.1).

Climate is strongly influenced by the oceanic storm patterns from the west and the rain-shadow effect of the Cascade Mountains. There is a very steep gradient from the deep snowpacks and high precipitation on the Cascade crest to the Columbia River where there is little snow and low precipitation. Precipitation is primarily in the form of winter snows, spring rains, and summer thunder storms and showers. The upper elevations near the crest of the Cascades have a relatively low gradient from wet winter and spring conditions, to moist-to-dry summer and fall conditions with a short growing season. Moving away from the Cascade crest, the moisture gradient changes rapidly to a steep gradient of moist winter and spring conditions, to very dry summer and fall conditions with a moderately-long growing season. The Northern Cascades ERU has very dynamic succession/disturbance regimes because of its inherent productivity, steep climatic gradients, and complex topography. The dynamic succession/disturbance regimes are also associated with high carbon and moderate water stress on upland areas.

Fire exclusion, low- and mid-elevation timber-harvest activities, invasion by exotics, and livestock grazing practices have substantially altered fire regimes within the Northern Cascades ERU (maps 3.22 and 3.23). Fire severity generally shifted from a mixture of non-lethal and mixed, to lethal in the forest PVGs. This change was caused by the harvest of large, shade-intolerant tree species that were more fire-, insect-, disease-, and stress-resistant, as well as longer fire-return intervals that promoted the dominance of shade-tolerant species. In the non-forest PVGs (particularly in the eastern portion of the ERU), invasion by exotic annual grasses shifted the fire regimes from non-lethal to lethal, and increased the variability of fire frequency. When not grazed, areas invaded by annual exotic grasses are highly flammable and often experience more frequent fires.

From a regional perspective, the Northern Cascades ERU does not have a high risk of drought because most of the ERU receives more than 30 centimeters annual precipitation (map 3.24). At the landscape scale however, there are areas that have steep, southerly exposures and droughty environments. These droughty environments are typically dominated by the dry grass, dry shrub, or dry forest PVGs, and are susceptible to invasions by exotic plants, especially diffuse knapweed. Approximately 11 percent of BLM/FS lands and 18 percent of All lands in the Northern Cascades ERU are of high susceptibility to invasion by diffuse knapweed (table 3.47; map 3.37).

A moderate portion of the Northern Cascades ERU has had a history of livestock grazing on public lands (map 3.25). Many allotments were closed on public lands as a result of forest succession and the subsequent decline of forage availability. Rangeland conditions on public lands have generally improved since the mid-1900s, except with respect to exotic plant invasions in the drier PVGs. Riparian conditions have improved in some areas, but problems continue to exist in many areas relative to stream-channel conditions and the lack of shrub and herbaceous cover.

Road densities in the Northern Cascades ERU are high at low and mid elevations, and low to none at higher elevations (map 3.28). High road densities typically occur on subwatersheds with higher sensitivity to hydrologic regime disruption (map 3.29). Because forested watersheds are generally steeper and has less developed soils, they are generally more susceptible to erosion and sediment transport. Road densities are commonly high where forested watersheds have been developed for timber harvest. Poor road-drainage design or lack of drainage maintenance may cause slumps and washouts. Because of the narrow valley bottoms and draws of the Northern Cascades ERU, many roads were historically developed in close proximity to the stream network. Consequently, these roads often constrict the stream floodplain energy and have very short distances for sediment delivery.

The land-ownership pattern indicates that BLM/FS lands are fairly contiguous in the Northern Cascades ERU (map 3.30). There are large areas with relatively uniform BLM/FS ownership and some interspersed areas with mixed ownership patterns. A large portion of the BLM/FS lands has moderate and high risk of fire occurrence and associated high-intensity wildfires that could be difficult to suppress (map 3.31). These areas generally occur among the steeper, mid- and lower-elevation terrain of the dry and moist forest PVGs. Some areas at the landscape scale, particularly the break landforms, have high fire risk. The moderate and high risk have been related primarily to potential wildfire occurrence from lightning and human-caused ignition; dry spring, summer, and fall conditions; steep terrain; and heavy forest fuels that create the potential for severe fire behavior.

The Northern Cascades ERU has many areas that have high fuel accumulations, high potential for crown fire, and high potential of forest insect, disease, and stress-related mortalities at lower elevations (map 3.32). These areas have been associated with the dry forest and moist forest PVGs which have a high rate of NPP and high carbon stress. Timber harvest practices in these areas often removed most of the large, shade-intolerant trees that were more resistant to these mortality agents. The large, shade-intolerant trees have generally been replaced by smaller, shade-tolerant tree species that are susceptible to these types of mortality.

There are moderate and high risks related to the rural/wildland interface on the BLM/FS lands (map 3.33). At the landscape scale, high-risk areas often occur at the edge of the steep foothill or mountain environments. Rural developments are typically associated with the adjacent narrow valley landforms that are on the edge of, or interspersed with, the steep foothill or mountain landforms.

PVG composition did not change substantially between the historical and current periods in the Northern Cascades ERU (maps 3.11 and 3.12). Agricultural development occurred primarily in the dry shrub, dry grass, and dry forest PVGs and directly affected 7 percent of the ERU (table 3.77). The moist forest and cold forest PVGs dominated the area. The composition of PVGs on BLM/FS lands was similar, whereas Other lands were dominated by the moist forest PVG. Roads occupied approximately 2.3 percent of the ERU, and were nearly evenly distributed between BLM/FS lands and Other land ownerships.

The physiognomic type composition of the dry forest PVG is summarized across land ownership strata in tables 3.78 and 3.79. On All ownerships, the areal extent of the mid-seral forest physiognomic type was more than twice as high as the HRV maximum. Although the amount of the late-seral multi-layer forest physiognomic type was above the historical range, the late-seral single-layer forest type was well below in comparison to the HRV. There were contrasting trends for BLM/FS and Other land ownerships. The abundance of the early-seral forest type on BLM/FS lands was well above the upper end of the HRV, probably in response to recent historical clearcut and seed tree harvest practices. On Other lands, the areal extent of the early-seral forest physiognomic type was at the lower end of the HRV, probably in response to recent selective harvests.

Table 3.77—Historical and current period potential vegetation groups (PVGs) for the Northern Cascades Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	7 / 15	0 / 0	7 / 7
Alpine	1 / 2	1 / 2	+[4]	+	1 / 1	1 / 1
Cold Forest	21 / 38	21 / 38	4 / 9	4 / 9	25 / 25	25 / 24
Cool Shrub	+	+	1 / 2	1 / 2	1 / 1	1 / 1
Dry Forest	6 / 11	6 / 11	7 / 16	6 / 13	13 / 13	12 / 12
Dry Grass	1 / 2	1 / 2	2 / 4	1 / 2	3 / 3	2 / 2
Dry Shrub	+	+	6 / 14	2 / 4	6 / 6	2 / 2
Moist Forest	26 / 47	26 / 46	23 / 52	23 / 51	49 / 49	49 / 48
Riparian Shrub	0 / 0	0 / 0	+	+	+	+
Riparian Woodland	+	+	+	+	+	+
Road	NA[5] / NA	1.0 / 2	NA / NA	1.3 / 3	NA / NA	2.3 / 2
Rock	0 / 0	0 / 0	0 / 0	0 / 0	0	0 / 0
Urban	0 / 0	0 / 0	0 / 0	+	0 / 0	+
Water	+	+	1 / 2	1 / 1	1 / 1	1 / 1
Woodland	0 / 0	0 / 0	+	+	+	+
Total[6]	55 / 100	56 / 101	44 / 99	45.3 / 101	99 / 99	102.3 / 100

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes. Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes. For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

Table 3.78—Current and historical period physiognomic types for the dry forest potential vegetation group (PVG) for Northern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	13	4	4	2
	Exotic Herbland	1	0	0	0
	Late-seral Multi-layer Forest	24	17	16	19
	Late-seral Single-layer Forest	0	36	63	71
	Mid-seral Forest	55	39	17	9
	Upland Herbland	7	2	0	0
	Upland Shrubland	0	2	+[3]	0
Other	Early-seral Forest	8	12	23	7
	Exotic Herbland	0	0	0	0
	Late-seral Multi-layer Forest	9	10	9	11
	Late-seral Single-layer Forest	3	24	31	51
	Mid-seral Forest	80	17	36	31
	Upland Herbland	+	18	+	0
	Upland Shrubland	0	20	1	0
All	Early-seral Forest	11	9	15	5
	Exotic Herbland	+	0	0	0
	Late-seral Multi-layer Forest	16	13	12	15
	Late-seral Single-layer Forest	2	29	45	60
	Mid-seral Forest	68	26	28	21
	Upland Herbland	3	11	+	0
	Upland Shrubland	0	12	1	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.79—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Northern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	3	3	3	1
	Early-seral Shade-tolerant Forest	10	1	1	+[3]
	Exotic Herbland	1	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	6	14	9	13
	Late-seral Shade-intolerant Single-layer Forest	0	34	62	70
	Late-seral Shade-tolerant Multi-layer Forest	18	3	7	6
	Late-seral Shade-tolerant Single-layer Forest	0	2	1	1
	Mid-seral Shade-intolerant Forest	42	28	13	6
	Mid-seral Shade-tolerant Forest	13	10	4	3
	Upland Herbland	7	2	0	0
	Upland Shrubland	0	2	+	0
Other	Early-seral Shade-intolerant Forest	7	12	22	6
	Early-seral Shade-tolerant Forest	1	1	1	1
	Exotic Herbland	0	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	3	9	6	8
	Late-seral Shade-intolerant Single-layer Forest	3	21	30	50
	Late-seral Shade-tolerant Multi-layer Forest	6	1	3	3
	Late-seral Shade-tolerant Single-layer Forest	+	3	1	1
	Mid-seral Shade-intolerant Forest	62	15	29	22
	Mid-seral Shade-tolerant Forest	18	3	7	9
	Upland Herbland	+	18	+	0
	Upland Shrubland	0	20	1	0
All	Early-seral Shade-intolerant Forest	5	8	14	4
	Early-seral Shade-tolerant Forest	6	1	1	1
	Exotic Herbland	+	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	4	11	7	10
	Late-seral Shade-intolerant Single-layer Forest	2	27	44	59
	Late-seral Shade-tolerant Multi-layer Forest	12	2	5	4
	Late-seral Shade-tolerant Single-layer Forest	+	2	1	1
	Mid-seral Shade-intolerant Forest	53	21	22	15
	Mid-seral Shade-tolerant Forest	16	6	6	6
	Upland Herbland	3	11	+	0
	Upland Shrubland	0	12	1	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

On BLM/FS lands, the areal extent of the late-seral multi-layer forest physiognomic types was substantially above the upper end of the HRV, while on Other lands it was at the lower end of the HRV.

The late-seral single-layer physiognomic type followed similar trends on both BLM/FS and Other ownerships. In general, both early- and late-seral types shifted to mid-seral types because of fire exclusion, harvest activities, and insect, disease, and stress mortality associated with the overstory. In areas where the forests were harvested using clearcut and seed tree treatments, forest succession was accelerated toward mid-seral types as a result of regeneration planting activities. Fire exclusion eliminated the non-lethal and mixed fires that had maintained the late-seral single-layer physiognomic types and thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer physiognomic types. Clearcut, seed tree, shelterwood, and group-selection timber-harvest activities commonly created a mosaic of early-seral patches with high down-fuel accumulations and fewer dead-standing or small, live tree structures. In the matrix areas surrounding the patches, the large trees and dead-standing trees were often selectively harvested. This combination of factors resulted in an overall landscape forest pattern that had high-risk conditions for fire, insects, disease, and stress mortalities.

In the dry forest PVG, the areal extent of the mid-seral physiognomic types dominated by shade-intolerant tree species was nearly twice as high as the upper limit of the HRV (table 3.79). This system was at very high risk of substantial mortality to insects, disease, and stress, as well as large, intense fires.

Trends in physiognomic types in the moist forest PVG of the Northern Cascades ERU were similar regardless of land ownership strata (tables 3.80 and 3.81). The areal extent of the early-seral forest type was generally well above the HRV for All ownerships. The amount of the late-seral single-layer forest type was well below the HRV. Departures from the HRV occurred as a result of timber harvest of late-seral forests and exclusion of fire.

The late-seral single- and multi-layer types shifted to mid-seral types due to harvest activities and insects, disease, and stress mortalities of the overstory. Fire exclusion eliminated non-lethal and mixed fires that had maintained late-seral single- and multi-layer types and thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer types. Clearcut, seed tree, shelterwood, and group-selection timber-harvest activities commonly created a mosaic of early-seral patches with few standing dead or live tree structures, and high down-fuel accumulations. Typically, the large trees and dead-standing trees were selectively harvested in the matrix areas surrounding the regeneration harvest patches. This combination of factors resulted in an overall landscape forest pattern that had high-risk conditions for fire, insects, disease, and stress mortalities.

In the Northern Cascades ERU moist forest PVG, the areal extent of the mid-seral forest types dominated by shade-tolerant tree species was at the upper limit of the HRV for All ownerships, was low in comparison to the HRV for BLM/FS ownerships, and was high in comparison to the HRV for Other ownerships (table 3.81).

In the cold forest PVG of the Northern Cascades ERU, composition and physiognomic type varied considerably among ownership strata (tables 3.82 and 3.83). During the current period, the early-seral physiognomic type was substantially higher in areal extent than in the HRV for all ownership strata as a result of the extensive even-age harvesting (that is, clearcut and seed tree) that occurred within the subalpine forest. There were fairly even amounts of early-seral and mid-seral forest types on BLM/FS lands, while on Other ownerships the areal extent of the mid-seral forest type was almost twice that of the early-seral forest type. Across the entire ERU, there has been less clearcutting and wildfire occurrence on Other land ownerships. The amount of cold forest PVG land area in Other ownerships was small and nearly evenly distributed between (1) National Park/Tribal

Table 3.80—Current and historical period physiognomic types for the moist forest potential vegetation group (PVG) for Northern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	46	15	22	24
	Late-seral Multi-layer Forest	18	18	28	33
	Late-seral Single-layer Forest	+[3]	13	8	7
	Mid-seral Forest	36	53	42	37
Other	Early-seral Forest	16	23	22	22
	Late-seral Multi-layer Forest	13	18	24	28
	Late-seral Single-layer Forest	8	24	16	12
	Mid-seral Forest	63	35	39	38
All	Early-seral Forest	32	19	22	23
	Late-seral Multi-layer Forest	16	18	26	31
	Late-seral Single-layer Forest	4	19	12	9
	Mid-seral Forest	49	45	40	37

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

lands, where there had been little effect from harvest and fire, and (2) private industrial timber lands that had been substantially harvested. On BLM/FS and Other ownerships, the areal extent of the early-seral forest physiognomic type was well above the HRV. For All ownerships, the amount of the early-seral forest physiognomic type was almost twice the upper end of the HRV. The areal extent of the late-seral single-layer forest physiognomic type was essentially non-existent for all strata because of timber harvest activities and the exclusion of non-lethal and mixed-severity fires. The areal extent of the late-seral multi-layer forest type was substantially below the lower end of the HRV regardless of ownership strata. Again, it appears that timber harvests converted a substantial proportion of the late-seral multi-layer type to the early-seral forest type. In the native system, mixed and non-lethal fires had maintained the late-seral single-layer and multi-layer physiognomic types at relatively constant levels. Lethal fires generally cycled the mid-seral stages to the early-seral type.

Structural stage and shade tolerance of the Northern Cascades ERU cold forest PVG is summarized in table 3.83. The areal extent of the mid-seral shade-tolerant forest physiognomic types was within the

Table 3.81—Current and historical period moist forest potential vegetation group (PVG) shade intolerance/shade tolerance for Northern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	15	7	14	15
	Early-seral Shade-tolerant Forest	30	8	8	9
	Late-seral Shade-intolerant Multi-layer Forest	5	8	11	12
	Late-seral Shade-intolerant Single-layer Forest	+[3]	13	7	5
	Late-seral Shade-tolerant Multi-layer Forest	13	10	17	21
	Late-seral Shade-tolerant Single-layer Forest	+	1	1	1
	Mid-seral Shade-intolerant Forest	17	19	16	13
	Mid-seral Shade-tolerant Forest	20	34	26	23
Other	Early-seral Shade-intolerant Forest	10	18	14	15
	Early-seral Shade-tolerant Forest	6	5	8	7
	Late-seral Shade-intolerant Multi-layer Forest	3	12	12	13
	Late-seral Shade-intolerant Single-layer Forest	1	24	15	10
	Late-seral Shade-tolerant Multi-layer Forest	10	6	12	16
	Late-seral Shade-tolerant Single-layer Forest	6	1	1	1
	Mid-seral Shade-intolerant Forest	36	21	20	19
	Mid-seral Shade-tolerant Forest	27	14	18	19
All	Early-seral Shade-intolerant Forest	13	12	14	15
	Early-seral Shade-tolerant Forest	19	7	8	8
	Late-seral Shade-intolerant Multi-layer Forest	4	10	11	12
	Late-seral Shade-intolerant Single-layer Forest	1	18	11	8
	Late-seral Shade-tolerant Multi-layer Forest	12	8	15	18
	Late-seral Shade-tolerant Single-layer Forest	3	1	1	1
	Mid-seral Shade-intolerant Forest	26	20	18	16
	Mid-seral Shade-tolerant Forest	23	24	23	21

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.82—Current and historical period physiognomic types for the cold forest potential vegetation group (PVG) for Northern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	52	15	26	25
	Late-seral Multi-layer Forest	6	15	24	25
	Late-seral Single-layer Forest	1	5	4	3
	Mid-seral Forest	42	65	46	47
Other	Early-seral Forest	32	18	22	23
	Late-seral Multi-layer Forest	7	12	22	28
	Late-seral Single-layer Forest	+[3]	5	3	3
	Mid-seral Forest	61	65	53	46
All	Early-seral Forest	49	15	25	25
	Late -seral Multi-layer Forest	6	15	24	26
	Late-seral Single-layer Forest	+	5	4	3
	Mid-seral Forest	45	65	48	47

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

HRV for Other ownerships, whereas it was somewhat below the HRV for All and BLM/FS ownership strata. Historically, the shade-tolerant forests in the late-seral single-layer type were always rare; in the current period, they were practically nonexistent, possibly because of insect- and disease-related mortalities. This trend was relatively unique to the Northern Cascades ERU.

In response to the changes in regional and landscape conditions, the succession/disturbance regimes underwent a substantial shift from acceleration, moderate-cycle, and maintenance regimes to long-cycle and retrogressive cycle regimes. Some of the area was roaded, and has been changed by harvest activities and fire exclusion. Most of the area within wilderness and roadless areas had low probabilities for re-establishment of the native regimes given the existing constraints of using prescribed fire. There was a low probability of returning to the native system mixture of succession regimes without the congruent restoration of the stand structures and fuel conditions.

Table 3.83—Current and historical period cold forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Northern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	38	8	18	18
	Early-seral Shade-tolerant Forest	14	6	8	6
	Late-seral Shade-intolerant Multi-layer Forest	4	9	10	7
	Late-seral Shade-intolerant Single-layer Forest	1	2	2	2
	Late-seral Shade-tolerant Multi-layer Forest	2	7	14	18
	Late-seral Shade-tolerant Single-layer Forest	0	3	1	2
	Mid-seral Shade-intolerant Forest	29	42	23	25
	Mid-seral Shade-tolerant Forest	13	23	24	22
Other	Early-seral Shade-intolerant Forest	16	7	18	16
	Early-seral Shade-tolerant Forest	16	11	4	7
	Late-seral Shade-intolerant Multi-layer Forest	5	5	9	7
	Late-seral Shade-intolerant Single-layer Forest	+[3]	2	1	2
	Late-seral Shade-tolerant Multi-layer Forest	2	7	13	21
	Late-seral Shade-tolerant Single-layer Forest	0	3	2	1
	Mid-seral Shade-intolerant Forest	32	43	23	24
	Mid-seral Shade-tolerant Forest	29	22	30	22
All	Early-seral Shade-intolerant Forest	35	8	18	18
	Early-seral Shade-tolerant Forest	14	7	7	7
	Late-seral Shade-intolerant Multi-layer Forest	4	8	10	7
	Late-seral Shade-intolerant Single-layer Forest	+	2	2	2
	Late-seral Shade-tolerant Multi-layer Forest	2	7	14	19
	Late-seral Shade-tolerant Single-layer Forest	0	3	2	1
	Mid-seral Shade-intolerant Forest	30	42	23	25
	Mid-seral Shade-tolerant Forest	15	23	25	22

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Northern Glaciated Mountains ERU

The Northern Glaciated Mountains ERU is located in northern Washington, Idaho, and Montana (map 3.3). This ERU has high relief (200 to 3,000 m) and complex landforms ranging from low-elevation broad valleys, to higher-elevation narrow valleys and breaks. The foothills and mountains developed primarily from glacial processes on volcanic, uplifted batholith granitic, and uplifted metasediments (map 3.17). Mountain ranges generally run from north to south with broad valleys in between. Watersheds are mixed between downstream and headwater systems (map 3.21). The Northern Glaciated Mountains ERU is primarily in ecoregion section M333D (map 3.1).

Climate is strongly influenced by the oceanic storm patterns from the west and the rain-shadow effect of the Cascade and Rocky Mountain ranges. There is a steep moisture gradient ranging from high precipitation zones of the mountain crests, to the low-elevation wide river valleys that receive little precipitation. However, this is variable depending on the geographic location of the mountain range and valley. Precipitation primarily falls in the form of winter snows, spring rains, and summer thunderstorms and showers. The upper elevations near the mountain crests have a relatively low gradient from wet winter and spring conditions, to moist-to-dry summer and fall conditions with a short growing season. The precipitation gradient changes rapidly at lower elevations on the mountain slopes, foothills, valleys, and breaks to a very steep gradient from moist winter and spring conditions to very dry summer and fall conditions with a moderately-long growing season. Precipitation is relatively high, averaging 82 centimeters per year, but ranges from 27 centimeters per year at low elevations to 315 centimeters per year at high elevations. The gradients of precipitation are not uniformly distributed throughout elevational ranges. Storms generally move from west to east, dropping moisture along orographic uplifts associated with mountain ranges. Valleys on the leeward side of the mountains often exist in a rain shadow. The east slopes of valleys are typically drier than their west slopes.

Soils in the Northern Glaciated Mountains ERU are highly diverse as a result of the diversity of parent materials and soil-forming processes associated with glacial deposition, glacially compacted till, volcanic ash fall, and erosion. The interaction of climate, parent material, and geomorphology has resulted in varied vegetation and disturbance regimes, and highly-complex biogeochemical processes. This ERU has dynamic succession/disturbance regimes because of its inherently high productivity, steep seasonal moisture gradients, complex topography, and high carbon stress and moderate water stress in upland areas.

Fire exclusion, timber harvest activities at low and mid elevations, invasion by exotic plants, and livestock grazing practices changed the fire regimes between the historical and current periods (see maps 3.22 and 3.23). Fire severity shifted from a mixture of lethal, mixed, and non-lethal, to mostly lethal in the forest PVGs. The harvest of large, shade-intolerant, fire-, insect-, disease-, and stress-resistant tree species, and the extended fire-return intervals promoted the dominance of shade-tolerant species. Shade-tolerant species are generally not as resistant to fire, insect, disease, and stress. In the non-forest PVGs, and in the herbaceous physiognomic type of the dry forest PVG, exotic forbs such as spotted knapweed, leafy spurge, sulfur cinquefoil, and diffuse knapweed became prevalent. Areas dominated by these species were relatively fire resistant, and had reduced fire frequencies.

From a regional scale perspective, the Northern Glaciated Mountains ERU is not highly susceptible to drought (map 3.24). However, at the landscape scale, there are areas located on steep topographic settings with southerly exposures that tend to have a droughty environment. These droughty environments are typically dominated by the dry forest, dry grass, or dry shrub PVGs, and are susceptible to invasion by exotic plants. Exotic forbs, in particular spotted knapweed, leafy spurge, sulfur cinquefoil, and diffuse knapweed, have been problematic in this ERU. Approximately 33, 13, and 15 percent of the Northern Glaciated Mountains

ERU is of high susceptibility to invasion by spotted knapweed, leafy spurge, and diffuse knapweed, respectively (table 3.47; maps 3.35, 3.36, and 3.37).

A moderate portion of this ERU has had a history of livestock grazing on public lands (map 3.25). Many allotments were closed on public lands as a result of forest succession and the subsequent decline of available forage. Rangeland conditions on public lands have generally improved since the mid-1900s, except where exotic vegetation has invaded the dry grass and dry shrub PVGs. Although riparian conditions have improved in some areas, problems continue to exist in many areas relative to stream channel conditions and the lack of shrub and herbaceous cover.

Road densities in the Northern Glaciated Mountains ERU range from high to moderate at low and mid elevations, and low to none at higher elevations (map 3.28). High and moderate road densities typically occur on watersheds that are more susceptible to the disruption of hydrologic regimes (map 3.29). In particular, the Northern Glaciated Mountains ERU has substantial amounts of moist-to-wet soils, which are subject to slumps and earth flows. Where forested watersheds have been developed for timber harvest, road densities are commonly moderate to high.

The pattern of BLM/FS and Other land ownerships within the Northern Glaciated Mountains ERU is fragmented (map 3.30). Typically, there are areas with relatively uniform BLM/FS ownership interspersed with areas of mixed, mosaic, and Other ownership patterns. A large portion of the BLM/FS lands have moderate risk of fire occurrence and associated high-intensity wildfires that could be difficult to suppress (map 3.31). These areas are mostly associated with mid and lower elevations, and with steep terrain comprised by dry and moist forests.

There are areas at the landscape scale, particularly the break landforms, that have high fire risks. The high risks have been related primarily to potential wildfire occurrence from lightning and human-caused ignitions; dry spring, summer, and fall conditions; complex steep terrain; and heavy forest fuels that create the potential for severe fire behavior. At lower elevations, the Northern Glaciated Mountains ERU contains areas with high fuel accumulations, high potential for crown fire, and high forest insect-, disease-, and stress-related mortalities (map 3.32). These areas have been associated with the dry and moist forest PVGs that have high NPP and high carbon stress. Historical timber harvest practices removed most of the large, shade-intolerant trees that are more resistant to these types of mortality. These large, shade-intolerant trees have typically been replaced by smaller, shade-tolerant tree species that are more susceptible to the above-mentioned mortality agents.

Moderate and high fire risks occur in the rural/wildland interface on the BLM/FS lands (map 3.33). At the landscape scale, the high-risk areas often occur at the edge of the steep foothill, mountain, or break environments. Rural developments are typically associated with the adjacent valley landforms.

Between the historical and current periods, PVG composition did not change substantially in the Northern Glaciated Mountains ERU (table 3.84, map 3.11 and 3.12). Agricultural development occurred at the expense of the dry shrub, dry grass, and dry forest PVGs, and directly affected 13 percent of the ERU. The moist forest and dry forest PVGs dominated the ERU as a whole, as well as the PVG composition of Other land ownerships. The PVG composition on BLM/FS lands was dominated by the moist forest. Approximately 2.7 percent of the ERU was converted to roads. Other land ownerships contained nearly 25 percent more roads than did BLM/FS lands.

Field experience in the Northern Glaciated Mountains ERU suggested that the extent of BLM/FS lands composed of the dry forest PVG had probably been underestimated. Inaccurate estimation of the dry forest extent may have been due to the fact that, on BLM/FS lands, these PVGs commonly occur in small patches within the complex terrain of the Northern Glaciated

Table 3.84—Historical and current period potential vegetation groups (PVGs) for the Northern Glaciated Mountains Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	13 / 21	0 / 0	13 / 13
Alpine	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Cold Forest	5 / 13	5 / 12	2 / 3	2 / 3	7 / 7	7 / 7
Cool Shrub	+[4]	+	1 / 2	1 / 2	1 / 1	1 / 1
Dry Forest	3 / 8	3 / 7	17 / 28	13 / 21	20 / 20	16 / 16
Dry Grass	+	+	6 / 10	2 / 3	6 / 6	2 / 2
Dry Shrub	0 / 0	0 / 0	4 / 7	1 / 2	4 / 4	1 / 1
Moist Forest	31 / 79	31 / 77	28 / 47	27 / 43	59 / 59	58 / 56
Riparian Shrub	+	+	+	+	+	+
Riparian Woodland	+	+	+	+	+	+
Road	NA[5] / NA	1.2 / 3	NA / NA	1.6 / 3	NA / NA	2.7 / 3
Rock	0 / 0	0 / 0	+	+	+	+
Urban	0 / 0	0 / 0	0 / 0	+	0 / 0	+
Water	+	+	2 / 3	2 / 3	2 / 2	2 / 2
Woodland	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Total[6]	39 / 100	40.2 / 99	60 / 100	62.6 / 101	99 / 100	102.7 / 101

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes. Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes. For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

Mountains ERU. Thus, even though our data indicated that the dry forest PVG composed less than 5 percent of BLM/FS lands, discussion of this PVG was warranted with respect to the changes of physiognomic types and associated succession/disturbance regimes.

The physiognomic type composition of the dry forest PVG varied among ownership strata in the Northern Glaciated Mountains ERU (tables 3.85 and 3.86). The areal extent of the early-seral forest physiognomic type was generally at the lower end of the HRV for All lands, substantially higher than the HRV on BLM/FS lands, and below the HRV on Other lands. These inconsistent trends occurred because timber harvest practices on much of the BLM/FS lands used mostly cycling treatments, such as clearcuts or seed tree cuts. However, on Other lands the emphasis was on selective harvest treatments. The areal extent of the mid-seral forest physiognomic type was two to three times as high as the HRV for all ownership strata, due to the retrogression of late-seral multi- or single-layer forest types to the mid-seral forest type. This retrogression was the result of selective harvesting of larger trees, fire exclusion, and the associated insect, disease, and stress mortalities of the residual, large, overstory trees. The late-seral multi-layer forest area was very low and the late-seral single-layer forest area was essentially non-existent in comparison to the HRV, regardless of land ownership strata.

In general, both the early- and late-seral physiognomic types shifted to the mid-seral physiognomic types because of fire exclusion, harvest activities, insects, disease, and stress mortalities in the overstory layer. In areas where the forests had been harvested using clearcut, seed tree and planting treatments, forest succession was accelerated toward mid-seral types faster than in the native system. Fire exclusion eliminated the non-lethal and mixed fires that had maintained the late-seral single- and multi-layer physiognomic types and thinned shade-tolerant tree species in the early-, mid-, and late-seral multi-layer physiognomic types. Clearcut, seed tree, shelterwood, and group-selection timber-harvest activities commonly created a mosaic of patches that comprised early-seral types, high down-fuel accumulations, and lacked dead and live structures. In the matrix areas surrounding the patches, the large trees and dead-standing trees were often selectively harvested. This combination of factors resulted in an homogenization of landscape forest patterns and increased the risks of fire, insect, disease, and stress mortalities.

The amount of the mid-seral physiognomic types in the dry forest PVG—which was dominated by both shade-tolerant and shade-intolerant tree species—was much higher than the HRV (table 3.86). This system was at very high risk of substantial mortality to insects, disease, stress, and large, high-intensity fires.

Trends in physiognomic type composition of the moist forest PVG of the Northern Glaciated Mountains ERU were similar in all ownership strata (tables 3.87 and 3.88). The areal extent of the early-seral forest physiognomic type was below the HRV because of fire exclusion and reduction of the early succession timeframe by advanced regeneration plantings. The areal extent of the mid-seral forest physiognomic type was twice the HRV. This was attributable to the lack of acceleration disturbances that would have moved the mid-seral forest type into the late-seral types; rapid succession of early-seral types into mid-seral stages; and the retrogression of late-seral forest types into mid-seral stages. The retrogression of late-seral forest types was caused by a lack of maintenance disturbances, loss of western white pine to blister rust, and selective harvesting of large, shade-intolerant trees that were more fire-, insect-, disease-, and stress-resistant.

The areal extent of the late-seral multi-layer forest physiognomic types was substantially below the HRV, and the late-seral single-layer physiognomic type was essentially non-existent. In areas where the forests were harvested using clearcut, seed tree, and planting treatments, forest succession was accelerated toward mid-seral types at a faster rate than in the native system.

Table 3.85—Current and historical period physiognomic types for the dry forest potential vegetation group (PVG) for Northern Glaciated Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	30	18	12	12
	Exotic Herbland	+[3]	0	0	0
	Late-seral Multi-layer Forest	4	28	19	21
	Late-seral Single-layer Forest	1	19	33	38
	Mid-seral Forest	64	35	36	29
	Upland Herbland	1	1	0	0
	Upland Shrubland	0	+	0	0
Other	Early-seral Forest	5	17	21	7
	Exotic Herbland	0	0	0	0
	Late-seral Multi-layer Forest	2	11	10	13
	Late-seral Single-layer Forest	+	23	37	53
	Mid-seral Forest	91	23	32	27
	Upland Herbland	1	21	+	0
	Upland Shrubland	+	5	+	+
All	Early-seral Forest	10	17	20	8
	Exotic Herbland	+	0	0	0
	Late-seral Multi-layer Forest	2	14	11	14
	Late-seral Single-layer Forest	+	22	36	50
	Mid-seral Forest	86	25	33	28
	Upland Herbland	1	18	+	0
	Upland Shrubland	+	4	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.86—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Northern Glaciated Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	27	9	9	9
	Early-seral Shade-tolerant Forest	3	9	3	3
	Exotic Herbland	+[3]	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	+	11	5	8
	Late-seral Shade-intolerant Single-layer Forest	1	7	23	29
	Late-seral Shade-tolerant Multi-layer Forest	4	16	14	12
	Late-seral Shade-tolerant Single-layer Forest	0	12	10	9
	Mid-seral Shade-intolerant Forest	10	16	17	13
	Mid-seral Shade-tolerant Forest	55	19	19	16
	Upland Herbland	1	1	0	0
	Upland Shrubland	0	+	0	0
Other	Early-seral Shade-intolerant Forest	4	16	19	6
	Early-seral Shade-tolerant Forest	1	2	2	1
	Exotic Herbland	0	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	+	8	6	9
	Late-seral Shade-intolerant Single-layer Forest	+	21	35	50
	Late-seral Shade-tolerant Multi-layer Forest	1	3	4	4
	Late-seral Shade-tolerant Single-layer Forest	0	2	2	2
	Mid-seral Shade-intolerant Forest	62	20	27	20
	Mid-seral Shade-tolerant Forest	29	4	6	7
	Upland Herbland	1	21	+	0
	Upland Shrubland	+	5	+	+
All	Early-seral Shade-intolerant Forest	9	15	18	6
	Early-seral Shade-tolerant Forest	2	3	2	2
	Exotic Herbland	+	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	+	9	6	9
	Late-seral Shade-intolerant Single-layer Forest	+	19	33	47
	Late-seral Shade-tolerant Multi-layer Forest	2	5	5	5
	Late-seral Shade-tolerant Single-layer Forest	0	4	3	3
	Mid-seral Shade-intolerant Forest	52	19	25	19
	Mid-seral Shade-tolerant Forest	34	6	8	9
	Upland Herbland	1	18	+	0
	Upland Shrubland	+	4	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.87—Current and historical period physiognomic types for the moist forest potential vegetation group (PVG) for Northern Glaciated Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	16	28	18	20
	Late-seral Multi-layer Forest	1	26	27	31
	Late-seral Single-layer Forest	+[3]	4	3	3
	Mid-seral Forest	83	42	51	45
Other	Early-seral Forest	16	29	21	21
	Late-seral Multi-layer Forest	2	22	25	29
	Late-seral Single-layer Forest	+	15	8	7
	Mid-seral Forest	82	35	46	43
All	Early-seral Forest	16	29	20	20
	Late-seral Multi-layer Forest	2	24	26	30
	Late-seral Single-layer Forest	+	9	6	5
	Mid-seral Forest	83	39	49	44

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Fire exclusion had eliminated the non-lethal and mixed-fire regimes that had maintained the late-seral single- and multi-layer physiognomic types, and thinned shade-tolerant tree species in the early-, mid-, and late-seral multi-layer physiognomic types. Clearcut, seed tree, shelterwood, and group-selection timber-harvest activities created a mosaic of early-seral patches with fewer live and dead trees, and high down-fuel accumulations. In the matrix areas surrounding the patches, the large trees and dead-standing trees were often selectively harvested. Consequently, landscape patterns were largely homogenized, increasing the risks of fire, insect, disease, and stress mortalities.

In general, the trends of shade-intolerant and shade-tolerant species were consistent with the physiognomic type trends of the moist forest PVG of the Northern Glaciated Mountains ERU (table 3.88). In the mid-seral physiognomic type, the amount of shade-tolerant forest was very high, relative to the HRV. The loss of western white pine from this system due to blister rust infestations resulted in the loss of a fast-growing, dominant tree in moist environments. This system had very high risks of substantial mortality from insects, disease, stress, and large high-intensity fires.

Table 3.88—Current and historical period moist forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Northern Glaciated Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	11	24	14	15
	Early-seral Shade-tolerant Forest	5	5	4	5
	Late-seral Shade-intolerant Multi-layer Forest	1	18	15	18
	Late-seral Shade-intolerant Single-layer Forest	0	3	3	3
	Late-seral Shade-tolerant Multi-layer Forest	1	8	13	14
	Late-seral Shade-tolerant Single-layer Forest	+[3]	1	+	+
	Mid-seral Shade-intolerant Forest	46	32	40	33
	Mid-seral Shade-tolerant Forest	36	10	11	12
Other	Early-seral Shade-intolerant Forest	12	27	15	16
	Early-seral Shade-tolerant Forest	4	2	5	5
	Late-seral Shade-intolerant Multi-layer Forest	1	18	17	19
	Late-seral Shade-intolerant Single-layer Forest	0	14	8	7
	Late-seral Shade-tolerant Multi-layer Forest	1	4	9	10
	Late-seral Shade-tolerant Single-layer Forest	+	1	1	+
	Mid-seral Shade-intolerant Forest	45	30	37	33
	Mid-seral Shade-tolerant Forest	37	5	9	11
All	Early-seral Shade-intolerant Forest	12	25	15	16
	Early-seral Shade-tolerant Forest	4	3	5	5
	Late-seral Shade-intolerant Multi-layer Forest	1	18	16	18
	Late-seral Shade-intolerant Single-layer Forest	0	8	5	5
	Late-seral Shade-tolerant Multi-layer Forest	1	6	11	12
	Late-seral Shade-tolerant Single-layer Forest	+	1	+	+
	Mid-seral Shade-intolerant Forest	46	31	39	33
	Mid-seral Shade-tolerant Forest	37	8	10	11

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

In response to the changes in regional and landscape conditions, the primary change in succession/disturbance regimes appears to have been a shift from moderate and accelerated cycles, to long and retrogressive cycles. Given the limitations of prescribed fire and the effects of blister rust on western white pine, we believe that restoration opportunities are limited in many of the wilderness and roadless areas. The current prescribed natural fire program experiences only a limited number of ignitions and a limited number of prescribed natural fires. The small number of ignitions are the result of efficient fire-suppression efforts. Wilderness and roadless areas have many restoration opportunities provided that a prescribed fire program allows an adequate number of ignitions. Restoration of roaded areas will require modification of landscape patterns, fuel conditions, and the promotion of western white pine and fire. Trends for the cold forest PVG are displayed in tables included in appendix 3-N.

Northern Great Basin ERU

The Northern Great Basin ERU is located primarily in Oregon (map 3.3). This ERU has a low relief (1,200 to 2,900 m) complex of wide valleys and plains with interspersed breaks and scattered foothills and mountains (map 3.17). Topography ranges from gentle to rugged as a result of differing types of volcanic and erosional processes. Landforms include a mix of valleys, plains, breaks, foothills, and a few scattered small mountain ranges, with a mix of headwater and downstream watersheds (map 3.21). The ERU is primarily in ecoregion section 342B (map 3.1).

Precipitation averages 32 centimeters per year (range = 23 to 82 cm). Most of the ERU is within 5 centimeters of the average. Areas on the low end of the precipitation range are generally confined to the desert areas; areas at the upper end of the range are confined to the mountainous areas. Climate is strongly influenced by the rain-shadow effect of the Cascade Mountains to the west and intermountain storm patterns from the southwest. Precipitation primarily falls in the form of winter rain or snow and some spring rains. Frequent winds and high temperatures during the growing season create high rates of evapotranspiration and soil surface moisture desiccation. There is a moderately steep gradient from relatively moist winter and spring conditions, to very dry summer and fall conditions. Soils are diverse due to the variation in type of parent material, effects of periglacial processes, soil depth, salinity, clay accumulation quantities, and presence of impermeable subsurface layers. However, the number of plant species able to dominate in this type of environment is relatively low. Consequently, vegetation diversity is fairly low. Net primary productivity is low, nutrient cycling is moderate, carbon stress is low, and water stress is high.

There were substantial changes in fire regimes in the Northern Great Basin ERU primarily as a result of exotic annual grass invasions, excessive livestock grazing pressure, and fire exclusion (maps 3.22 and 3.23). Exotic annual grasses are more flammable than the native vegetation, but excessive livestock grazing pressure normally reduced fuels to levels where fires would not carry. In contrast to ERUs that had more moisture, more forest vegetation, and higher fire occurrence during drought years, the Northern Great Basin ERU typically has experienced fire events during years that produce higher amounts of fine-grass fuels. In the forest PVGs, fire severity generally shifted from non-lethal and mixed, to lethal. In the non-forest PVGs, the primary change was increased variability in fire intervals.

From a regional-scale perspective, the Northern Great Basin ERU has substantial area that receives less than 30 centimeters of precipitation annually (map 3.24). Drought was frequent, occurring 18 percent of the years from 1895 to 1994. Conversely, there were periods of above-normal precipitation two or more years in succession (table 3.38; climate division: Oregon South Central). The droughty environment of the Northern Great Basin reduces the potential for successful restoration efforts in non-forest and dry forest PVG areas which have been altered by exotic vegetation or excessive livestock grazing pressure.

The Northern Great Basin ERU has had a long history of livestock grazing on both private and public lands (map 3.25). Excessive livestock grazing pressure in the late-1800s was documented in this ERU by Griffiths (1902). Reduction in palatable shrubs, grasses, and forbs in the valleys, foothills, and mountains (such as the Steens Mountain area) was evident by 1901. Most rangeland riparian areas were already in a very degraded condition by the turn of the century. Many stream and riverbanks had typically been downcut to the extent that their associated riparian area no longer existed. By the mid-1900s however, some improvements in rangeland conditions and associated watershed conditions were apparent.

During the last 100 years, invasion and spread of exotic plants has been extensive. Halogeton (*Halogeton glomeratus*), cheatgrass, medusahead, Scotch thistle (*Onopordum acanthium*), Mediterranean sage (*Salvia aethiopis*), perennial pepperweed (*Lepidium latifolium*), and dalmatian toadflax were prevalent in portions of the Northern Great Basin ERU in the current period. Approximately 64 percent of All lands, and 66 percent of BLM/FS lands in this ERU were of high susceptibility to invasion by cheatgrass (table 3.47; map 3.26). Invasions by these exotic plants have caused a decline in native biodiversity, particularly in the riparian and the dry shrub PVGs. Many upland rangelands have been seeded to desirable, exotic, perennial grasses, particularly crested wheatgrass, which in some areas also contributed to the decline of biodiversity. Even though there is little similarity in species composition relative to the native communities, the seeded exotic perennial-grass communities are more similar in structure and disturbance regimes than are exotic annual-grass communities. Currently, areas that support native plant communities without much exotic vegetation continue to persist in the Northern Great Basin ERU. These areas are typically located in inaccessible areas, or are devoid of open water and therefore have little history of excessive livestock grazing pressure.

Road densities in the Northern Great Basin ERU are generally low to moderate with few areas of very low and none (map 3.28). Most of the ERU has watersheds that are in relatively good condition (map 3.29). Soils susceptible to erosion by wind are extensive in the Northern Great Basin ERU (table 3.46; maps 3.18, 3.19, and 3.34). Saline soils, soils susceptible to shrinking or swelling from drying or wetting, and soils susceptible to erosion by water, are less extensive but still prevalent (table 3.46; maps 3.19, 3.20, 3.34, 3.41, 3.42, and 3.43).

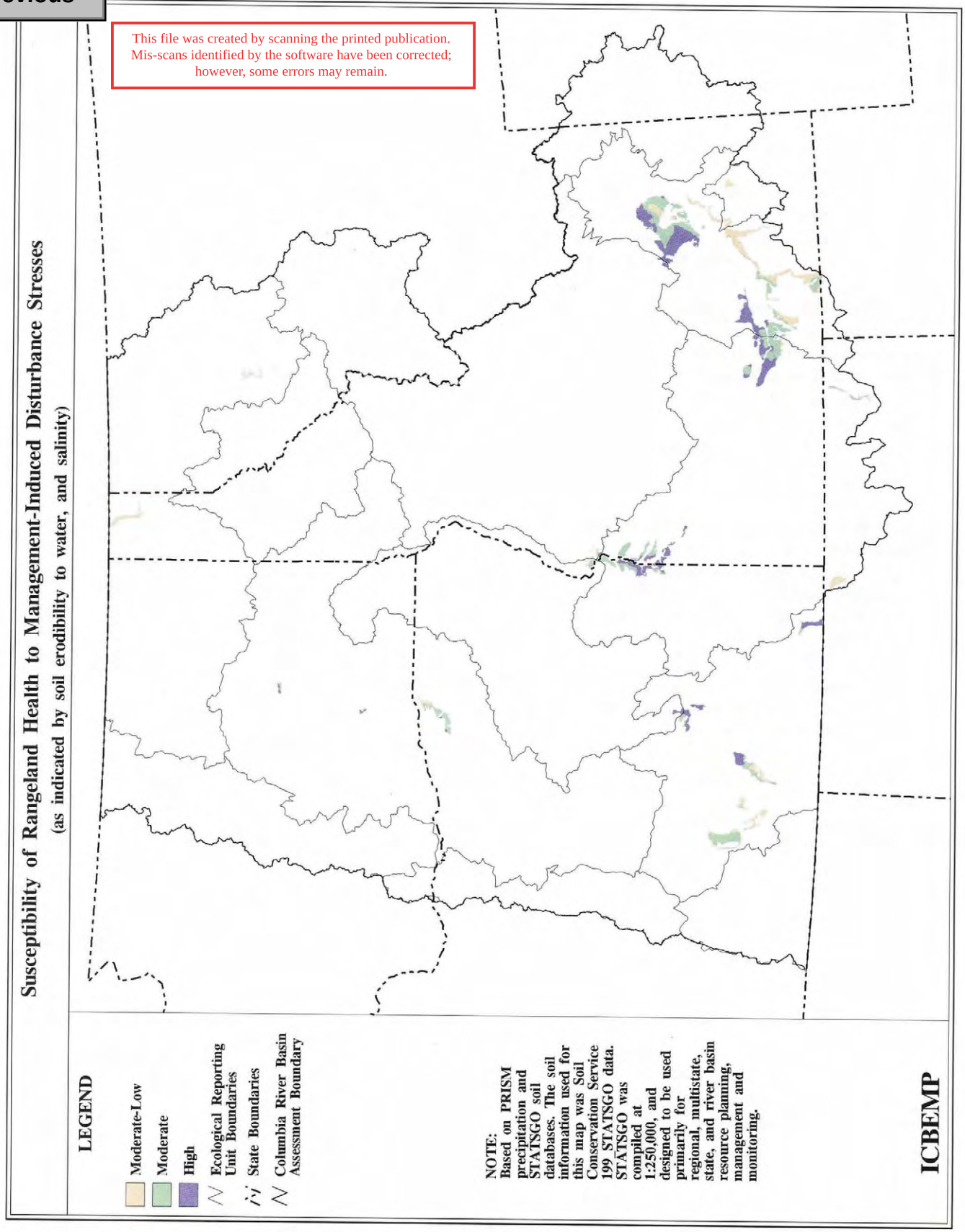
Patterns of BLM/FS and Other land ownerships are moderately fragmented. A relatively high proportion of the Northern Great Basin ERU is under BLM/FS ownership (map 3.30). Most of the breaks, plains, foothills, and mountains are in uniform BLM/FS ownership, with mixed and mosaic land ownerships in the valley areas. Approximately 50 percent of the BLM/FS lands has moderate risk of fire occurrence and associated high-intensity wildfires that could be difficult to suppress (map 3.31). These fires generally occur in areas with a mosaic of dry shrub and dry forest PVGs. There are some areas at the landscape scale, particularly the break landforms, that have high fire risks.

The Northern Great Basin ERU has a very small component of forest and woodland that has high fuel accumulations, and high potential for crown fires, forest insects, diseases, and stress-related mortalities (map 3.32). Moderate and high risks are due to potential wildfire occurrence from lightning or human-caused ignition; dry spring, summer, and fall conditions; complex break or foothill terrain; and flammable annual grass fuels intermingled with dry shrub PVGs which created the potential for severe fire behavior. There are no substantial risks related to the rural/wildland interface on the BLM/FS lands (map 3.33). At the landscape scale, there are some high-risk areas adjacent to small rural developments. These communities often occur at the edge of valleys adjacent to steep break or foothill environments.

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Map 3.41—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to water, and salinity. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having these specific soil-property indicators: an erodibility factor (K factor) exceeding 0.37, and salinity of 8 to 16 millimhos per centimeter (mmhos/cm); none of the other three, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Map 3.42—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil salinity. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having salinity of 8 to 16 millimhos per centimeter (mmhos/cm); none of the other four, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Map 3.43—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil salinity and potential for soil to shrink or swell from drying or wetting. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having these specific soil-property indicators: salinity of 8 to 16 millimhos per centimeter (mmhos/cm), and a high shrink-swell potential (SSP); none of the other three, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Rural developments are typically associated with the adjacent valley and plain landforms that are on the edge of, or interspersed with, the steep, complex topography of the break landforms. The break landforms are typically the BLM/FS lands or other public lands.

Between the historical and current periods, PVG composition did not change substantially in the Northern Great Basin ERU (table 3.89; maps 3.11 and 3.12). Only 3 percent of the ERU was developed for agriculture. Agricultural conversion primarily affected the dry forest, dry shrub, and riparian shrub PVGs. The dry shrub PVG dominated all ownership strata in the ERU. Approximately 1.8 percent of the total area was roaded, of which 1.3 percent was on BLM/FS lands and 0.5 percent was on Other lands.

The historical to current period trends in physiognomic type composition of the dry shrub PVG were similar for all ownership strata (table 3.90). Exotic herbland types were furthest outside the HRV as these species were not present in native systems. The amount of area occupied by exotic herblands was substantially underestimated for the current period. Exotic vegetation, especially cheatgrass, was scattered throughout the dry shrub PVG within the upland herbland and upland shrubland physiognomic types. The native system was generally dominated by a shifting mosaic of upland herbland and upland shrubland physiognomic types that were maintained by frequent non-lethal and mixed fires. As a result of excessive livestock grazing pressure and fire exclusion, the upland herbland physiognomic type declined, whereas the upland shrubland physiognomic type increased. Thus, the shifting mosaic that existed historically was generally replaced by a relatively static mosaic of annual grass patches and patches of shrubs mixed with annual grasses.

The historical trends of physiognomic type composition in the dry forest PVG were similar for all ownership strata (tables 3.91 and 3.92). The amount of the exotic herbland type was substantially underestimated because of forest overstory cover and misidentification as early-seral vegetation. The amount of the late-seral multi-layer forest physiognomic type was well above the HRV. The amount of the late-seral single-layer forest physiognomic type occurred substantially below or at the low end of the HRV. These conditions related primarily to the exclusion of non-lethal and mixed-underburn fires. There were no substantial timber harvest effects in this ERU. The environments of the dry forest were very dry and succession to multi-layer physiognomic types in the absence of fire was very slow.

In essence, the trends toward (1) decreases in the early-seral type as a result of exclusion of cycling fires, (2) large increases in the mid-seral types as a result of retrogression from the late-seral multi-layer types and succession to the mid-seral types, and (3) loss of the late-seral single-layer types, occurred in this ERU at a very slow rate. The rate was slow because sites were very dry and lacked recent harvesting of the large shade-intolerant overstory trees. In general, the dry forest had fairly low risks of fire-, insect-, disease-, and stress-related mortalities. The amount of the mid-seral forest types, dominated by shade-intolerant tree species, was generally above the lower limit of the HRV, while the amount of the late-seral forests was substantially above the HRV (table 3.92).

In response to the changes in regional and landscape conditions on forest and rangelands, the succession/disturbance regimes went through a substantial shift from moderate-cycle and maintenance regimes to retrogressive-cycle regimes, primarily due to extensive livestock grazing pressure, fire exclusion, and secondarily to exotic vegetation invasion. Given the lack of technology related to long-term rehabilitation of areas invaded by exotic forbs or annual grasses, there is a low probability of restoring native succession/disturbance regimes. However, with improved grazing practices and restoration of the more productive (generally more mesic) environments, much of the native composition and structure could be restored. Riparian environments have more potential for restoration given stabilization of the hydrologic regime.

Table 3.89—Historical and current period potential vegetation groups (PVGs) for the Northern Great Basin Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	3 / 12	0 / 0	3 / 3
Alpine	+[4]	+	+	+	+	+
Cold Forest	+	+	+	+	+	+
Cool Shrub	3 / 4	3 / 4	2 / 8	2 / 8	5 / 5	5 / 5
Dry Forest	8 / 10	8 / 10	3 / 12	3 / 12	11 / 11	11 / 11
Dry Grass	1 / 1	1 / 1	+	+	1 / 1	1 / 1
Dry Shrub	60 / 79	60 / 78	16 / 64	14 / 55	76 / 75	74 / 72
Moist Forest	1 / 1	1 / 1	+	+	1 / 1	1 / 1
Riparian Shrub	2 / 3	2 / 3	2 / 8	1 / 4	4 / 4	3 / 3
Riparian Woodland	+	+	+	+	+	+
Road	NA[5] / NA	1.3 / 2	NA / NA	0.5 / 2	NA / NA	1.8 / 2
Rock	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0
Urban	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0
Water	1 / 1	1 / 1	2 / 8	2 / 8	3 / 3	3 / 3
Woodland	+	+	+	+	+	+
Total[6]	76 / 99	77.3 / 100	25 / 100	25.5 / 101	101 / 100	102.8 / 101

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes.

Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes. For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

Table 3.90—Current and historical period physiognomic types for the dry shrub potential vegetation group (PVG) for Northern Great Basin Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Woodland	+[3]	+	0	+
	Exotic Herbland	3	0	0	0
	Late-seral Single-layer Woodland	0	0	+	+
	Mid-seral Woodland	0	0	+	+
	Upland Herbland	1	1	65	66
	Upland Shrubland	97	99	35	34
Other	Early-seral Woodland	+	+	0	+
	Exotic Herbland	1	0	0	0
	Late-seral Single-layer Woodland	0	0	+	0
	Mid-seral Woodland	0	0	+	+
	Upland Herbland	+	2	65	65
	Upland Shrubland	99	98	35	35
All	Early-seral Woodland	+	+	0	+
	Exotic Herbland	2	0	0	0
	Late-seral Single-layer Woodland	0	0	+	+
	Mid-seral Woodland	0	0	+	+
	Upland Herbland	1	1	65	66
	Upland Shrubland	97	99	35	34

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]< 0.5%.

Table 3.91—Current and historical period physiognomic types for the dry forest potential vegetation group (PVG) for Northern Great Basin Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	12	18	13	9
	Exotic Herbland	+[3]	0	0	0
	Late-seral Multi-layer Forest	27	10	12	14
	Late-seral Single-layer Forest	27	34	47	56
	Mid-seral Forest	34	32	27	21
	Upland Herbland	+	3	0	0
	Upland Shrubland	0	4	+	0
Other	Early-seral Forest	5	17	16	9
	Exotic Herbland	0	0	0	0
	Late-seral Multi-layer Forest	36	10	12	14
	Late-seral Single-layer Forest	36	33	43	54
	Mid-seral Forest	23	24	28	23
	Upland Herbland	0	9	0	0
	Upland Shrubland	0	7	+	0
All	Early-seral Forest	10	17	14	9
	Exotic Herbland	+	0	0	0
	Late-seral Multi-layer Forest	30	10	12	14
	Late-seral Single-layer Forest	29	34	46	55
	Mid-seral Forest	31	30	28	21
	Upland Herbland	+	5	0	0
	Upland Shrubland	0	5	+	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.92—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Northern Great Basin Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	11	17	12	8
	Early-seral Shade-tolerant Forest	+[3]	+	1	1
	Exotic Herbland	+	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	20	10	10	11
	Late-seral Shade-intolerant Single-layer Forest	25	34	46	54
	Late-seral Shade-tolerant Multi-layer Forest	8	+	2	3
	Late-seral Shade-tolerant Single-layer Forest	2	0	1	1
	Mid-seral Shade-intolerant Forest	32	31	23	15
	Mid-seral Shade-tolerant Forest	2	1	4	6
	Upland Herbland	+	3	0	0
	Upland Shrubland	0	4	+	0
Other	Early-seral Shade-intolerant Forest	5	17	15	8
	Early-seral Shade-tolerant Forest	0	0	1	2
	Exotic Herbland	0	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	20	10	10	11
	Late-seral Shade-intolerant Single-layer Forest	33	33	42	52
	Late-seral Shade-tolerant Multi-layer Forest	16	0	2	3
	Late-seral Shade-tolerant Single-layer Forest	3	0	1	2
	Mid-seral Shade-intolerant Forest	21	24	25	17
	Mid-seral Shade-tolerant Forest	2	0	4	6
	Upland Herbland	0	9	0	0
	Upland Shrubland	0	7	+	0
All	Early-seral Shade-intolerant Forest	10	17	13	8
	Early-seral Shade-tolerant Forest	+	+	1	1
	Exotic Herbland	+	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	20	10	10	11
	Late-seral Shade-intolerant Single-layer Forest	27	34	45	54
	Late-seral Shade-tolerant Multi-layer Forest	10	+	2	3
	Late-seral Shade-tolerant Single-layer Forest	3	0	1	2
	Mid-seral Shade-intolerant Forest	29	29	24	16
	Mid-seral Shade-tolerant Forest	2	1	4	6
	Upland Herbland	+	5	0	0
	Upland Shrubland	0	5	+	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Owyhee Uplands ERU

The Owyhee Uplands ERU is located primarily in southwestern Idaho and southeastern Oregon (map 3.3). This ERU has relatively high relief (640 to 3,200 m) with a complex of plains interspersed with valleys and breaks, and scattered foothills and mountains (map 3.17). Topography is generally rugged as a result of different volcanic and erosional processes. Landforms include a mosaic of plains, valleys, breaks, foothills, and mountain ranges, with a mix of headwater and downstream watersheds (map 3.21). The Owyhee Uplands ERU is primarily in ecoregion section 342C (map 3.1).

The precipitation average for the ERU is 29 centimeters per year (range = 19 to 67 cm). Precipitation for most of the area is within 5 centimeters of the average. Areas on the low end of the range are generally confined to the desert and break areas, while areas at the upper end of the range are confined to the mountainous areas. Climate is strongly influenced by the rain-shadow effect of the Cascade Mountains to the west and intermountain storm patterns from the southwest. Precipitation primarily comes in the form of winter rain or snow, and some spring rains.

Frequent winds and relatively high temperatures during the growing season cause high rates of evapotranspiration and soil surface moisture desiccation. There is a moderately steep gradient from somewhat moist winter and spring conditions, to very dry summer and fall conditions with a long growing season. Soils are quite complex and varied in parent material type, periglacial process effects, depth, salinity, quantity of clay accumulation, and presence of impermeable subsurface layers. Few plant species dominate this environment, and vegetation diversity is fairly low. Net primary productivity is low, nutrient cycling is moderate, carbon stress is low, and water stress is high.

There were substantial changes in fire regimes between the historical and current periods, primarily resulting from the invasion of exotic annual grasses, excessive livestock grazing pressure, and fire exclusion (maps 3.22 and 3.23). Exotic annual grasses are more flammable than the native vegetation, but excessive livestock grazing pressure can reduce fuels to levels unable to carry fires. In contrast to ERUs that have greater moisture levels, more forest vegetation, and high fire occurrence during drought years, the Owyhee Uplands ERU typically has fires during moist years that produce higher amounts of fine-grass fuels. In the forest PVGs, fire severity has generally shifted from nonlethal and mixed, to a lethal regime. In the nonforest (rangeland) PVGs, the primary change has been a greater variability of fire intervals.

From a regional-scale perspective, a substantial proportion of the Owyhee Uplands ERU receives less than 30 centimeters of annual precipitation (map 3.24). Drought is frequent, occurring 16 to 20 percent of the time during the period 1895 to 1994 for this ERU (table 3.38; climate divisions: Oregon Southeast, Idaho Southwest Highlands, Idaho Central Plains, and Idaho Southwest Valleys). Conversely, only six to nine periods of above-normal precipitation, two or more years in succession, were detected from 1895 to 1994 (table 3.38). The droughty conditions of the Owyhee Uplands ERU reduce the potential for successful restoration efforts within the non-forest PVGs that have been altered by the invasion of exotic plants or excessive livestock grazing pressure.

The Owyhee Uplands ERU has had a long history of livestock grazing on both private and public lands (map 3.25). Excessive livestock grazing pressure was observed in this ERU in the late-1800s (Hodgeson 1948, in Yensen 1981; Piemeisel 1938, in Yensen 1981). Reduction in palatable shrubs, grasses, and forbs in the valleys, foothills, and mountains was evident by 1900. Most rangeland riparian areas were in a degraded condition by the turn of the century. By the mid-1900s however, some improvements in rangeland conditions and associated watershed conditions were apparent.

During the last 100 years, the invasion and spread of exotic plants has been extensive in the Owyhee Uplands ERU. Currently, cheatgrass, medusahead,

Scotch thistle, rush skeletonweed (*Chondrilla juncea*), Russian knapweed (*Centaurea repens*), whitetop, spotted knapweed (*Centaurea maculosa*), and diffuse knapweed are prevalent in portions of the ERU. Approximately 67 percent of All lands and 73 percent of BLM/FS lands in this ERU are of high susceptibility to invasion by cheatgrass (table 3.47; map 3.26). At present, a substantial portion of the ERU has cheatgrass and/or medusahead as either a monoculture or as an understory component (Pellant and Hall 1994). Consequently, native biodiversity has declined, particularly in the riparian and dry shrub PVGs. In addition, many upland rangelands have been seeded to exotic perennial grasses, especially crested wheatgrass, which in some areas has contributed to a reduction in biodiversity. Even though there is little similarity in species composition relative to the native communities, the structure and disturbance regimes of the seeded exotic perennial grass communities are more similar to the native communities than are the exotic annual grass communities. Some areas, typically those that were inaccessible to livestock use, continue to support native plant communities and do not have a prevalent exotic plant component.

Road densities in the Owyhee Uplands ERU are mostly low to moderate with a few areas having very low to none (map 3.28). Most of this ERU has watersheds that are in relatively good condition (map 3.29). Soils susceptible to erosion by water and wind, soils susceptible to shrinking or swelling from drying or wetting, and saline soils are extensive in the Owyhee Uplands ERU (table 3.46; maps 3.18, 3.19, 3.20, 3.34, 3.38, 3.39, 3.40, 3.41, and 3.42).

BLM/FS ownerships comprise a relatively large proportion of the Owyhee Uplands ERU. The pattern of BLM/FS and Other ownerships is moderately fragmented (map 3.30). Most of the breaks, plains, foothills, and mountains are in uniform BLM/FS ownership with mixed and mosaic ownerships in the valley areas. Approximately 70 percent of the BLM/FS lands have moderate risks of fire occurrence and associated high-intensity wildfires that could be difficult to suppress (map 3.31). These risk areas are generally located where a mosaic of dry shrub and dry forest PVGs occur. There are areas at the landscape scale, particularly the break landforms, that have high fire risk.

The Owyhee Uplands ERU has a very small component of dry forest and woodlands with high fuel accumulations, and high potential for crown fires, forest insects, diseases, and stress-related mortalities (map 3.32). Moderate and high risks have been related primarily to potential wildfire occurrence from lightning or human-caused ignition; dry spring, summer, and fall conditions; complex break or foothill terrain; and flammable annual grass fuels intermingled with dry shrub that create the potential for severe fire behavior. There are no substantial risks related to the rural/wildland interface on the BLM/FS lands (map 3.33). At the landscape scale, there are some high-risk areas adjacent to small rural developments. These communities are typically associated with the adjacent valley and plain landforms that are on the edge of, or interspersed with, the steep and complex topography of the break landforms. The break landforms are typically located on BLM/FS lands or other public lands.

PVG composition changed substantially in the Owyhee Uplands ERU between the historical and current periods, due to agricultural development (table 3.93; maps 3.11 and 3.12). Thirteen percent of the lands were converted to agriculture, which were primarily developed from the dry shrub, riparian shrub, and cool shrub PVGs. Regardless of ownership strata, the dry shrub PVG dominated the ERU, followed by the cool shrub PVG. Approximately 1.5 percent of the total area has been developed into roads, which are nearly evenly distributed between BLM/FS and Other land ownerships.

The physiognomic type composition of the dry shrub PVG was similar for all ownership strata (table 3.94). The exotic herbland type was far outside the HRV since they were not represented in the native systems. The areal extent of the exotic

Table 3.93—Historical and current period potential vegetation groups (PVGs) for the Owyhee Uplands Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agriculture	0 / 0	0 / 0	0 / 0	13 / 39	0 / 0	13 / 13
Alpine	+[4]	+	0 / 0	0 / 0	+	+
Cold Forest	+	+	+	+	+	+
Cool Shrub	19 / 28	19 / 27	5 / 16	4 / 12	24 / 24	23 / 22
Dry Forest	1 / 1	1 / 1	1 / 3	1 / 3	2 / 2	2 / 2
Dry Grass	1 / 1	1 / 1	1 / 3	1 / 3	2 / 2	2 / 2
Dry Shrub	47 / 68	47 / 67	20 / 63	13 / 39	67 / 66	60 / 58
Moist Forest	+	+	+	+	+	+
Riparian Shrub	+	+	4 / 13	+	4 / 4	+
Riparian Woodland	+	+	+	+	+	+
Road	NA[5] / NA	0.8 / 1	NA / NA	0.6 / 2	NA / NA	1.5 / 1
Rock	0 / 0	0	0 / 0	0 / 0	0 / 0	0 / 0
Urban	0 / 0	0	0 / 0	+	0 / 0	+
Water	+	+	+	+	+	+
Woodland	1 / 1	1 / 1	1 / 3	1 / 1	2 / 2	2 / 2
Total[6]	69 / 99	69.8 / 100	32 / 101	33.6 / 101	101 / 100	103.5 / 100

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes.

Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes. For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

Table 3.94—Current and historical period physiognomic types for the dry shrub potential vegetation group (PVG) for Owyhee Uplands Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Woodland	0	+[3]	0	0
	Exotic Herbland	4	0	0	0
	Late-seral Woodland	0	0	+	+
	Mid-seral Woodland	0	+	+	+
	Upland Herbland	4	2	61	61
	Upland Shrubland	92	98	39	39
Other	Early-seral Woodland	0	0	0	0
	Exotic Herbland	5	0	0	0
	Late-seral Woodland	0	0	0	0
	Mid-seral Woodland	0	0	0	0
	Upland Herbland	2	3	66	65
	Upland Shrubland	93	97	34	35
All	Early-seral Woodland	0	+	0	0
	Exotic Herbland	4	0	0	0
	Late-seral Woodland	0	0	+	+
	Mid-seral Woodland	0	+	+	+
	Upland Herbland	3	2	63	62
	Upland Shrubland	92	98	37	38

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

herbland physiognomic type was substantially underestimated for the current period because of misidentification as the upland herbland physiognomic type, and presence of the upland shrubland physiognomic type in the understory. Exotic vegetation composition may have been as high as 50 percent of the upland herbland physiognomic type. The historical system was generally dominated by a shifting mosaic of upland herbland and upland shrubland types that were maintained by frequent non-lethal and mixed fires. As a result of the invasion of exotic annual grasses and forbs, excessive livestock grazing pressure, and fire exclusion, this shifting mosaic was generally replaced by a relatively static mosaic of patches of annual grass, patches of shrub/annual grass, and some remnants of native upland shrub/bunchgrass patches.

The physiognomic type composition and trends of the cool shrub PVG were similar for all ownership strata (table 3.95). The areal extent of the exotic herbland physiognomic type was far outside the HRV. The areal extent of exotic herbland types was substantially underestimated for the current period because of difficulty in differentiating exotic forbs, perennial grasses, and annual grasses from the native upland herbland and upland shrubland types. The exotic component could have been as high as 35 percent of the upland herbland type and was common in much of the upland shrubland type. The areal extent of the mid-seral woodland physiognomic type exceeded the HRV, primarily because of the encroachment of western juniper (*Juniperus occidentalis*) into the cool shrub PVG. The historical systems were generally dominated by a shifting mosaic of upland herbland and upland shrubland types maintained by a mix of frequent non-lethal, mixed, and lethal fires. As a result of the invasion of exotic annual grasses and forbs, excessive livestock grazing pressure, seeding of desirable exotic-perennial grasses, and fire exclusion, this shifting mosaic was generally replaced by a relatively static mosaic of patches of exotics, patches of upland shrubland types, remnants of native upland shrubland/bunchgrass types, and woodlands dominated by western juniper.

Due to the invasion of exotic plants, excessive livestock grazing pressure, and fire exclusion, the succession/disturbance regimes of this PVG underwent substantial shifts from moderate-cycle and maintenance regimes, to retrogressive and short-cycle regimes. Given the lack of technology related to long-term rehabilitation of areas invaded by exotic species, there is little chance of restoring native succession/disturbance regimes. However, with improved grazing practices and restoration of the more productive environments (that is, more mesic), much of the existing composition and structure could be restored. Riparian environments have more potential for restoration, given that the hydrologic regime is stabilized.

Snake Headwaters ERU

The Snake Headwaters ERU is located in southeastern Idaho and western Wyoming (map 3.3). This ERU has moderate relief (1,300 to 3,700 m) with a complex of wide valleys, foothills, and mountains (map 3.17). The ERU contains a mixture of headwater and downstream watersheds (map 3.21). Erosional, fluvial, and glacial processes have created a complex topography. The ERU is primarily in ecoregion sections M331A and M331D (map 3.1).

Precipitation averages 71 centimeters per year (range = 26 to 131 cm). The precipitation and topographic gradients support moderately diverse vegetation. Climate is strongly influenced by oceanic storms from the west, the continental climates to the east, and intermountain storm patterns from the southwest. Precipitation primarily falls as winter snows, spring rains, and summer thunder storms. The gradient from relatively moist spring conditions, to dry summer and fall conditions is moderately steep and the growing season is moderately long. Consequently, the inherent rate of NPP and nutrient cycling is moderately high, as is the carbon and water stress on upland areas.

Substantial changes in fire regimes occurred between the historical and current periods, primarily as a result of fire exclusion (maps 3.22 and 3.23).

Table 3.95—Current and historical period physiognomic types for the cool shrub potential vegetation group (PVG) for Owyhee Uplands Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Woodland	1	1	1	1
	Exotic Herbland	1	0	0	0
	Late-seral Single-layer Woodland	0	+[3]	+	+
	Mid-seral Woodland	4	2	1	1
	Upland Herbland	1	3	31	31
	Upland Shrubland	93	94	68	68
Other	Early-seral Woodland	6	1	2	2
	Exotic Herbland	0	0	0	0
	Late-seral Single-layer Woodland	0	+	+	0
	Mid-seral Woodland	14	2	2	2
	Upland Herbland	7	15	41	41
	Upland Shrubland	74	83	56	55
All	Early-seral Woodland	2	1	1	1
	Exotic Herbland	1	0	0	0
	Late-seral Single-layer Woodland	0	+	+	+
	Mid-seral Woodland	6	2	1	1
	Upland Herbland	2	6	33	33
	Upland Shrubland	89	92	65	65

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Fire severity generally shifted from non-lethal and mixed to lethal regimes, and non-lethal to mixed regimes in the forest PVGs, and fire-return intervals became longer. In the non-forest PVGs, fire severity generally shifted from mixed to lethal, and fire-return intervals increased due to the removal of fine fuels by livestock grazing, encroachment of conifers, and fire exclusion.

From a regional perspective, the Snake Headwaters ERU is generally not in a high-risk drought climate; nearly all of the ERU averages greater than 30 centimeters annual precipitation (map 3.24). Therefore, most of the non-forest PVGs that have been altered by exotic plant invasions or by excessive livestock grazing pressure have a fairly high restoration potential. However, at the landscape scale, steep topographic settings with southerly exposures and thin soils tend to be droughty environments (approximately 5% of the area).

There has been a long history of livestock grazing on the public lands of the Snake Headwaters ERU (map 3.25). Since the late-1800s, much of the public land-ownership area that was in allotments has been grazed by sheep and cattle. Substantial improvements in range conditions and associated watershed conditions have occurred since the mid-1900s. Prevalent and important exotic plants in the Snake Headwaters ERU include dyers woad (*Isatis tinctoria*), spotted knapweed, and leafy spurge. The current period dry grass and riparian woodland PVGs were of high susceptibility to invasion by spotted knapweed and leafy spurge. Approximately 31 and 14 percent of All lands in the Snake Headwaters ERU were of high susceptibility to invasion by spotted knapweed and leafy spurge, respectively. Similarly, 18 and 3 percent of the BLM/FS lands within the ERU were of high susceptibility to invasion by spotted knapweed and leafy spurge (table 3.47; maps 3.35 and 3.36).

Road densities generally range from low to none in this ERU, but there are some areas with moderate and high densities (map 3.28). Because of its steep topography and moist-to-wet soils, much of the Snake Headwaters ERU has sensitive watersheds. Some of the watersheds on the outer edges of the ERU are in degraded conditions due to moderate-to-high road densities located in sensitive watersheds (map 3.29).

The pattern of BLM/FS and Other land ownerships is moderately fragmented in the Snake Headwaters ERU (map 3.30). A substantial component is in uniform BLM/FS lands, whereas mixed and mosaic patterns occur on the western side of the ERU. Very few of the BLM/FS lands have moderate or high risks of fire occurrence and associated high-intensity wildfires, which could be difficult to suppress (map 3.31). At the landscape scale, some of the area has high fire risks, particularly the lower-elevation, steeper, foothill topography. In addition, a minor component of the western edge of the Snake Headwaters ERU also has high fuel accumulations, high potential for crown fire, and high forest insect-, disease-, and stress-related mortalities (map 3.32). These areas are typically dry forests that have high carbon and water stress. There are also substantial risks to large areas of lodgepole pine in the cold forest PVG associated with mountain pine beetle mortality. There are moderate fire risks related to the rural/wildland interface on the BLM/FS lands that are adjacent to rural developments (map 3.33). At the landscape scale, high-risk areas are often at the edge of the steep foothill environments. Rural developments are typically associated with the bench or valley landforms that are on the edge of, or interspersed with, the steep topography of the foothill landforms. The foothill landforms are typically located on BLM/FS lands.

From the historical to the current period, PVG composition changed substantially in the Snake Headwaters ERU, the result of agricultural development on approximately 10 percent of the area (table 3.96; maps 3.11 and 3.12). Most of the agricultural development occurred in the dry shrub, dry forest, cold forest, and riparian woodland PVGs. In the current period, the ERU was dominated by the cold forest, riparian woodland, and dry forest PVGs (45, 18, and 17%, respectively), with lesser amounts of the dry grass PVG. BLM/FS lands were dominated by the cold forest

Table 3.96—Historical and current period potential vegetation groups (PVGs) for the Snake Headwaters Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	10 / 26	0 / 0	10 / 10
Alpine	1 / 2	1 / 2	1 / 3	1 / 3	2 / 2	2 / 2
Cold Forest	36 / 57	36 / 56	10 / 26	9 / 23	46 / 45	45 / 44
Cool Shrub	+[4]	+	+	+	+	+
Dry Forest	11 / 17	11 / 17	7 / 18	6 / 15	18 / 18	17 / 17
Dry Grass	2 / 3	2 / 3	3 / 8	3 / 8	5 / 5	5 / 5
Dry Shrub	1 / 2	1 / 2	9 / 23	1 / 3	10 / 10	2 / 2
Moist Forest	+	+	+	+	+	+
Riparian Shrub	+	+	1 / 3	1 / 3	1 / 1	1 / 1
Riparian Woodland	11 / 17	11 / 17	8 / 21	7 / 18	19 / 19	18 / 18
Road	NA[5] / NA	0.8 / 1	NA / NA	1.0 / 3	NA / NA	1.8 / 2
Rock	+	+	0 / 0	0 / 0	+	+
Urban	0 / 0	+	0 / 0	+	0 / 0	+
Water	1 / 2	1 / 2	+	+	1 / 1	1 / 1
Woodland	+	+	+	+	+	+
Total[6]	63 / 100	63.8 / 100	39 / 102	39 / 102	102 / 101	102.8 / 102

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes.

Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes. For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

PVG, whereas Other lands were dominated by the cold forest, dry shrub, and riparian woodland PVGs. Approximately 1.8 percent of the total ERU area was in roads of which 1.0 percent occurred on Other lands and 0.8 percent occurred on BLM/FS lands.

Although the dry shrub PVG composed less than 5 percent of BLM/FS lands in the Snake Headwaters ERU, we included a discussion of its physiognomic type changes, with respect to succession/disturbance regimes, because we believe that the areal extent of the dry shrub PVG on BLM/FS lands was underestimated. The dry shrub PVG commonly occurs in small patches within the complex terrain found throughout the Snake Headwaters ERU. Further, underestimations of the dry grass and cool shrub PVGs may have also occurred in this ERU, but it was determined that the trends of the dry shrub PVG are similar enough to provide an example of what has potentially occurred on the other non-forest PVGs.

The physiognomic type composition of the dry shrub PVG is summarized in table 3.97. The exotic herbland types were furthest outside the HRV, particularly on BLM/FS lands. However, the amount on Other lands was underestimated for the current period condition. The areal extent of the upland herbland physiognomic type was above the HRV for All, BLM/FS, and Other land ownerships. In contrast, the areal extent of the upland shrubland physiognomic type was well below the HRV as a result of fire exclusion, excessive livestock grazing pressure, and the invasion of exotic forbs such as dyers woad, spotted knapweed, and leafy spurge.

The physiognomic type composition of the Snake Headwaters ERU riparian woodland PVG was similar for all ownership strata (table 3.98). The exotic herbland types were far outside the HRV since they did not exist historically. The exotic herbland component on both BLM/FS lands and Other lands was probably underestimated for the current period because of misidentification as native herbland types, which either existed alone, or as the understory of the shrubland and woodland types. The areal extent of the upland herbland physiognomic type was well below the HRV, especially on BLM/FS lands. This decline of the upland herbland type was caused by conversion to exotic vegetation, and successional development as a result of fire suppression. The areal extent of the early-seral riparian woodland physiognomic type was well below the HRV as a result of fire exclusion. Conversely, the areal extent of the mid-seral riparian woodland type was substantially above the HRV due to the development of early-seral stages into mid-seral stages, and the retrogression of late-seral riparian woodland into mid-seral stages. The areal extent of the late-seral riparian woodland physiognomic type was substantially below the HRV. This retrogression was caused by insect and disease mortality of the large overstory trees; harvest of overstory trees; and excessive livestock grazing pressure that eliminated understory reproduction of broadleaf trees.

The physiognomic type composition of the Snake Headwaters ERU dry forest PVG varied by ownership strata (tables 3.99 and 3.100). The upland herbland and upland shrubland physiognomic type areas were below the HRV on all ownership strata due to the decline of non-lethal fires that had maintained herb and shrub dominance. The amount of the early-seral forest physiognomic type was within the HRV for All ownerships. However, on BLM/FS lands, the area of the early-seral forest physiognomic type was above the HRV, whereas on Other lands, it was at the lower end of the HRV. The area of the mid-seral forest physiognomic type was very high relative to the HRV on all ownership strata. This was due to the retrogression of the late-seral multi-layer type into the mid-seral type as a result of mortality of the large, overstory trees from insects, disease, stress, and selective timber harvest practices. For all strata, the late-seral multi-layer type was quite low compared to the HRV, whereas the late-seral single-layer forest type was above or at the upper end of the HRV. The increased trend for late-seral single-layer physiognomic type development was the opposite of the trends observed for this type in every other ERU in the Basin. This unique trend may have

Table 3.97—Current and historical period physiognomic types for the dry shrub potential vegetation group (PVG) for Snake Headwaters Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Exotic Herbland	46	0	0	0
	Upland Herbland	54	9	28	26
	Upland Shrubland	0	91	72	74
Other	Exotic Herbland	15	0	0	0
	Upland Herbland	68	24	48	47
	Upland Shrubland	17	76	52	53
All	Exotic Herbland	34	0	0	0
	Upland Herbland	59	23	46	45
	Upland Shrubland	7	78	54	55

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

been related to the mortality of understory tree species due to root rot diseases and spruce budworm, even in the absence of non-lethal fires that would have maintained single-layer structures. Fire exclusion eliminated the non-lethal and mixed fires that had maintained late-seral single- and multi-layer types, and thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer types. In the peripheral areas that had been harvested, the larger shade-intolerant tree species had often been selectively cut. These were the trees that were more resistant to insect, disease, and stress mortalities.

In the dry forest PVG, the areal extent of the mid-seral forest types, dominated by shade-tolerant tree species, was well above the HRV (table 3.100). The conversion to dominance by shade-tolerant species was not as dramatic in the Snake Headwaters ERU as in many other ERUs because selective harvests of large, shade-intolerant trees had not been as extensive.

The physiognomic type composition of the cold forest PVG of the Snake Headwaters ERU also varied by ownership strata (tables 3.101 and 3.102). The areal extent of the early-seral physiognomic types was at the upper end of the HRV for the entire ERU and for BLM/FS lands. However, the areal extent of the early-seral type was well above the HRV for Other ownerships. The areal extent of the mid-seral forest physiognomic type occurred within the HRV for all ownership strata. The amount of the late-seral multi-layer forest physiognomic type was almost non-existent, while the amount of the single-layer physiognomic type was within HRV for all ownership strata. This general shift from late-seral to mid- and early-seral types appears to be related primarily to whitebark pine mortalities due to blister rust infestations combined with a lack of fire. Aspen (*Populus tremuloides*) was also in steep decline in the cold forest PVG in response to fire exclusion and excessive grazing pressure by livestock and native ungulates.

Table 3.98—Current and historical period physiognomic types for the riparian woodland potential vegetation group (PVG) for Snake Headwaters Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	+[3]	3	8	14
	Early-seral Riparian Woodland	6	44	7	13
	Exotic Herbland	+	0	0	0
	Late-seral Multi-layer Forest	0	0	0	0
	Late-seral Multi-layer Riparian Woodland	0	0	0	0
	Late-seral Single-layer Forest	0	0	0	0
	Mid-seral Forest	0	0	0	0
	Mid-seral Riparian Woodland	94	46	75	62
	Riparian Shrub Closed	0	0	0	0
	Riparian Shrub Open	0	0	0	0
	Upland Herbland	+	7	11	11
Other	Early-seral Forest	+	18	12	12
	Early-seral Riparian Woodland	1	23	10	9
	Exotic Herbland	3	0	0	0
	Late-seral Multi-layer Forest	0	0	+	+
	Late-seral Multi-layer Riparian Woodland	0	0	+	+
	Late-seral Single-layer Forest	0	0	+	+
	Mid-seral Forest	+	1	+	+
	Mid-seral Riparian Woodland	88	24	60	67
	Riparian Shrub Closed	0	1	+	+
	Riparian Shrub Open	0	0	0	0
	Upland Herbland	8	32	17	10
All	Early-seral Forest	+	9	9	13
	Early-seral Riparian Woodland	4	35	8	11
	Exotic Herbland	2	0	0	0
	Late-seral Multi-layer Forest	0	0	+	+
	Late-seral Multi-layer Riparian Woodland	0	0	+	+
	Late-seral Single-layer Forest	0	0	+	+
	Mid-seral Forest	+	1	+	+
	Mid-seral Riparian Woodland	92	37	69	64
	Riparian Shrub Closed	0	+	+	+
	Riparian Shrub Open	0	0	0	0
	Upland Herbland	3	18	13	11

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50;Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.99—Current and historical period physiognomic types for the dry forest potential vegetation group (PVG) for Snake Headwaters Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	21	20	14	7
	Late-seral Multi-layer Forest	3	19	27	34
	Late-seral Single-layer Forest	5	4	4	5
	Mid-seral Forest	70	40	47	55
	Upland Herbland	0	1	0	0
	Upland Shrubland	0	17	9	+[3]
Other	Early-seral Forest	12	30	20	7
	Late-seral Multi-layer Forest	0	7	7	13
	Late-seral Single-layer Forest	14	2	2	3
	Mid-seral Forest	75	13	49	77
	Upland Herbland	0	1	0	0
	Upland Shrubland	+	48	22	+
All	Early-seral Forest	18	24	17	7
	Late-seral Multi-layer Forest	2	14	19	25
	Late-seral Single-layer Forest	8	3	3	4
	Mid-seral Forest	72	30	48	63
	Upland Herbland	0	1	0	0
	Upland Shrubland	+	29	14	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.100—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Snake Headwaters Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	3	14	3	3
	Early-seral Shade-tolerant Forest	18	6	11	4
	Late-seral Shade-intolerant Multi-layer Forest	+[3]	1	1	1
	Late-seral Shade-intolerant Single-layer Forest	+	0	1	2
	Late-seral Shade-tolerant Multi-layer Forest	3	18	26	33
	Late-seral Shade-tolerant Single-layer Forest	5	4	3	3
	Mid-seral Shade-intolerant Forest	3	1	3	3
	Mid-seral Shade-tolerant Forest	68	38	44	52
	Upland Herbland	0	1	0	0
	Upland Shrubland	0	17	9	+
Other	Early-seral Shade-intolerant Forest	9	28	5	3
	Early-seral Shade-tolerant Forest	3	2	15	3
	Late-seral Shade-intolerant Multi-layer Forest	0	2	1	1
	Late-seral Shade-intolerant Single-layer Forest	+	+	1	1
	Late-seral Shade-tolerant Multi-layer Forest	0	5	6	12
	Late-seral Shade-tolerant Single-layer Forest	13	2	1	2
	Mid-seral Shade-intolerant Forest	5	5	8	9
	Mid-seral Shade-tolerant Forest	70	8	42	68
	Upland Herbland	0	1	0	0
	Upland Shrubland	+	48	22	+
All	Early-seral Shade-intolerant Forest	5	19	4	3
	Early-seral Shade-tolerant Forest	13	5	13	4
	Late-seral Shade-intolerant Multi-layer Forest	+	1	1	1
	Late-seral Shade-intolerant Single-layer Forest	+	+	1	2
	Late-seral Shade-tolerant Multi-layer Forest	2	13	19	25
	Late-seral Shade-tolerant Single-layer Forest	8	3	2	3
	Mid-seral Shade-intolerant Forest	3	3	5	5
	Mid-seral Shade-tolerant Forest	69	27	43	58
	Upland Herbland	0	1	0	0
	Upland Shrubland	+	29	14	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.101—Current and historical period physiognomic types for the cold forest potential vegetation group (PVG) for Snake Headwaters Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	24	14	28	22
	Early-seral Riparian Woodland	6	+[3]	2	2
	Late-seral Multi-layer Forest	2	28	23	21
	Late-seral Single-layer Forest	3	3	4	3
	Mid-seral Forest	49	52	38	44
	Mid-seral Riparian Woodland	16	3	6	8
Other	Early-seral Forest	38	26	31	24
	Early-seral Riparian Woodland	7	+	1	1
	Late-seral Multi-layer Forest	1	16	21	18
	Late-seral Single-layer Forest	5	3	5	6
	Mid-seral Forest	45	52	37	46
	Mid-seral Riparian Woodland	4	3	5	5
All	Early-seral Forest	27	17	28	23
	Early-seral Riparian Woodland	6	+	2	2
	Late-seral Multi-layer Forest	2	25	22	20
	Late-seral Single-layer Forest	3	3	4	3
	Mid-seral Forest	48	52	38	45
	Mid-seral Riparian Woodland	13	3	6	7

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.102—Current and historical period cold forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Snake Headwaters Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	8	12	22	18
	Early-seral Shade-tolerant Forest	16	3	6	4
	Late-seral Shade-intolerant Multi-layer Forest	+[3]	11	9	6
	Late-seral Shade-intolerant Single-layer Forest	2	1	3	2
	Late-seral Shade-tolerant Multi-layer Forest	2	17	14	15
	Late-seral Shade-tolerant Single-layer Forest	1	2	1	1
	Mid-seral Shade-intolerant Forest	8	37	21	25
	Mid-seral Shade-tolerant Forest	41	15	18	19
	Riparian Woodland	22	3	8	10
Other	Early-seral Shade-intolerant Forest	29	25	28	21
	Early-seral Shade-tolerant Forest	9	2	3	3
	Late-seral Shade-intolerant Multi-layer Forest	0	7	11	8
	Late-seral Shade-intolerant Single-layer Forest	4	1	5	6
	Late-seral Shade-tolerant Multi-layer Forest	1	9	9	10
	Late-seral Shade-tolerant Single-layer Forest	1	1	+	1
	Mid-seral Shade-intolerant Forest	16	42	25	34
	Mid-seral Shade-tolerant Forest	30	10	12	12
	Riparian Woodland	11	3	6	6
All	Early-seral Shade-intolerant Forest	13	15	23	19
	Early-seral Shade-tolerant Forest	15	2	5	4
	Late-seral Shade-intolerant Multi-layer Forest	+	10	9	6
	Late-seral Shade-intolerant Single-layer Forest	2	1	3	3
	Late-seral Shade-tolerant Multi-layer Forest	2	15	13	14
	Late-seral Shade-tolerant Single-layer Forest	1	2	1	1
	Mid-seral Shade-intolerant Forest	10	38	22	27
	Mid-seral Shade-tolerant Forest	39	14	17	18
	Riparian Woodland	20	3	7	9

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Historically, aspen forest structures dominated much of the late-seral single-layer and mid-seral physiognomic types in the Snake Headwaters ERU.

The areal extent of the late-seral shade-tolerant forest physiognomic type were well below the HRV in the cold forest PVG (table 3.102). This followed the same general trend observed for the other forest types, including increased mid-seral types dominated by shade-tolerant species.

In response to the changes in regional and landscape conditions on forests, the primary changes in succession/disturbance regimes appears to have been a shift from moderate- and long-cycles, to a retrogressive-cycle regime. Most of the area within the wilderness and roadless areas has a low probability for the re-establishment of the native succession/disturbance regimes given the current limitations of prescribed fire use and the effects of blister rust on whitebark pine. The areas on the periphery of the Snake Headwaters ERU are in a similar state. There is a low probability of returning to the cycling, maintenance, and acceleration regimes of this system without restoration of landscape structures, fuel conditions, whitebark pine, and fire.

Southern Cascades ERU

The Southern Cascades ERU is located in north central Oregon (map 3.3). This ERU has very high relief (20 to 3,600 m) and a complex of low-elevation to high-elevation valleys, and steep mountains that developed primarily from glacial and erosional processes (map 3.17). Topography is generally steep and complex. Landforms include a mix of river valleys with breaks, and mountains and foothills with narrow valleys. Headwater and downstream watersheds are juxtaposed (map 3.21). Precipitation across the ERU is relatively high, averaging 92 centimeters per year, and has a steep gradient ranging from 36 centimeters at low elevations to 248 centimeters at high elevations. The diverse climate and topography support a high diversity of vegetation and dynamic disturbance regimes. The Southern Cascades ERU is primarily in ecoregion section M242C (map 3.1).

Climate is strongly influenced by oceanic storm patterns from the west and the rain-shadow effect of the Cascade Mountains. There is a very steep gradient from the deep snowpacks and high precipitation that occur on the Cascade crest, to little snow and the low precipitation of the Columbia River Gorge and its tributaries. Precipitation primarily falls in the form of winter snows, spring rains, and summer thunderstorms and showers. The upper elevations near the crest of the Cascades have a relatively low gradient from wet winter and spring conditions to moist-to-dry summer and fall conditions with a short growing season. Moving away from the Cascade crest, this changes rapidly to a very steep gradient from moist winter and spring conditions to very dry summer and fall conditions with a moderately-long growing season. The Southern Cascades ERU has very dynamic succession/disturbance regimes because of its inherent productivity, very-steep seasonal-moisture gradients, complex topography, and high carbon and moderate water stresses in upland areas.

There were substantial changes in fire regimes between the historical and current periods in the Southern Cascades ERU, primarily as a result of fire exclusion, timber harvest activities conducted at low and mid elevations, and livestock grazing practices (maps 3.22 and 3.23). Fire severity generally shifted from a mixture of non-lethal, mixed, and lethal regimes, to lethal in the forest PVGs due to the harvesting of the large, shade-intolerant and fire-, insect-, disease-, and stress-resistant species. Furthermore, the associated longer intervals between fires promoted the dominance of shade-tolerant species. These species are generally not as resistant to fires, insects, diseases, and stress factors.

From a regional-scale perspective, the Southern Cascades ERU is not highly susceptible to drought. Only the northeast portion of Deschutes County (that is, north of Bend and west of Redmond, Oregon) within this ERU receives less than 30 centimeters of precipitation annually (map 3.24). Currently, exotic plants are not prevalent in the Southern Cascades ERU, but diffuse knapweed is

present and expanding, particularly along roads. Approximately 23 percent of All lands and 21 percent of BLM/FS lands in this ERU are of high susceptibility to invasion by diffuse knapweed (table 3.47; map 3.37).

A moderate portion of public lands in the Southern Cascades ERU have had a history of livestock grazing (map 3.25). Many allotments were closed on public lands due to the decline of forage attributed to forest succession. Rangeland conditions on public lands have generally improved since the mid-1900s, except where exotic plants have become established in the dry PVGs. Riparian conditions have improved in some areas, but problems continue to persist in many areas with respect to stream-channel conditions and the lack of shrub and herbaceous cover.

Road densities in the Southern Cascades ERU are high throughout most of the area (map 3.28). However, landforms and soils generally have a low-to-moderate sensitivity to disruption of the hydrologic regimes (map 3.29). The Southern Cascades ERU landforms, geology, and soil development are generally not as susceptible to erosion and sediment transport as other mountainous ERUs. Where forested watersheds have been developed for timber harvest, road densities are commonly high. Because of the narrow valley bottoms and draws of the Southern Cascades ERU, many roads were developed in close proximity to streams. Consequently, these roads often constrict stream floodplain energy and have very short distances for sediment delivery.

The pattern of BLM/FS and Other land ownerships is moderately fragmented in the Southern Cascades ERU (map 3.30). There are some areas with relatively uniform BLM/FS ownership interspersed with areas of mixed and mosaic ownership patterns. A large portion of the BLM/FS lands has moderate and high risk of fire occurrence and associated high-intensity wildfires that could be difficult to suppress (map 3.31). These high-risk areas generally occur on the mid and lower elevations of the dry forest and moist forest PVGs.

At the landscape scale, there are some areas, particularly the break landforms, that also have high risk of fire. The moderate and high risks have been related primarily to potential wildfire occurrence from lightning and human-caused ignitions; dry spring, summer, and fall conditions; complex terrain; and heavy forest fuels that create the potential for severe fire behavior. The Southern Cascades ERU has a substantial area that has high fuel accumulations, high potential for crown fires, and high potential of forest insect-, disease-, and stress-related mortalities (map 3.32). These mortality agents more commonly occur in areas of dry forest and moist forest PVGs that have high NPP and high carbon stress. Past timber-harvest practices often removed most of the large, shade-intolerant trees that tend to be more resistant to these mortality agents. These large, shade-intolerant trees have generally been replaced by smaller, shade-tolerant tree species that are more susceptible to the above-mentioned mortality agents.

There are high and moderate risks related to the rural/wildland interface on the BLM/FS lands (map 3.33). At the landscape scale, the high-risk areas often occur at the edge of the break, foothill, or mountain landforms. Rural developments are typically associated with the adjacent narrow valley landforms that are on the edge of, or interspersed with, these landforms.

The composition of PVGs did not change substantially in the Southern Cascades ERU between the historical and current periods (table 3.103; maps 3.11 and 3.12). Six percent of the ERU was converted to the agricultural PVG at the expense of the dry shrub and cool shrub PVGs. Almost 4 percent of the ERU was converted to roads. The ERU was dominated by the moist, dry, and cold forest PVGs. A greater proportion of the cold forest PVG occurred on BLM/FS lands. PVG composition on Other ownerships was dominated by dry forest and moist forest PVGs. Approximately two-thirds of the road development occurred on BLM/FS lands.

Table 3.103—Historical and current period potential vegetation groups (PVGs) for the Southern Cascades Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	6 / 13	0 / 0	6 / 6
Alpine	+[4]	+	+	+	+	+
Cold Forest	10 / 18	10 / 17	2 / 5	2 / 4	12 / 12	12 / 12
Cool Shrub	3 / 5	3 / 5	3 / 7	2 / 4	6 / 6	5 / 5
Dry Forest	18 / 32	18 / 30	16 / 37	15 / 34	34 / 34	33 / 32
Dry Grass	+	+	2 / 5	2 / 4	2 / 2	2 / 2
Dry Shrub	1 / 2	1 / 2	5 / 12	1 / 2	6 / 6	2 / 2
Moist Forest	23 / 40	23 / 39	14 / 33	14 / 33	37 / 37	37 / 36
Riparian Shrub	+	+	+	+	+	+
Riparian Woodland	0 / 0	0 / 0	+	0 / 0	+	0
Road	NA[5] / NA	2.2 / 4	NA / NA	1.7 / 4	NA / NA	3.9 / 4
Rock	+	+	+	+	+	+
Urban	0 / 0	+	0 / 0	+	0 / 0	+
Water	2 / 4	2 / 3	1 / 2	1 / 2	3 / 3	3 / 3
Woodland	0 / 0	0 / 0	+	+	+	+
Total[6]	57 / 101	59.2 / 100	43 / 101	44.7 / 98	100 / 100	103.9 / 102

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes.

Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes. For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

The physiognomic type composition of the dry forest PVG in the Southern Cascades ERU varied by ownership strata (tables 3.104 and 3.105). Exotic herbland physiognomic types were likely underestimated across all ownerships. Although the areal extent of the early-seral forest type occurred within the HRV for the entire ERU, it was above the range for BLM/FS lands, and just below the range for Other ownerships. These conflicting trends were likely due to the proportionately higher clearcutting and seed tree harvesting that had occurred on BLM/FS lands, and the greater proportion of selective and group harvest treatments on Other lands. The areal extent of the mid-seral forest physiognomic type on BLM/FS lands occurred within the HRV, whereas it was substantially above the HRV of Other lands. Most of the timber harvest activity on Other lands included the selective harvest of large, shade-intolerant trees from the late-seral types, which converted much of the type to mid-seral, whereas much of the timber harvesting on BLM/FS lands moved the late-seral to the early-seral types. The areal extent of the late-seral multi-layer forest physiognomic type occurred well above the HRV on BLM/FS lands, and well below the HRV on Other lands. In general, the late-seral type shifted to the mid-seral type because of fire exclusion, timber harvest activities, and insects, disease, and stress mortalities of overstory species. The areal extent of the late-seral single-layer physiognomic type was below the HRV for the ERU as a whole, at the lower end of the HRV on BLM/FS lands, and well below the HRV on Other lands. Again, the varying trends were due to much higher rates of selective cutting of the large, overstory trees on Other lands than on BLM/FS lands.

The formation of multiple canopy layers occurred much slower in the Southern Cascades ERU relative to adjacent ERUs. Consequently, much of the single-layer late-seral forest types remained in the single-layer stage for a longer time than in other ERUs, except for the Snake Headwaters and Upper Klamath ERUs, which had similar patterns. In areas where the forests were harvested using clearcut, seed tree, and planting treatments, forest succession was accelerated toward the mid-seral physiognomic types. Fire exclusion eliminated the non-lethal and mixed fire regimes that had maintained late-seral single- and multi-layer physiognomic types, and thinned shade-tolerant tree species in the early-, mid-, and late-seral multi-layer physiognomic types. This removed the trees that were more resistant to insects, disease, and stress mortalities.

The mid-seral forest physiognomic types, dominated by both shade-tolerant and shade-intolerant tree species, were at the upper limit of the HRV in the dry forest PVG of the Southern Cascades ERU (table 3.105). The areal extent of the late-seral single-layer shade-tolerant types was well above the HRV, whereas the areal extent of the late-seral multi-layer shade-tolerant types was at the upper limit of the HRV. Consequently, the dry forest PVG had high risks of substantial mortality from insects, disease, stress factors, and large, high-intensity fires.

In response to the changes in regional and landscape conditions, the succession/disturbance regimes went through a substantial shift from maintenance and acceleration regimes, to cycling and retrogression regimes. Most of the areas have been roaded and have changed from maintenance to cycling regimes via timber harvest activities and fire exclusion. There is a low probability of restoring native succession/disturbance regimes without simultaneous restoration of the stand structures and fuel conditions.

The physiognomic type composition of the Southern Cascades ERU moist forest PVG varied by ownership strata (table 3.106 and 3.107). The areal extent of the early-seral forest physiognomic type was within the HRV on BLM/FS lands, but well below the HRV on Other ownerships. This difference was likely attributable to fewer clearcut and seed tree timber harvests on Other lands relative to BLM/FS lands. The areal extent of the mid-seral physiognomic type also varied by ownership; it was well below the HRV on BLM/FS lands, but well above the HRV on Other lands. Again, it appears that most of the harvests on

Table 3.104—Current and historical period physiognomic types for dry forest potential vegetation group (PVG) for Southern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	17	10	10	11
	Late-seral Multi-layer Forest	21	12	13	16
	Late-seral Single-layer Forest	25	24	49	57
	Mid-seral Forest	35	53	27	17
	Upland Herbland	1	1	0	0
	Upland Shrubland	1	+[3]	+	0
Other	Early-seral Forest	9	17	15	10
	Late-seral Multi-layer Forest	11	15	14	18
	Late-seral Single-layer Forest	18	29	45	53
	Mid-seral Forest	62	32	25	20
	Upland Herbland	0	5	0	0
	Upland Shrubland	+	2	1	0
All	Early-seral Forest	14	13	13	10
	Late-seral Multi-layer Forest	17	13	14	17
	Late-seral Single-layer Forest	22	27	47	55
	Mid-seral Forest	47	43	26	18
	Upland Herbland	1	3	0	0
	Upland Shrubland	+	1	1	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.105—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Southern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	15	9	9	10
	Early-seral Shade-tolerant Forest	2	1	1	1
	Late-seral Shade-intolerant Multi-layer Forest	15	10	11	12
	Late-seral Shade-intolerant Single-layer Forest	10	23	48	56
	Late-seral Shade-tolerant Multi-layer Forest	6	2	3	3
	Late-seral Shade-tolerant Single-layer Forest	15	2	1	1
	Mid-seral Shade-intolerant Forest	30	48	23	13
	Mid-seral Shade-tolerant Forest	5	5	5	4
	Upland Herbland	1	1	0	0
	Upland Shrubland	1	+[3]	+	0
Other	Early-seral Shade-intolerant Forest	7	16	14	9
	Early-seral Shade-tolerant Forest	2	1	1	1
	Late-seral Shade-intolerant Multi-layer Forest	5	9	8	12
	Late-seral Shade-intolerant Single-layer Forest	3	26	44	52
	Late-seral Shade-tolerant Multi-layer Forest	6	6	6	6
	Late-seral Shade-tolerant Single-layer Forest	15	4	2	1
	Mid-seral Shade-intolerant Forest	49	23	17	12
	Mid-seral Shade-tolerant Forest	14	9	8	8
	Upland Herbland	0	5	0	0
	Upland Shrubland	+	2	1	0
All	Early-seral Shade-intolerant Forest	11	12	11	9
	Early-seral Shade-tolerant Forest	2	1	1	1
	Late-seral Shade-intolerant Multi-layer Forest	11	9	9	12
	Late-seral Shade-intolerant Single-layer Forest	6	24	46	54
	Late-seral Shade-tolerant Multi-layer Forest	6	4	4	5
	Late-seral Shade-tolerant Single-layer Forest	15	3	1	1
	Mid-seral Shade-intolerant Forest	39	36	20	13
	Mid-seral Shade-tolerant Forest	9	7	6	6
	Upland Herbland	1	3	0	0
	Upland Shrubland	+	1	1	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.106—Current and historical period physiognomic types for the moist forest potential vegetation group (PVG) for Southern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	19	11	18	23
	Late-seral Multi-layer Forest	19	18	31	34
	Late-seral Single-layer Forest	34	26	12	10
	Mid-seral Forest	29	45	38	34
Other	Early-seral Forest	8	21	24	28
	Late-seral Multi-layer Forest	20	19	25	29
	Late-seral Single-layer Forest	21	21	11	9
	Mid-seral Forest	51	39	41	35
All	Early-seral Forest	15	15	20	25
	Late-seral Multi-layer Forest	19	18	29	32
	Late-seral Single-layer Forest	29	24	12	9
	Mid-seral Forest	37	43	39	34

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

Other lands were selective cuts of the large, overstory trees of the late-seral types, which converted these types to mid-seral or late-seral single-layer types. The late-seral multi- and single-layer forest physiognomic types changed in a like manner, regardless of ownership strata. The areal extent of the late-seral multi-layer physiognomic type was at the lower limit of the HRV, while the late-seral single-layer physiognomic type was above the upper areal extent of the HRV. In areas where the forests were cycled using clearcut and seed tree treatments, forest succession was accelerated toward the mid-seral physiognomic type through the use of advanced regeneration plantings.

Fire exclusion eliminated the non-lethal and mixed fire regimes that had maintained late-seral single- and multi-layer physiognomic types, and thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer physiognomic types. This removed the trees that were more resistant to insects, disease, and stress mortalities. Clearcut, seed tree, shelterwood, and group-selection timber-harvest activities created a mosaic of early-seral patches containing few live or dead-standing tree structures, and high down-fuel accumulations. In the matrix areas surrounding these patches, the large trees and dead-standing trees were often selectively harvested. This combination of factors homogenized landscape patterns and increased the risks of fire-, insect-, disease-, and stress-related mortality.

Table 3.107—Current and historical period moist forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Southern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	7	2	13	16
	Early-seral Shade-tolerant Forest	12	9	5	7
	Late-seral Shade-intolerant Multi-layer Forest	8	10	17	16
	Late-seral Shade-intolerant Single-layer Forest	19	25	11	9
	Late-seral Shade-tolerant Multi-layer Forest	10	8	14	18
	Late-seral Shade-tolerant Single-layer Forest	14	1	1	1
	Mid-seral Shade-intolerant Forest	18	33	19	17
	Mid-seral Shade-tolerant Forest	11	12	19	17
Other	Early-seral Shade-intolerant Forest	2	7	18	20
	Early-seral Shade-tolerant Forest	7	14	6	8
	Late-seral Shade-intolerant Multi-layer Forest	2	7	13	15
	Late-seral Shade-intolerant Single-layer Forest	9	20	9	7
	Late-seral Shade-tolerant Multi-layer Forest	17	13	12	13
	Late-seral Shade-tolerant Single-layer Forest	12	1	2	1
	Mid-seral Shade-intolerant Forest	20	18	19	19
	Mid-seral Shade-tolerant Forest	32	21	22	16
All	Early-seral Shade-intolerant Forest	5	4	15	17
	Early-seral Shade-tolerant Forest	10	11	5	8
	Late-seral Shade-intolerant Multi-layer Forest	6	9	16	16
	Late-seral Shade-intolerant Single-layer Forest	16	23	11	8
	Late-seral Shade-tolerant Multi-layer Forest	13	10	13	16
	Late-seral Shade-tolerant Single-layer Forest	13	1	1	1
	Mid-seral Shade-intolerant Forest	19	28	19	18
	Mid-seral Shade-tolerant Forest	18	15	20	17

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

In the current period, the amount of shade-tolerant species in the moist forest PVG of the Southern Cascades ERU appears to have been very high in the late-seral single-layer physiognomic type relative to the HRV, regardless of ownership strata (table 3.107). This suggests that the timber harvests that converted forests from multi-layer to single-layer types, or that maintained single-layer structures, selected against the shade-intolerant species. The areal extent of the shade-tolerant species for the mid-seral types were within the HRV for the entire ERU, within the HRV on BLM/FS lands, but above the HRV on Other land ownerships. Consequently, risks of substantial mortality from insects, disease, stress, and large high-intensity fires, were higher on Other lands.

With the exception of the late-seral multi-layer physiognomic type, the changes to the Southern Cascades ERU cold forest PVG physiognomic type compositions were similar among ownership strata (tables 3.108 and 3.109). The observed increase in the areal extent of the early-seral physiognomic type was likely due to recent clearcut and seed-tree harvest activities in systems that had mixed or maintenance regimes, as well as to the loss of whitebark pine to blister rust. The observed decrease in the areal extent of the mid-seral physiognomic type was a consequence of succession to late-seral multi-layer forest type in relation to fire exclusion. The areal extent of the late-seral multi-layer forest types were substantially above the HRV of the ERU and BLM/FS lands, but within the HRV of Other ownerships. The late-seral single-layer physiognomic type was essentially non-existent for all ownership strata. Fire exclusion eliminated the non-lethal and mixed fire regimes that had maintained late-seral single- and multi-layer physiognomic types, and thinned shade-tolerant tree species in the early-, mid-, and late-seral multi-layer physiognomic types. These were the trees that were more resistant to insects, disease, and stress mortalities.

Shade-intolerant species increased in the cold forest PVG of the Southern Cascades ERU, increased in comparison to the HRV in the early-seral and late-seral multi-layer physiognomic types, and decreased in comparison to the HRV in the mid-seral physiognomic type (table 3.109). Although the amounts of shade-intolerant species in the late-seral single-layer physiognomic type were almost non-existent, they were also very low in the HRV. The observed trends were similar, regardless of ownership strata. The increase of shade-intolerant species in the early-seral type appears to be a response to artificial planting of harvest units, while the increase in the late-seral type may be a relative increase as a result of insect- and pathogen-caused mortality of shade-tolerant species.

In response to the changes in regional and landscape conditions, the succession/disturbance regimes went through a substantial shift from a mix of moderate-cycle and maintenance regimes, to a mix of long-cycle and retrogressive-cycle regimes. There is a low probability of restoring native succession/disturbance regimes without restoring native landscape structures and fuel conditions. Trends for the cool shrub PVG are displayed in table 3.109a.

Upper Clark Fork ERU

The Upper Clark Fork ERU is located in western Montana (map 3.3). This ERU has moderately high relief (1,000 to 3,200 m) with a complex of wide valleys, foothills, and mountains (map 3.17). Topography is complex as a result of erosional processes and mountain glaciation. Landforms include a complex mix of wide valleys, foothills, mountains, and narrow valleys with a mix of headwater and downstream watersheds (map 3.21). The ERU is primarily in ecoregion section M332B (map 3.1).

Precipitation throughout the Upper Clark Fork ERU averages 73 centimeters per year with a range from 36 to 163 centimeters. The steep precipitation gradient in conjunction with the complex topography results in very diverse vegetation. Climate is strongly influenced by both oceanic storms from the west as well as the continental climates from the east. The area is strongly affected

Table 3.108—Current and historical period physiognomic types for the cold forest potential vegetation group (PVG) for Southern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	40	18	27	23
	Late-seral Multi-layer Forest	47	9	22	24
	Late-seral Single-layer Forest	1	2	3	4
	Mid-seral Forest	13	71	48	50
Other	Early-seral Forest	69	20	26	19
	Late-seral Multi-layer Forest	19	14	21	20
	Late-seral Single-layer Forest	0	9	4	6
	Mid-seral Forest	13	57	50	55
All	Early-seral Forest	44	18	27	22
	Late-seral Multi-layer Forest	43	9	22	24
	Late-seral Single-layer Forest	1	3	3	4
	Mid-seral Forest	13	69	48	51

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

by the rain-shadow effect of the Bitterroot Mountains to the west. Precipitation primarily falls in the form of winter snows, spring rains, and summer thundershowers. There is a moderate gradient from relatively moist spring conditions, to dry summer and fall conditions with a fairly long growing season. The Upper Clark Fork ERU has relatively high biogeochemical energy dynamics, moderately high rates of inherent NPP and nutrient cycling, and moderate carbon stress and low water stress in upland areas.

There were substantial changes in fire regimes in the Upper Clark Fork ERU primarily as a result of fire exclusion (maps 3.22 and 3.23). Fire severity generally shifted from non-lethal and mixed, to lethal regimes in the forest PVGs, due to fire suppression and longer intervals between fires. Severity did not change substantially, but intervals between fires increased in the non-forest PVGs due to fire exclusion, removal of fine fuels by livestock grazing, and encroachment of conifers.

From a regional perspective, the Upper Clark Fork ERU does not have a substantial area with high risk of drought; only a small portion of the ERU receives less than 30 centimeters annual precipitation (map 3.24). Consequently, the dry forest PVG and most of the non-forest PVGs that were altered by the invasion of exotic plants or from excessive livestock grazing pressure have a fairly high potential for restoration. However, at the landscape scale, the foothill landforms have a high proportion of steep, south-facing topographic settings and tend to be droughty environments.

Table 3.109—Current and historical period cold forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Southern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	28	5	21	17
	Early-seral Shade-tolerant Forest	12	13	6	5
	Late-seral Shade-intolerant Multi-layer Forest	34	2	4	4
	Late-seral Shade-intolerant Single-layer Forest	1	1	1	1
	Late-seral Shade-tolerant Multi-layer Forest	13	6	18	20
	Late-seral Shade-tolerant Single-layer Forest	0	2	2	2
	Mid-seral Shade-intolerant Forest	9	31	17	26
	Mid-seral Shade-tolerant Forest	4	41	31	24
Other	Early-seral Shade-intolerant Forest	62	5	21	14
	Early-seral Shade-tolerant Forest	7	15	5	5
	Late-seral Shade-intolerant Multi-layer Forest	14	5	6	1
	Late-seral Shade-intolerant Single-layer Forest	0	1	1	2
	Late-seral Shade-tolerant Multi-layer Forest	5	9	16	19
	Late-seral Shade-tolerant Single-layer Forest	0	8	3	4
	Mid-seral Shade-intolerant Forest	8	16	13	27
	Mid-seral Shade-tolerant Forest	5	41	37	28
All	Early-seral Shade-intolerant Forest	33	5	21	17
	Early-seral Shade-tolerant Forest	11	14	6	5
	Late-seral Shade-intolerant Multi-layer Forest	31	3	5	3
	Late-seral Shade-intolerant Single-layer Forest	1	1	1	1
	Late-seral Shade-tolerant Multi-layer Forest	12	7	18	20
	Late-seral Shade-tolerant Single-layer Forest	0	3	2	3
	Mid-seral Shade-intolerant Forest	9	29	17	26
	Mid-seral Shade-tolerant Forest	4	41	32	25

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

There has been a long history of livestock grazing on the public lands of the Upper Clark Fork ERU (map 3.25). Much of the land area in public ownership has been grazed by sheep and cattle since the late-1800s. Substantial improvements in rangeland conditions and associated watershed conditions have occurred since the mid-1900s. However, many of the high-elevation sheep allotments that were subjected to excessive grazing pressure, and that experienced soil-cover loss and extensive erosion, have been very slow to recover. Even though many of these high-elevation allotments were closed or experienced stocking-rate reductions, there are areas that have not recovered vegetation cover.

The dry forest and dry grass PVGs in the Upper Clark Fork ERU have been particularly susceptible to exotic plant invasions, especially the perennial forbs: spotted knapweed, leafy spurge, and sulfur cinquefoil. Approximately 39 and 13 percent of All lands, and 19 and 2 percent of BLM/FS lands in this ERU are of high susceptibility to invasion by spotted knapweed and leafy spurge, respectively (table 3.47; maps 3.35 and 3.36). Currently, rangeland riparian areas are also in a somewhat degraded condition, but are recovering relatively quickly because of the recent emphasis on riparian management on BLM/FS lands.

Road densities in the Upper Clark Fork ERU are mostly moderate and high, with some areas of low and very-low densities, and a few areas without roads (map 3.28). Much of this ERU has sensitive watersheds because of its steep topography and highly-erosive granitic or metasedimentary soils. Some of the watersheds are in degraded conditions due to the moderate and high road densities on sensitive watersheds (map 3.29).

The pattern of BLM/FS and Other land ownerships is highly fragmented in the Upper Clark Fork ERU (map 3.30). Most of the area is in mixed or mosaic BLM/FS ownership with a few areas having uniform patterns. Much of the BLM/FS land has moderate risks of fire occurrence and associated high-intensity wildfires that could be difficult to suppress (map 3.31). At the landscape scale, there are areas of high fire risks. The moderate- and high-risk areas have been attributed to wildfire occurrence from lightning ignition, dry summer and fall conditions, dissected and steep terrain, and a mosaic of woody and grass fuels. The Upper Clark Fork ERU also has a moderate component of areas with high fuel accumulations, high potential for crown fire, and high forest insect-, disease-, and stress-related mortalities (map 3.32). The high-risk areas are predominantly dry forests that have high carbon stress. Past timber harvests often removed most of the large, shade-intolerant trees that were more resistant to these types of mortalities. The large shade-intolerant trees have generally been replaced by smaller, shade-tolerant tree species that are more susceptible to the above-mentioned mortality agents.

There are moderate- and high-risk areas of rural/wildland interface on the BLM/FS lands in the Upper Clark Fork ERU (map 3.33). At the landscape scale, the high-risk areas often occur at the edge of the foothill environments. Rural developments are typically associated with the wide valley, bench, or narrow valley landforms that are on the edge of, or interspersed with, the steeper, complex topography of the foothill landforms. The foothill landforms typically occur on the BLM/FS lands.

Between the historical and current periods, PVG composition did not change substantially in the Upper Clark Fork ERU (table 3.110, maps 3.11 and 3.12). Approximately 9 percent of the area was developed for agricultural and urban uses at the expense of the dry grass and cool shrub PVGs. Another 2.8 percent of the ERU was converted to roads. The majority (61%) of roads are located on Other land ownerships. The cold, dry, and moist forest PVGs dominated the ERU as a whole. The cold forest PVG dominated BLM/FS lands, whereas the dry forest PVG dominated Other lands.

Changes in the physiognomic type composition of the dry forest PVG were similar for all ownership strata in the Upper Clark Fork ERU (tables 3.111 and 3.112). The amount of exotic herbland was substantially underestimated because of forest overstory cover.

Table 3.110—Historical and current period potential vegetation groups (PVGs) for the Upper Clark Fork Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	9 / 18	0 / 0	9 / 9
Alpine	+[4]	+	+	+	+	+
Cold Forest	28 / 52	28 / 51	6 / 13	6 / 12	34 / 34	34 / 33
Cool Shrub	+	+	3 / 7	1 / 2	3 / 3	1 / 1
Dry Forest	9 / 17	9 / 16	17 / 35	17 / 35	26 / 26	26 / 25
Dry Grass	1 / 2	1 / 2	11 / 24	5 / 10	12 / 12	6 / 6
Dry Shrub	+	+	+	+	+	+
Moist Forest	12 / 22	12 / 22	7 / 15	7 / 14	19 / 19	19 / 18
Riparian Shrub	+	+	1 / 2	1 / 1	1 / 1	1 / 1
Riparian Woodland	+	+	1 / 2	1 / 1	1 / 1	1 / 1
Road	NA[5] / NA	1.1 / 2	NA / NA	1.7 / 3	NA / NA	2.8 / 3
Rock	4 / 7	4 / 7	+	+	4 / 4	4 / 4
Urban	0 / 0	0 / 0	0 / 0	+	0 / 0	+
Water	+	+	+	+	+	+
Woodland	0 / 0	0 / 0	+	+	+	+
Total[6]	54 / 100	55.1 / 100	46 / 100	48.7 / 98	100 / 100	1038 / 101

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes.

Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes. For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

Table 3.111—Current and historical period physiognomic types for the dry forest potential vegetation group (PVG) for Upper Clark Fork Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	8	17	12	6
	Exotic Herbland	+[3]	0	0	0
	Late-seral Multi-layer Forest	1	15	12	20
	Late-seral Single-layer Forest	0	12	44	60
	Mid-seral Forest	90	52	32	14
	Upland Herbland	+	4	0	0
	Upland Shrubland	+	0	0	0
Other	Early-seral Forest	20	8	35	11
	Exotic Herbland	0	0	0	0
	Late-seral Multi-layer Forest	+	13	8	11
	Late-seral Single-layer Forest	0	12	31	49
	Mid-seral Forest	79	23	26	28
	Upland Herbland	0	45	+	0
	Upland Shrubland	+	+	+	0
All	Early-seral Forest	16	11	27	9
	Exotic Herbland	+	0	0	0
	Late-seral Multi-layer Forest	1	13	9	14
	Late-seral Single-layer Forest	0	12	35	53
	Mid-seral Forest	83	33	28	23
	Upland Herbland	+	31	+	0
	Upland Shrubland	+	+	+	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.112—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Upper Clark Fork Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	7	11	10	5
	Early-seral Shade-tolerant Forest	1	6	3	1
	Exotic Herbland	+[3]	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	1	10	6	13
	Late-seral Shade-intolerant Single-layer Forest	0	8	42	59
	Late-seral Shade-tolerant Multi-layer Forest	+	5	6	7
	Late-seral Shade-tolerant Single-layer Forest	0	4	2	1
	Mid-seral Shade-intolerant Forest	58	31	22	10
	Mid-seral Shade-tolerant Forest	32	22	10	4
	Upland Herbland	+	4	0	0
	Upland Shrubland	+	0	0	0
Other	Early-seral Shade-intolerant Forest	20	5	33	10
	Early-seral Shade-tolerant Forest	1	2	2	1
	Exotic Herbland	0	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	+	10	4	8
	Late-seral Shade-intolerant Single-layer Forest	0	10	30	49
	Late-seral Shade-tolerant Multi-layer Forest	+	2	4	4
	Late-seral Shade-tolerant Single-layer Forest	+	2	1	+
	Mid-seral Shade-intolerant Forest	59	15	22	27
	Mid-seral Shade-tolerant Forest	21	8	4	2
	Upland Herbland	0	45	+	0
	Upland Shrubland	0	+	+	0
All	Early-seral Shade-intolerant Forest	15	7	25	9
	Early-seral Shade-tolerant Forest	1	4	2	1
	Exotic Herbland	+	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	+	10	5	9
	Late-seral Shade-intolerant Single-layer Forest	0	10	34	52
	Late-seral Shade-tolerant Multi-layer Forest	+	3	5	5
	Late-seral Shade-tolerant Single-layer Forest	0	3	1	1
	Mid-seral Shade-intolerant Forest	59	21	22	21
	Mid-seral Shade-tolerant Forest	25	12	6	3
	Upland Herbland	+	31	+	0
	Upland Shrubland	+	+	+	0

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

The areal extent of the mid-seral forest physiognomic type was almost three times the HRV across all ownership strata due to the shift of the late-seral forest types to the mid-seral types. This was caused by the selective harvesting of large, overstory trees and tree mortalities related to stress, insects, and diseases. The shift was also partly due to the succession of the early-seral types into the mid-seral types. Current period late-seral multi- and single-layer physiognomic types were essentially non-existent in all ownership strata. The late-seral multi- and single-layer forest types had shifted primarily to mid-seral types because of the selective harvest of large overstory trees; insect, disease, and stress mortalities associated with overstory trees; and the growth of shade-tolerant species in the understory. The cause for the stress-, insect-, and disease-related mortalities was the change to higher-density stocking levels of the more susceptible, shade-tolerant tree species.

Fire exclusion in the Upper Clark Fork ERU eliminated the non-lethal and mixed fires that had maintained late-seral single- and multi-layer physiognomic types, and thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer physiognomic types. The larger shade-intolerant tree species were often selectively harvested. These trees were more resistant to insect, disease, and stress mortalities. Clearcutting and seed-tree timber-harvest activities commonly created small early-seral patches containing few live or dead-standing trees, and higher down-fuel accumulations. These factors, in conjunction with a climatic trend commencing in the 1980s that appears to have resulted in drier spring, summer, and fall periods, increased the risks of wildfire.

The current period composition of the dry forest PVG in the Upper Clark Fork ERU was dominated by mid-seral physiognomic types, regardless of ownership strata (table 3.112). The ERU was so strongly dominated by the mid-seral physiognomic type that the mid-seral types composed of both shade-tolerant and shade-intolerant species exceeded their HRV.

The historical to current period change in physiognomic type composition of the Upper Clark Fork ERU moist forest PVG was similar across all land ownership strata (tables 3.113 and 3.114). The areal extent of the early-seral forest physiognomic type was below the HRV due to fire exclusion, a lack of cycling treatments that mimic lethal fire regimes, and the decreased duration of the early-seral stage attributed to tree planting and the promotion of rapid regeneration. The areal extent of the mid-seral forest physiognomic type was nearly double the HRV as a consequence of early-seral forest succession into, and the retrogression of late-seral forests into mid-seral forests. The late-seral multi- and single-layer forest types were essentially eliminated in the Upper Clark Fork ERU in response to the harvesting of large, overstory trees. The non-lethal and mixed fire regimes that had maintained, accelerated, and cycled late-seral and mid-seral forest types had substantially declined since the historical period. Harvesting of the large, shade-intolerant, overstory trees left smaller trees as the dominant layer, but did not promote their growth to dominance.

With the exception of the mid-seral type, the areal extent of the moist forest physiognomic types composed of shade-intolerant species were below their HRV, regardless of ownership strata. With respect to the mid-seral types, those dominated by shade-intolerant species exceeded the HRV, as did those dominated by shade-tolerant species. As with the dry forest PVG, the current distribution of physiognomic types was so strongly skewed toward the mid-seral types that both shade-tolerant and shade-intolerant mid-seral types exceeded their respective HRV (table 3.114).

We detected different trends in physiognomic type composition of the cold forest PVG among the ownership strata (tables 3.115 and 3.116). The areal extent of the early-seral forest physiognomic type was substantially below the HRV for the entire Upper Clark Fork ERU, as well as for BLM/FS lands. However, the areal extent of the early-seral type on Other land ownerships fell within the HRV range. There was such a small amount of

Table 3.113—Current and historical period physiognomic types for the moist forest potential vegetation group (PVG) for Upper Clark Fork Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	17	28	17	19
	Late-seral Multi-layer Forest	1	12	27	36
	Late-seral Single-layer Forest	0	5	3	3
	Mid-seral Forest	82	55	53	42
Other	Early-seral Forest	11	50	27	22
	Late-seral Multi-layer Forest	1	11	18	27
	Late-seral Single-layer Forest	0	8	5	5
	Mid-seral Forest	89	31	50	46
All	Early-seral Forest	15	36	20	20
	Late-seral Multi-layer Forest	1	11	24	33
	Late-seral Single-layer Forest	0	6	4	4
	Mid-seral Forest	84	47	52	43

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

this PVG on Other lands that it was difficult to speculate why the trends were not similar. For BLM/FS lands, the primary factor of change was succession of the early-seral into the mid-seral type. The areal extent of the mid-seral forest physiognomic type was almost double the HRV, whereas the late-seral multi- and single-layer forest physiognomic types were essentially non-existent. The large increase in the areal extent of mid-seral types and decrease in the areal extent of late-seral types was attributed to the succession of early-seral to mid-seral, and the retrogression of late-seral to mid-seral. In general, there had been little timber harvest activity within the cold forest PVG of this ERU. Most changes were likely related to fire exclusion, bark beetle attacks, blister rust, and succession.

The relationship between the cold forest physiognomic types, dominated by shade-tolerant or shade-intolerant species, mirrored those of the dry forest and moist forest PVGs in the Upper Clark Fork ERU (table 3.116). That is, the areal extent of the late-seral and early-seral forest types composed by shade-intolerant species in the current period were below the HRV, whereas the mid-seral shade-intolerant forest type occurred above its HRV (as did the mid-seral shade-tolerant forest type). The trend generally indicates that the shade-intolerant whitebark pine was declining due to fire exclusion and mortality from blister rust, and was being replaced by subalpine fir. Subalpine larch was also declining as a result of fire exclusion, and was being replaced by subalpine fir.

Table 3.114—Current and historical period moist forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Upper Clark Fork Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	13	22	13	14
	Early-seral Shade-tolerant Forest	5	7	4	5
	Late-seral Shade-intolerant Multi-layer Forest	1	7	17	22
	Late-seral Shade-intolerant Single-layer Forest	0	4	2	2
	Late-seral Shade-tolerant Multi-layer Forest	+[3]	5	10	14
	Late-seral Shade-tolerant Single-layer Forest	0	+	1	1
	Mid-seral Shade-intolerant Forest	56	41	41	29
	Mid-seral Shade-tolerant Forest	27	15	12	13
Other	Early-seral Shade-intolerant Forest	7	48	18	17
	Early-seral Shade-tolerant Forest	3	3	8	6
	Late-seral Shade-intolerant Multi-layer Forest	1	9	13	18
	Late-seral Shade-intolerant Single-layer Forest	0	8	4	4
	Late-seral Shade-tolerant Multi-layer Forest	+	1	5	9
	Late-seral Shade-tolerant Single-layer Forest	0	1	1	1
	Mid-seral Shade-intolerant Forest	60	22	41	36
	Mid-seral Shade-tolerant Forest	29	9	9	10
All	Early-seral Shade-intolerant Forest	11	31	15	15
	Early-seral Shade-tolerant Forest	4	5	6	5
	Late-seral Shade-intolerant Multi-layer Forest	1	8	15	21
	Late-seral Shade-intolerant Single-layer Forest	0	6	3	3
	Late-seral Shade-tolerant Multi-layer Forest	+	4	8	12
	Late-seral Shade-tolerant Single-layer Forest	0	1	1	1
	Mid-seral Shade-intolerant Forest	57	34	41	32
	Mid-seral Shade-tolerant Forest	27	13	11	12

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.115—Current and historical period physiognomic types for the cold forest potential vegetation group (PVG) for Upper Clark Fork Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	12	24	22	25
	Early-seral Riparian Woodland	+[3]	+	0	0
	Late-seral Multi-layer Forest	1	10	15	27
	Late-seral Single-layer Forest	2	5	4	5
	Mid-seral Forest	85	62	59	43
	Mid-seral Riparian Woodland	1	+	+	+
Other	Early-seral Forest	25	32	22	20
	Early-seral Riparian Woodland	+	0	0	0
	Late-seral Multi-layer Forest	1	19	17	25
	Late-seral Single-layer Forest	1	8	4	4
	Mid-seral Forest	73	41	58	52
	Mid-seral Riparian Woodland	1	+	+	0
All	Early-seral Forest	14	25	22	24
	Early-seral Riparian Woodland	+	+	0	0
	Late-seral Multi-layer Forest	1	12	15	27
	Late-seral Single-layer Forest	1	5	4	5
	Mid-seral Forest	83	58	59	45
	Mid-seral Riparian Woodland	1	+	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.116—Current and historical period cold forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Upper Clark Fork Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		..... Percent			
BLM/FS	Early-seral Shade-intolerant Forest	4	17	18	20
	Early-seral Shade-tolerant Forest	8	7	3	5
	Late-seral Shade-intolerant Multi-layer Forest	1	4	4	12
	Late-seral Shade-intolerant Single-layer Forest	2	2	3	4
	Late-seral Shade-tolerant Multi-layer Forest	+[3]	6	11	15
	Late-seral Shade-tolerant Single-layer Forest	0	3	1	1
	Mid-seral Shade-intolerant Forest	46	40	40	28
	Mid-seral Shade-tolerant Forest	39	22	20	15
	Riparian Woodland	1	+	+	+
Other	Early-seral Shade-intolerant Forest	19	27	17	16
	Early-seral Shade-tolerant Forest	6	5	5	4
	Late-seral Shade-intolerant Multi-layer Forest	1	7	2	4
	Late-seral Shade-intolerant Single-layer Forest	1	1	1	1
	Late-seral Shade-tolerant Multi-layer Forest	+	11	15	21
	Late-seral Shade-tolerant Single-layer Forest	0	6	3	3
	Mid-seral Shade-intolerant Forest	45	18	31	32
	Mid-seral Shade-tolerant Forest	28	23	27	20
	Riparian Woodland	1	+	+	0
All	Early-seral Shade-intolerant Forest	6	19	18	19
	Early-seral Shade-tolerant Forest	8	6	4	5
	Late-seral Shade-intolerant Multi-layer Forest	1	5	3	10
	Late-seral Shade-intolerant Single-layer Forest	1	2	3	3
	Late-seral Shade-tolerant Multi-layer Forest	+	7	12	16
	Late-seral Shade-tolerant Single-layer Forest	0	3	2	1
	Mid-seral Shade-intolerant Forest	46	36	38	28
	Mid-seral Shade-tolerant Forest	37	22	21	16
	Riparian Woodland	1	+	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

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There was an increase in the mid-seral type because of succession from the early-seral type and retrogression from the late-seral type. We suspect that the shade-intolerant species remained strong because of lodgepole pine predominance in the mid-seral stages of these warmer and moister cold forest PVGs of the Upper Clark Fork ERU.

In response to the changes in regional and landscape conditions on the Upper Clark Fork ERU forest and rangelands, the primary change in succession/disturbance regimes appears to have been a shift from a mix of moderate and accelerated cycles, to a mix of long and retrogressive cycles. There is a low probability of restoring native succession/disturbance regimes without a concurrent restoration of landscape structures, fuel conditions, whitebark pine, and fire.

Upper Klamath ERU

The Upper Klamath ERU is located in south central Oregon (map 3.3). This ERU has moderate relief (900 to 2,600 m) with a complex of wide, low-elevation valleys interspersed with foothills and mountains (map 3.17). Topography is moderately complex. Landforms include a mix of river valleys with breaks, foothills, and mountains. Watersheds are mixed between downstream and headwater systems (map 3.21). Precipitation is moderate (averaging 59 centimeters per year) and has a moderate gradient ranging from 39 centimeters at lower elevations, to 105 centimeters at higher elevations. The overall diversity of vegetation is low. The Upper Klamath ERU is primarily in ecoregion section M261G and M242C (map 3.1).

Climate is strongly influenced by the oceanic storm patterns from the west. The rain-shadow effect in the Upper Klamath ERU is less than for the Northern Cascades and Southern Cascades ERUs because of lower crest elevations. However, the influence of the Pacific Coast range is substantial at this latitude, creating a rain shadow that affects both the westside and eastside of the Cascade Mountains. Precipitation primarily falls as winter snows, spring rains, and summer thunderstorms and showers. There is a very steep seasonal gradient from moist winter and spring conditions, to very dry summer and fall conditions with a moderately-long growing season. The Upper Klamath ERU has very dynamic succession/disturbance regimes because of moderate inherent productivity, very-steep seasonal-moisture gradients, complex topography, and the associated high carbon and high water stress on upland areas.

There were substantial changes in fire regimes between the historic and current periods, primarily as a result of fire exclusion and past timber harvest activities (maps 3.22 and 3.23). In the Upper Klamath ERU forest PVGs, fire severity generally shifted from a mixture of non-lethal, mixed, and lethal regimes, to predominantly a lethal regime. Changed fire regimes resulted from harvesting of large, shade-intolerant, and fire-, insect-, disease-, and stress-resistant tree species, as well as longer fire-intervals that allowed successional dominance by shade-tolerant species. These shade-tolerant species were generally less resistant to fire, insect, disease, and stress.

In the non-forest PVGs, some areas have experienced invasions by exotic annuals including grasses, cheatgrass, and medusahead. If exotic communities are not grazed, they become highly flammable. If they are grazed, fine-fuels are reduced and fire intervals are extended. In general, the fire regime of the non-forest PVGs of the Upper Klamath ERU shifted from non-lethal to lethal. There was an associated increase in the variability of fire interval length in these areas, which was attributed to differing levels of grazing pressure.

The Upper Klamath ERU has a negligible amount of area that receives less than 30 centimeters of annual precipitation (map 3.24). However, drought is relatively frequent in this ERU. During the period from 1895 to 1994, drought was documented 18 percent of the time (table 3.38; climate division: Oregon South Central). This level of drought frequency, in conjunction with the relatively infrequent periods of above-normal precipitation for two or more years in succession (only 7 such periods were documented during the 1895-1994

period, table 3.38), confirmed that this ERU has a high-risk, droughty environment. Such an environment reduces success rates of restoration in non-forest PVGs that have been altered by the invasion of exotics or by excessive livestock grazing pressure.

Cheatgrass, medusahead, and yellow starthistle are prevalent exotic plants in the Upper Klamath ERU. The dry forest and dry grass PVGs are notably susceptible to invasion by these species. Approximately 28 and 7 percent of All lands, and 26 and 1 percent of BLM/FS lands in the Upper Klamath ERU are of high susceptibility to invasion by cheatgrass and yellow starthistle, respectively (table 3.47; maps 3.26 and 3.27). Distribution of medusahead within this ERU has been associated greatly with soils that shrink or swell from drying or wetting (table 3.46; map 3.19).

A moderate portion of this ERU has had a history of livestock grazing on public lands (map 3.25). Rangeland conditions on public lands have generally improved since the mid-1900s, except where exotics have invaded the dry PVGs. In some areas, current riparian conditions have improved, but problems continue to persist in many areas relative to stream-channel conditions, and the lack of shrub and herbaceous cover.

Road densities throughout most of the Upper Klamath ERU are high (map 3.28). However, landforms and soils in this ERU generally have a low to moderate sensitivity to the disruption of hydrologic regimes (map 3.29). The types of landforms, geology, and soil development found in this ERU are generally not as susceptible to erosion and sediment transport as those in other mountainous ERUs. Where forested watersheds have been developed for timber harvest, road densities are commonly high.

The pattern of BLM/FS and Other land ownerships is highly fragmented in the Upper Klamath ERU (map 3.30). Few areas have a uniform distribution of BLM/FS lands; most areas have mixed and mosaic BLM/FS ownership patterns. Most of the BLM/FS lands have moderate and high risks of fire occurrence and associated high-intensity wildfires that could be difficult to suppress (map 3.31). High-risk areas generally occur on lower-elevation dry forests. At the landscape scale, there are some areas, particularly the break landforms, that also have high fire risk. The moderate and high risks are related primarily to potential wildfire occurrence from lightning and human-caused ignition; very dry summer and fall conditions; complex terrain; and heavy forest fuels that create the potential for severe fire behavior.

A substantial portion of the Upper Klamath ERU has high fuel accumulations, high potential for crown fires, and high risks of forest insect-, disease-, and stress-related mortalities (map 3.32). These high-risk areas have been associated with the dry forest and moist forest PVGs, which have high NPP, high carbon stress, and high water stress. Past timber harvest practices often removed many of the large, shade-intolerant trees that were more resistant to these mortality agents. These large, shade-intolerant trees have been generally replaced by large and small shade-tolerant tree species that are more susceptible to the above-mentioned mortality agents.

There are high and moderate risks related to the rural/wildland interface on the BLM/FS lands (map 3.33). At the landscape scale, the high-risk areas often occur at the edge of the break and foothill landforms. Rural developments are typically associated with the adjacent valley landforms that are on the edge of, or interspersed with, these landforms.

PVG composition did not change substantially from the historical to the current period in the Upper Klamath ERU (table 3.117; maps 3.11 and 3.12). Seven percent of the ERU was converted to the agricultural PVG, which was derived primarily from the dry grass PVG. The dry forest PVG dominated the ERU. Composition of PVGs on BLM/FS lands followed the same pattern, but with a slightly higher proportion of moist forest

Table 3.117—Historical and current period potential vegetation groups (PVGs) for the Upper Klamath Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	7 / 13	0 / 0	7 / 7
Alpine	+[4]	+	+	+	+	+
Cold Forest	2 / 4	2 / 4	1 / 2	1 / 2	3 / 3	3 / 3
Cool Shrub	2 / 4	2 / 4	3 / 6	3 / 5	5 / 5	5 / 5
Dry Forest	35 / 76	35 / 73	30 / 56	29 / 52	65 / 65	64 / 62
Dry Grass	1 / 2	1 / 2	8 / 15	3 / 5	9 / 9	4 / 4
Dry Shrub	1 / 2	1 / 2	3 / 6	3 / 5	4 / 4	4 / 4
Moist Forest	5 / 11	5 / 10	2 / 4	2 / 4	7 / 7	7 / 7
Riparian Shrub	+	+	2 / 4	1 / 2	2 / 2	1 / 1
Riparian Woodland	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Road	NA[5] / NA	1.8 / 4	NA / NA	2.0 / 4	NA / NA	3.8 / 4
Rock	+	+	+	+	+	+
Urban	0 / 0	0 / 0	0 / 0	+	0	+
Water	+	+	5 / 9	5 / 9	5 0	5 / 5
Woodland	+	+	+	+	+	+
Total[6]	46 / 99	47.8 / 99	54 / 102	56 / 101	100 / 100	103.8 / 102

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes. Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes. For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

and cold forest PVGs than on Other lands. PVG composition on Other ownerships was dominated by the dry forest PVG, with small amounts of the dry grass, dry shrub, and cool shrub PVGs. Approximately 3.8 percent of the total area was converted to roads, and nearly evenly distributed between BLM/FS lands and Other ownerships.

The physiognomic type composition of the Upper Klamath ERU dry forest PVG changed in a similar manner among ownership strata (tables 3.118 and 3.119). Exotic herblands were underestimated across all ownerships. The areal extent of the early-seral forest physiognomic type was at the lower end of the HRV due to recent clearcut and seed-tree harvest activities. The areal extent of the mid-seral forest physiognomic type was below the HRV for all strata, due to the succession of mid-seral to late-seral types. The amount of the late-seral multi-layer forest physiognomic type was substantially above the HRV, whereas, the amount of the late-seral single-layer physiognomic type occurred within the HRV for all strata. There was a general shift from the late-seral single-layer to the late-seral multi-layer type, and from the mid-seral to the late-seral multi-layer type as a result of fire exclusion and selective harvesting of large, shade-intolerant trees. In areas where the forests were harvested by clearcut and seed-tree treatments, forest succession was accelerated toward the mid-seral physiognomic types through the use of planting and other silvicultural techniques that promote rapid regeneration.

Fire exclusion in the Upper Klamath ERU eliminated the non-lethal and mixed fire regimes that had maintained late-seral single- and multi-layer physiognomic types, and thinned shade-tolerant tree species in early-, mid-, and late-seral multi-layer structures. These were the trees that were more resistant to insect, disease, and stress mortality. Clearcut, seed-tree, shelterwood, and group-selection timber-harvest activities commonly created a mosaic of early-seral patches with few live or dead-standing trees, and higher down-fuel accumulations. In the matrix areas surrounding the patches, the large trees and dead-standing trees were often selectively harvested. This combination of factors homogenized landscape patterns and increased the risks of fire, insect, disease, and stress mortalities.

In the dry forest PVG of the Upper Klamath ERU, the areal extents of the mid-seral and late-seral physiognomic types composed by shade-tolerant species were below their HRV for the ERU as a whole (table 3.119). Conversely, the area of the late-seral shade-intolerant multi-layer forest physiognomic type exceeded its HRV. With the exception of the mid-seral shade-intolerant physiognomic type, these trends were similar for BLM/FS lands within the Upper Klamath ERU. Tree mortality risks associated with fire, insects, disease, and stress seem particularly problematic within the late-seral shade-tolerant physiognomic types, both of which substantially exceeded their HRV.

From the historical to the current period, physiognomic type composition of the moist forest PVG in the Upper Klamath ERU varied between ownership strata (tables 3.120 and 3.121). The areal extent of the early-seral forest physiognomic type was within the HRV for All and BLM/FS ownership strata, whereas it was well above the HRV for Other ownerships. These trends were likely because of the extensive even-age timber harvesting (that is, clearcuts or seed-tree cuts) and wildfire that occurred on Other lands. The areal extent of the mid-seral forest physiognomic type was below the HRV of all ownership strata due to its succession to the late-seral multi-layer physiognomic type. The amount of the late-seral single- and multi-layer forest types was well above the HRV for all ownership strata. This was most likely the result of extensive selective timber harvesting of large, shade-intolerant trees, which allowed the development of forests comprised mainly of mid-seral shade-tolerant species.

Mid-seral forests, dominated by shade-tolerant tree species, were generally not present in the Upper Klamath ERU. This reflected the overall decline of the mid-seral physiognomic types. The late-seral shade-tolerant composition for both the multi- and single-layer physiognomic types was well

Table 3.118—Current and historical period physiognomic types for the dry forest potential vegetation group (PVG) for Upper Klamath Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	5	10	8	6
	Exotic Herbland	+[3]	0	0	0
	Late-seral Multi-layer Forest	47	14	12	15
	Late-seral Single-layer Forest	34	39	59	65
	Mid-seral Forest	14	35	21	14
	Upland Herbland	+	3	0	0
	Upland Shrubland	0	+	+	0
Other	Early-seral Forest	6	9	15	4
	Exotic Herbland	0	0	0	0
	Late-seral Multi-layer Forest	37	11	8	11
	Late-seral Single-layer Forest	45	26	49	65
	Mid-seral Forest	12	29	28	20
	Upland Herbland	+	19	+	0
	Upland Shrubland	0	6	+	+
All	Early-seral Forest	5	10	11	5
	Exotic Herbland	+	0	0	0
	Late-seral Multi-layer Forest	42	13	10	13
	Late-seral Single-layer Forest	39	33	54	65
	Mid-seral Forest	13	32	24	17
	Upland Herbland	+	10	+	0
	Upland Shrubland	0	3	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3.119—Current and historical period dry forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Upper Klamath Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	5	10	6	6
	Early-seral Shade-tolerant Forest	0	+[3]	2	1
	Exotic Herbland	+	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	29	13	11	13
	Late-seral Shade-intolerant Single-layer Forest	22	39	59	65
	Late-seral Shade-tolerant Multi-layer Forest	18	+	1	2
	Late-seral Shade-tolerant Single-layer Forest	12	0	+	1
	Mid-seral Shade-intolerant Forest	14	33	18	9
	Mid-seral Shade-tolerant Forest	1	2	3	5
	Upland Herbland	+	3	0	0
	Upland Shrubland	0	+	+	0
Other	Early-seral Shade-intolerant Forest	6	8	13	4
	Early-seral Shade-tolerant Forest	+	+	2	+
	Exotic Herbland	0	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	27	11	7	10
	Late-seral Shade-intolerant Single-layer Forest	38	26	49	64
	Late-seral Shade-tolerant Multi-layer Forest	11	+	1	1
	Late-seral Shade-tolerant Single-layer Forest	8	+	+	+
	Mid-seral Shade-intolerant Forest	12	29	26	16
	Mid-seral Shade-tolerant Forest	+	+	3	4
	Upland Herbland	+	19	+	0
	Upland Shrubland	0	6	+	+
All	Early-seral Shade-intolerant Forest	5	9	9	5
	Early-seral Shade-tolerant Forest	+	+	2	+
	Exotic Herbland	+	0	0	0
	Late-seral Shade-intolerant Multi-layer Forest	28	12	9	11
	Late-seral Shade-intolerant Single-layer Forest	29	33	54	65
	Late-seral Shade-tolerant Multi-layer Forest	15	+	1	2
	Late-seral Shade-tolerant Single-layer Forest	10	+	+	1
	Mid-seral Shade-intolerant Forest	13	31	21	12
	Mid-seral Shade-tolerant Forest	+	1	3	4
	Upland Herbland	+	10	+	0
	Upland Shrubland	0	3	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3] + = < 0.5%.

Table 3.120—Current and historical period physiognomic types for the moist forest potential vegetation group (PVG) for Upper Klamath Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	10	10	23	23
	Late-seral Multi-layer Forest	66	25	32	33
	Late-seral Single-layer Forest	21	17	10	9
	Mid-seral Forest	2	48	35	36
Other	Early-seral Forest	36	12	24	25
	Late-seral Multi-layer Forest	44	14	27	23
	Late-seral Single-layer Forest	19	18	15	16
	Mid-seral Forest	2	56	35	36
All	Early-seral Forest	17	11	23	23
	Late-seral Multi-layer Forest	60	22	30	30
	Late-seral Single-layer Forest	21	17	11	11
	Mid-seral Forest	2	50	35	36

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

above the HRV as a result of the selective harvesting of shade-intolerant trees, fire exclusion, and succession. These past disturbances and successional regimes increased the susceptibility of the moist forest PVG to mortality from stress, insects, disease, and fire.

In response to the changes in regional and landscape conditions, the succession/disturbance regimes in the Upper Klamath ERU went through a substantial shift from a mix of maintenance and long-cycle regimes, to a mix of short-cycle and retrogressive-cycle regimes. Most of the areas are roaded and have been altered by timber harvest and fire exclusion. Restoration of native succession/disturbance regimes can only be accomplished by a concurrent modification of vegetation structure and composition, and fuel conditions.

Upper Snake ERU

The Upper Snake ERU is located primarily in southern Idaho (map 3.3). This ERU has relatively low relief (1,200 to 3,000 m) with a complex of valleys and plains with interspersed breaks, scattered foothills, and mountains (map 3.17). Topography is generally gentle to rugged due to different types of fluvial, volcanic, and erosional processes. Landforms include a mix of plains, valleys, breaks, foothills, and mountain ranges, with a mix of headwater and mainstem watersheds (map 3.21). The ERU is primarily in ecoregion sections 342B and 342D (map 3.1).

Precipitation averages 27 centimeters per year and ranges from 18 to 60 centimeters. However, precipitation on most sites is within 5 centimeters

Table 3.121—Current and historical period moist forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for Upper Klamath Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade-intolerant Forest	10	3	14	16
	Early-seral Shade-tolerant Forest	+[3]	7	9	7
	Late-seral Shade-intolerant Multi-layer Forest	27	12	14	14
	Late-seral Shade-intolerant Single-layer Forest	11	17	9	7
	Late-seral Shade-tolerant Multi-layer Forest	39	13	18	19
	Late-seral Shade-tolerant Single-layer Forest	10	+	1	2
	Mid-seral Shade-intolerant Forest	2	28	18	17
	Mid-seral Shade-tolerant Forest	+	20	17	19
Other	Early-seral Shade-intolerant Forest	36	11	20	21
	Early-seral Shade-tolerant Forest	0	2	4	5
	Late-seral Shade-intolerant Multi-layer Forest	31	12	13	12
	Late-seral Shade-intolerant Single-layer Forest	9	18	15	16
	Late-seral Shade-tolerant Multi-layer Forest	13	2	14	12
	Late-seral Shade-tolerant Single-layer Forest	10	0	0	0
	Mid-seral Shade-intolerant Forest	2	51	23	23
	Mid-seral Shade-tolerant Forest	0	5	11	12
All	Early-seral Shade-intolerant Forest	17	5	16	17
	Early-seral Shade-tolerant Forest	+	6	8	6
	Late-seral Shade-intolerant Multi-layer Forest	28	12	14	13
	Late-seral Shade-intolerant Single-layer Forest	11	17	11	9
	Late-seral Shade-tolerant Multi-layer Forest	32	10	17	17
	Late-seral Shade-tolerant Single-layer Forest	10	+	1	1
	Mid-seral Shade-intolerant Forest	2	34	19	19
	Mid-seral Shade-tolerant Forest	+	16	16	17

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

of the average. Areas on the low end of the annual-precipitation range are generally confined to the desert and break areas; areas at the upper end of the range are confined to the mountain areas.

Climate is influenced by a mix of weather patterns. The Upper Snake ERU is influenced by the rain-shadow effect of the Cascade Mountains to the west, strongly affected by the intermountain storm patterns from the southwest, and influenced by the continental weather patterns from the east. Precipitation falls as winter rains or snows, spring rains, and summer thunderstorms and showers. Winds are common and when combined with relatively high growing-season temperatures cause high rates of evapotranspiration and soil surface desiccation. There is a moderately-steep moisture gradient from somewhat moist winter and spring conditions, to dry summer and fall conditions with a long growing season. Soils are quite complex due to variation in parent material, effects of periglacial processes, depth, salinity, clay accumulation, and presence of impermeable subsurface layers. The number of plant species able to dominate in this type of environment is relatively low. Consequently, vegetation diversity is fairly low. Net primary productivity is low, nutrient cycling is moderate, carbon stress is low, and water stress is high.

There have been substantial changes in fire regimes of the Upper Snake ERU between the historical and current periods, primarily as a result of fire exclusion, excessive livestock grazing pressure, and the invasion of exotic annual grasses (particularly cheatgrass)(maps 3.22 and 3.23). In the non-forest PVGs, cheatgrass is prevalent, particularly in the northwest portion of the ERU (Pellant and Hall 1994). If these cheatgrass-invaded areas had not been grazed in the past, they became highly flammable. If the areas had been grazed however, fine-fuel production was reduced, and fire-return intervals extended. However, for the most part, fire frequency has declined in these cheatgrass-invaded areas of the Upper Snake ERU (map 3.23). In contrast to other ERUs that have more moisture, greater forest vegetation cover, and high fire occurrence in drought years, the Upper Snake ERU has typically experienced fires in the moister years that have produced higher amounts of fine-grass fuels.

From a regional-scale perspective, the Upper Snake ERU has substantial area that receives less than 30 centimeters of precipitation annually (map 3.24). Compared with the Owyhee Uplands ERU to the west however, drought years in the Upper Snake ERU have been documented less frequently (only 15% of the time from 1895-1994; table 3.38, climate division: Idaho Upper Snake River Plains). As a consequence, the potential for restoration activities in the non-forest PVGs in the Upper Snake ERU is higher relative to more westerly ERUs, particularly for non-forest PVGs that have been altered by excessive livestock grazing pressure or the invasion of exotics.

The Upper Snake ERU has had a long history of livestock grazing on both its private and public lands (map 3.25). Much of the public land-ownership area in grazing allotments has been grazed by livestock since the late-1800s. Currently, most rangeland riparian areas are in degraded conditions. Stream and river banks have typically been downcut to the point where they have no associated riparian area. By the mid-1900s however, some improvements in rangeland conditions and associated watershed condition had become apparent.

In the last 100 years, the invasion and spread of exotic plants has been noteworthy. Cheatgrass, dyers woad, leafy spurge, spotted knapweed, and Russian knapweed have become prevalent in portions of the Upper Snake ERU. Across All ownerships, areas of high susceptibility to invasion by cheatgrass, leafy spurge, and spotted knapweed compose 46, 39, and 25 percent of the ERU, respectively (table 3.47; maps 3.26, 3.35, and 3.36). Approximately 75, 6, and 9 percent of BLM/FS lands are of high susceptibility to invasion by cheatgrass, leafy spurge, and spotted knapweed, respectively (table 3.47; maps 3.26, 3.35, and 3.36).

Native biodiversity declined in the Upper Snake ERU between the historical and current periods because of exotic plant invasions, particularly in the dry shrub PVG (table 3.122). However, native plant communities that do not have a major exotic component currently persist in this ERU, for example on the Idaho National Engineering Laboratory land. These native plant communities are typically located in historically inaccessible areas, or in areas without water or water developments, and have had little to no history of excessive livestock grazing pressure. However, there are extensive areas that are characterized as saline soils, or susceptible to erosion by water and wind (table 3.46; maps 3.18, 3.34, 3.38, 3.39, 3.40, 3.41, 3.42, 3.43, and 3.44).

Road densities in the Upper Snake ERU are generally moderate to high, with some areas having low and very-low densities (map 3.28). Landforms and soils in this ERU generally are not sensitive to hydrologic regime disruption attributable to steep topography or high density of roads (map 3.29).

The pattern of BLM/FS and Other land ownerships is relatively fragmented; only a moderate proportion of the Upper Snake ERU is under BLM/FS ownership (map 3.30). Most of the breaks, plains, foothills, and mountains occur as a mosaic of BLM/FS ownership, and mixed or Other ownership patterns occur in valley areas.

Approximately 35 percent of the BLM/FS lands has moderate risks of fire occurrence and the associated high-intensity wildfires that could be difficult to suppress (map 3.31). These fire risk areas generally occur in the dry shrub PVG. At the landscape scale, there are some areas, particularly the break landforms, that have high fire risks. The moderate and high risks have been related primarily to potential wildfire occurrence from lightning or human-caused ignition; dry spring, summer, and fall conditions; complex break or foothill terrain; and flammable annual grass fuels intermingled with dry shrublands that create the potential for severe fire behavior. The Upper Snake ERU has very few areas with high fuel accumulations, high potential for crown fire, and high potential of forest insect, disease, and stress-related mortalities (map 3.32).

There are moderate risks related to the rural/wildland interface on the BLM/FS lands in the mixed and mosaic ownership patterns (map 3.33). At the landscape scale, there are some high-risk areas adjacent to small rural developments. Rural developments are typically associated with the adjacent valley and plains landforms that are on the edge of, or interspersed with, the steep and complex topography of the break landforms. The break landforms are typically located on BLM/FS lands or other public lands.

Between the historical and current periods, PVG composition changed substantially in the Upper Snake ERU due to agricultural development (table 3.122; maps 3.11 and 3.12). Thirty-six percent of the ERU was developed for agriculture at the expense of the dry shrub PVG. The dry shrub PVG dominated all ownership strata. Approximately 2.4 percent of the total area was converted to roads, of which 0.7 percent was on BLM/FS lands and 1.6 percent was on Other lands.

Trends in physiognomic type composition of the dry shrub PVG were similar across all ownership strata (table 3.123). Exotic herblands were a substantial component of the current period dry shrub PVG. The exotic herbland component on both BLM/FS and Other lands was probably underestimated for the current period because of misidentification as the upland herbland physiognomic type, which either existed alone or as the understory of the upland shrubland physiognomic type. Exotic plants may have dominated as much as 70 percent of the upland herbland physiognomic type and were a common component in much of the upland shrubland physiognomic type. The native system was dominated by a shifting mosaic of upland herbland and upland shrubland physiognomic types that was maintained by frequent non-lethal and mixed fires. As a result of the invasion of exotic forbs and annual grasses, excessive livestock grazing pressure, and fire exclusion, this shifting mosaic was generally replaced by a relatively static mosaic of patches of exotic forbs

Table 3.122—Historical and current period potential vegetation groups (PVGs) for the Upper Snake Ecological Reporting Unit (ERU).

PVG	Land Ownership Group					
	BLM/FS[1]		Other		All[2]	
	Historical	Current	Historical	Current	Historical	Current
	ERU / Ownership[3]	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership	ERU / Ownership
	Percent					
Agricultural	0 / 0	0 / 0	0 / 0	36 / 61	0 / 0	36 / 36
Alpine	+[4]	+	0 / 0	0 / 0	+	+
Cold Forest	1 / 2	1 / 2	+	+	1 / 1	1 / 1
Cool Shrub	4 / 10	4 / 9	3 / 5	3 / 5	7 / 7	7 / 7
Dry Forest	+	+	1 / 2	+	1 / 1	+
Dry Grass	1 / 2	1 / 2	1 / 2	1 / 2	2 / 2	2 / 2
Dry Shrub	35 / 83	35 / 82	47 / 81	13 / 22	82 / 82	48 / 47
Moist Forest	+	+	+	+	+	+
Riparian Shrub	+	+	2 / 3	+	2 / 2	+
Riparian Woodland	1 / 2	1 / 2	3 / 5	3 / 5	4 / 4	4 / 4
Road	NA[5] / NA	0.7 / 2	NA / NA	1.7 / 3	NA	2.4 / 2
Rock	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
Urban	0 / 0	0 / 0	0 / 0	+	0 / 0	+
Water	0 / 0	0 / 0	+	+	+	+
Woodland	+	+	1 / 2	1 / 2	1 / 1	1 / 1
Total[6]	42 / 99	42.7 / 99	58 / 100	58.7 / 100	100 / 100	101.4 / 100

[1]Land Ownership Group: BLM/FS = BLM- and FS-administered lands; Other = all land other than BLM- and FS-administered lands; All = BLM/FS lands + Other lands.

[2]The PVG percentage for All land ownership group = each PVG percentage for BLM/FS land ownership group + the PVG percentage for Other land ownership group. The totals for All land ownership will exceed 100 percent because the area in roads was not subtracted from PVG categories.

[3]ERU = relative percent of ERU area that the PVG (under that specific ownership and time period) contributes.

Ownership = relative percent of the entire ownership within the ERU that the PVG (under that specific ownership and time period) contributes. For example, given: "BLM/FS, Historical, PVG X, 10 / 20"; ERU would indicate that during the historical period, 10 percent of the ERU area was made up of PVG X on BLM/FS ownership. Given the same example, Ownership would indicate that during the historical period, PVG X on BLM/FS ownership contributes 20 percent to the BLM/FS lands.

[4]+ = < 0.5%.

[5]NA = Not Applicable.

[6]Total percent may not equal 100 due to rounding.

Map 3.44—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil salinity and soil sodicity. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having these specific soil-property indicators: salinity of 8 to 16 millimhos per centimeter (mmhos/cm), and a SAR between 5 to 12; none of the other three, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Table 3.123—Current and historical period physiognomic types for the dry shrub potential vegetation group (PVG) for Upper Snake Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Exotic Herbland	16	0	0	0
	Upland Herbland	8	+[3]	68	67
	Upland Shrubland	76	100	32	33
Other	Exotic Herbland	14	0	0	0
	Upland Herbland	18	11	68	67
	Upland Shrubland	68	90	32	33
All	Exotic Herbland	16	0	0	0
	Upland Herbland	11	6	68	67
	Upland Shrubland	74	94	32	33

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

and annual grasses, patches of shrub/annual grasses, and a few remnant patches of native upland shrub/bunchgrass.

In response to the changes in regional and landscape conditions on rangelands, the succession/disturbance regimes went through a substantial shift from a mixture of moderate- and long-cycle regimes to a mix of retrogressive- and short-cycle regimes, primarily in response to the invasion of exotic species, extensive livestock grazing, and fire exclusion. Given the lack of technology related to long-term rehabilitation of areas invaded by exotic species, there is little chance of restoring native succession/disturbance regimes. A higher likelihood of restoration opportunities occurs in the more productive environments. Riparian environments have high potential for restoration given stabilization of their hydrologic regimes. Trends for the cool shrub PVG are displayed in a table in appendix 3-N.

Regional Relationships of Biogeochemical Processes and Succession/Disturbance Regimes

Each ERU has a combination of biogeochemical processes, seasonal climates, and topoedaphic conditions that has produced a complex of succession/disturbance regimes (table 3.124). The NPP, NAI, CSI, and WSI values shown in table 3.124 are base values, and were not influenced by management. The trend change symbols (+, -, or NC) indicate: increased, reduced, or no change in trend, respectively, from historical to current period conditions for each of the variables. The seasonal climate gradient index (SCI) and topoedaphic index (TEI) did not change unless climate or land-forming changes occurred. The SCI and TEI also accounted for landscape continuity that influenced disturbances across space.

Table 3.124—Relative[1] values for biogeochemical characteristics of Ecological Reporting Units (ERUs) and relationships with succession/disturbance regimes (SDR[2]).

ERU	Net Primary Productivity	Nutrient Availability Index	Carbon Stress Index	Water Stress Index	Seasonal Climate Gradient Index[3]	Topoedaphic Index[4]	Dominant Physiognomy	Geographic Area[5]	Dominant SDR-Historical	Dominant SDR-Historical
Blue Mountains	0.7	0.7	1.0	0.7	0.4	0.8	Forest	Cascade-Rocky Mountain Transition	MC-FM	LC-RC
Trend	–[6]	–	+[7]	+						
Central Idaho Mountains	0.6	0.4	0.7	0.5	0.6	1.0	Forest	Central Rocky Mountains	MC-AC	LC-RC
Trend	–	–	+	+						
Columbia Plateau	0.5	1.0	0.6	0.8	0.5	0.2	Non-forest	Intermountain Basin	MC-FM	SC-RC
Trend	+	–	+	+						
Lower Clark Fork	1.0	0.5	0.9	0.2	0.5	0.6	Forest	Northern Rocky Mountains	AC-IM	MC-RC
Trend	–	–	+	+						
Northern Cascades	0.9	0.5	0.8	0.3	1.0	0.9	Forest	Cascade Mountains	MC-IM	LC-RC
Trend	–	–	+	+						
Northern Glaciated Mountains	0.8	0.6	0.8	0.4	0.4	0.8	Forest	Northern Rocky Mountains	AC-IM	MC-RC
Trend	–	–	+	+						
Northern Great Basin	0.4	0.8	0.5	1.0	0.4	0.4	Non-forest	Intermountain Basin	MC-FM	RC-MC
Trend	–	–	+	NC[8]						

Table 3.124 (continued).

ERU	Net Primary Productivity	Nutrient Availability Index	Carbon Stress Index	Water Stress Index	Seasonal Climate Gradient Index[3]	Topoedaphic Index[4]	Dominant Physiognomy	Geographic Area[5]	Dominant SDR-Historical	Dominant SDR-Historical
Owyhee Uplands	0.4	0.9	0.4	0.9	0.7	0.5	Non-forest	Intermountain Basin	MC-FM	RC-SC
Trend	–	–	+	NC						
Snake Headwaters	0.6	0.2	0.6	0.5	0.5	0.7	Forest	Central Rocky Mountains	MC-LC	RC-LC
Trend	+	+	–	NC						
Southern Cascades	0.8	0.6	0.7	0.4	0.8	0.7	Forest	Cascade Mountains	MC-IM	LC-RC
Trend	–	–	+	+						
Upper Clark Fork	0.7	0.4	0.7	0.5	0.3	0.6	Forest	Central Rocky Mountains	MC-AC	LC-RC
Trend	–	–	+	NC						
Upper Klamath	0.3	0.7	0.4	1.0	0.4	0.4	Forest	Cascade-Sierra Transition	MC-LC	RC-SC
Trend	+	–	+	NC						
Upper Snake	0.3	0.7	0.4	1.0	0.4	0.4	Non-forest	Intermountain	MC-LC	RC-SC
Trend	–	–	+	NC						

[1]Relative values = values are expressed relative to the highest value among ERUs. The highest value was assigned 1.0.

[2]See table 3.6 for description of succession/disturbance regimes.

[3]Seasonal Climate Gradient Index = index of spring-to-summer evapotranspiration gradient. High values indicate steep gradients that result in high stress and high risk of very dry fuels.

[4]Topoedaphic Index = index of topographic and soil complexity. High values indicate complex terrain and potential for complex fire weather and fuel conditions.

[5]Geographic Area = in reference to subbasin group map and adjacent areas outside the Basin.

[6] – = Decrease.

[7]+ = Increase.

[8]NC = No Change in trend.

As discussed in the proceeding "Biogeochemical Processes" subsection, the NPP, NAI, CSI, and WSI could change as a result of succession or disturbance. Broad native spatial patterns and succession/disturbance regimes can be predicted at multiple scales based on the differences between the six indices (NPP, NAI, CSI, WSI, SCI, and TEI).

Current succession/disturbance regimes could be spatially predicted based on ERU, PVG composition and physiognomic type composition, native composition of succession/disturbance regimes, and recent history of management and disturbance. This information provides a means of stratifying regional and subregional areas and disturbances at multiple spatial and temporal scales, without the need for a current vegetation map, which would require continual updating. Management prescriptions could then be designed to achieve a desired succession/disturbance regime. A set of prescriptions could be applied during project planning or implementation, which would promote coarse- or fine-scale objectives. Additionally, this information provides managers the tools necessary for applying an ecological and landscape systems approach to understanding vegetation and disturbance processes, and potential responses.

The Blue Mountains ERU is quite different from any of the other forest-PVG dominated ERUs. The Blue Mountains ERU occurs in a transition area between the Cascade Mountain environments and central Rocky Mountain environments. The Blue Mountains ERU has moderate NPP and NAI with high carbon stress and moderate water stress in comparison to other ERUs. There is a moderate gradient from moist winter to dry summer conditions, and topoedaphic conditions are complex. These conditions produced an inherent succession/disturbance regime that is dominated by a complex of moderate-cycle and frequent-maintenance regimes. Fire exclusion and timber harvesting of the large, shade-intolerant, and fire-, insect- and disease-resistant trees shifted the succession/disturbance regime to one dominated by a complex of long- and retrogressive-cycle regimes. These changes caused an associated decline in NPP and NAI with increases in both carbon and water stress.

The forest PVGs of the three ERUs located in the central Rocky Mountains (that is, the Central Idaho Mountains, Snake Headwaters, and Upper Clark Fork ERUs) have relatively similar characteristics. They generally have moderate NPP, low NAI, and moderate carbon and water stress. The seasonal gradient is moderate to high with cold and moist winters, to warm and dry summers.

The native succession/disturbance regimes of the three central Rocky Mountains ERUs were a complex, dominated by moderate-, accelerated-, and long-cycle regimes. Fire exclusion, traditional timber harvest activities, loss of whitebark pine to blister rust, widespread growing-season livestock grazing, and invasion by exotic forb and grass species, resulted in a shift to a system dominated by retrogressive- and long-cycle regimes. In general, the Upper Clark Fork ERU has been more substantially affected by fire exclusion, traditional timber harvest activities, and exotic plant invasion than the Central Idaho Mountains or Snake Headwaters ERUs. In general, the Snake Headwaters and Upper Clark Fork ERUs have been more affected by widespread growing-season livestock grazing, and exotic plant invasions than the Central Idaho Mountains ERU.

The associated changes of biogeochemical processes included declining trends of NPP and NAI, and increased trends in carbon or water stress in the Central Idaho Mountains and Upper Clark Fork ERUs (table 3.124). Opposite trends were detected in the Snake Headwaters ERU as a result of its inherently low NAI (caused by low average temperatures). The primary differences between the Central Idaho Mountains ERU and the Upper Clark Fork ERU were related to topography and moisture.

The Northern Glaciated Mountains and Lower Clark Fork ERUs are located in the northern Rocky Mountains. They share characteristics with northern temperate latitude systems that

developed on soils and landforms greatly influenced by continental glaciation, mountain glaciation, and erosional processes. Both ERUs have high NPP, moderate NAI, high carbon stress, and low water stress. They also have a moderate gradient in available precipitation from winter to the summer growing season, and moderate to high topoedaphic complexity.

For the northern Rocky Mountains ERUs, the native succession/disturbance regimes were dominated by accelerated- and irregular-cycle regimes. Fire exclusion, traditional timber harvest activities, loss of western white pine and whitebark pine from blister rust, and invasions by exotic forb species resulted in a shift to a system dominated by moderate- and retrogressive-cycle regimes. In general, the Lower Clark Fork ERU has been more substantially affected by fire exclusion and traditional harvest than the Northern Glaciated Mountains ERU. The changes in biogeochemical processes include declining trends of NPP and NAI, and increasing trends in carbon and water stress. The primary differences between the two ERUs are higher water stress and more complex topoedaphic conditions in the Northern Glaciated Mountains ERU.

The Northern Cascades and the Southern Cascades ERUs share characteristics with northern temperate latitude systems that developed on soils and landforms highly influenced by geologic uplift, volcanos, continental glaciation in the north, mountain glaciation in the south, and erosional processes. The two Cascade Mountains ERUs have high NPP, moderate NAI, high carbon stress, and low water stress, which is very similar to the ERUs of the northern Rocky Mountains. However, the Cascade Mountains ERU has a very steep precipitation gradient associated with wet winters and very dry summers. Topoedaphic complexity is also very high as a result of steep elevational gradients, narrow valleys, and rugged terrain.

The Cascade Mountains ERUs, had native succession/disturbance regimes dominated by moderate- and irregular-cycle regimes. Fire exclusion, traditional harvest activities, and exotic plant invasion (particularly in the eastern portion of the ERUs) resulted in a shift to a system dominated by long- and retrogressive-cycle regimes. In general, the Southern Cascades ERU has been more substantially affected by fire exclusion and traditional harvest activities than the Northern Cascades ERU. The associated changes of biogeochemical processes include declining trends of NPP and NAI, and increasing trends in carbon and water stress. The Northern Cascades ERU has slightly higher NPP and CSI, slightly lower NAI and WSI, a somewhat steeper seasonal climate gradient and more complex topoedaphic conditions than the Southern Cascades ERU.

The Upper Klamath ERU is relatively unique in that it is located in a transition area between the temperate mountain climates of the Cascades and the warmer semi-desert mountain climates of the south. NPP is quite low, NAI is moderate, carbon stress is low, and water stress is very high in the Upper Klamath ERU. The seasonal gradient from low winter precipitation to low summer precipitation is moderate. The average growing-season temperatures are high and the terrain is relatively gentle. Although the characteristics of the Upper Klamath ERU are very similar to the non-forest dominated ERUs of the Intermountain Basin, it is dominated by forests, that have adapted to the topoedaphic conditions and drier climate more similar to the Sierra Mountains to the south.

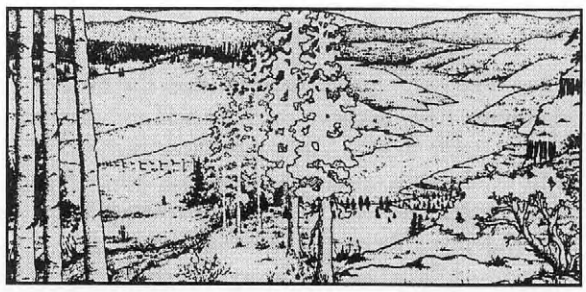
The native succession/disturbance regimes of the Upper Klamath ERU was dominated by moderate- and irregular-cycle regimes. Fire exclusion and traditional harvest activities resulted in a shift to a system dominated by moderate- and long-cycle regimes. Invasion and abundance of exotic annual grasses into this ERU has resulted in short-cycle regimes. The associated changes of biogeochemical processes include a decline of NPP and NAI, and an increase of carbon and water stress.

The non-forest dominated ERUs all have similar characteristics and are located in the Intermountain Basin geographic area. They include the Columbia Plateau, Northern Great Basin, Owyhee Uplands,

and Upper Snake ERUs. These ERUs generally have low NPP, moderate to high NAI, low to moderate CSI, and high WSI. Seasonal climate gradients (from winter to summer) varied from low to moderate, while topoedaphic variability is generally low. The primary differences between the Columbia Plateau ERU and other Intermountain Basin ERUs are: (1) lower topoedaphic complexity, (2) slightly lower water stress, and (3) the presence of wind-deposited, deep loess, and productive soils in the Palouse region of the Columbia Plateau ERU. The Northern Great Basin and Upper Snake ERUs have the highest water stress of the four Intermountain Basin ERUs. The Owyhee Uplands ERU has the steepest gradient from moist winter conditions to very dry summer conditions. We suspect this is a result of interactions of climate and soil conditions.

These non-forest ERUs had a native succession/disturbance regimes that were dominated by frequent-maintenance and moderate-cycle regimes. The combination of fire exclusion, extensive selective grazing of perennial grasses by livestock during the growing season, agricultural development, and exotic forb and annual grass invasions has altered native regimes. Current succession/disturbance regim and Upper Snake ERUs have been altered more by agricultural development than the Northern Great Basin and Owyhee Uplands ERUs. All four of these non-forest ERUs were altered substantially by excessive livestock grazing pressure in the historical period.

REGIONAL AND ECOLOGICAL REPORTING UNIT COVER TYPE TRENDS



We reported the broad-scale trends of cover types from the historical to the current period for the Basin as a whole and by the 13 Ecological Reporting Units within the Basin. When a cover type was reported absent from the historical or current periods this means that it was not detectable with 1-km^2 resolution data. It may, however, be detectable with finer scale data.

The Basin

The richness of cover types increased between the historical and current periods due to the addition of three anthropogenic cover types [urban, exotic forbs/annual grass, and cropland/hay/pasture (hereafter referred to as croplands); table 3.125]. We did not detect measurable changes in areal extent of the alpine tundra, barren, Oregon white oak (*Quercus garryana*), red fir (*Abies magnifica*), or water cover types. Ecologically significant changes were detected for 66 and 34 percent of the cover types relative to class and the Basin, respectively. Two cover types (western white pine and whitebark pine/subalpine larch) were virtually eliminated between the historical and current periods, experiencing a greater than 95 percent decline. Only the barren, lodgepole pine, and antelope bitterbrush/bluebunch wheatgrass (*Purshia tridentata/Agropyron spicatum*) (hereafter referred to as bitterbrush/bluebunch wheatgrass) cover types occurred within their median historical ranges during the current period.

Transition matrices (Jones 1996) indicate that agricultural development was largely responsible for the substantial areal declines of the fescue (*Festuca* spp.)-bunchgrass, wheatgrass bunchgrass, big sagebrush (*Artemisia tridentata*), and native forb cover types. Similarly, nearly 12 percent of the mountain big sagebrush (*Artemisia tridentata vaseyana*) cover type was also converted to agricultural cover types, although most of its decline was attributable to the encroachment of the juniper/sagebrush cover type. Another major change that occurred in non-forest cover types was a transition to the exotic forbs/annual grass cover type. The increase in the exotic forbs/annual grass cover type occurred at the expense of the big sagebrush cover type, and to a lesser extent to the wheatgrass bunchgrass, mountain big sagebrush, and fescue-bunchgrass cover types.

Our observed changes of forest cover types were dominated by the transition of early-seral, shade-intolerant tree species to shade-tolerant tree species. For example, the areal decline of the interior ponderosa pine cover type was attributable to increasing areas of the grand fir/white fir (*Abies grandis/A. concolor*) and interior Douglas-fir cover types; areal declines of the western larch cover type was due to increases of the Douglas-fir, lodgepole pine, or grand fir/white fir cover types; a large proportion of the western white pine cover type was converted to the grand fir/white fir cover type; and a large proportion of the whitebark pine cover type was converted to the Engelmann spruce (*Picea engelmannii*)/subalpine fir cover type.

Blue Mountains ERU

Cover type richness decreased within the Blue Mountains ERU between the historical and current periods (table 3.126). Although three anthropogenic cover types appeared (cropland, exotic forbs/annual grass, and urban) in the current period, four endemic cover types were not detected [bitterbrush/bluebunch wheatgrass, cottonwood/willow (*Populus trichocarpa/Salix*), western larch, and whitebark pine/subalpine larch].

We detected ecologically significant trends of 56 and 41 percent of the cover types relative to class and the Blue Mountains ERU, respectively (table 3.126). Only the alpine tundra, interior Douglas-fir, mountain mahogany (*Cercocarpus ledifolius*), native forb, and water cover types occurred within their median historical ranges during the current period. However, the departures of eight of the cover types were not ecologically significant.

The cover type composition within the Blue Mountains ERU was most affected by areal increases of the croplands and grand fir/white fir cover types, and areal declines of the fescue-bunchgrass and interior ponderosa pine cover types. The cover type transition matrix indicates that 41 percent of the fescue-bunchgrass type was converted to the croplands cover type (Jones 1996). Other areas converted to agricultural uses were derived predominantly from the big sagebrush, mountain big sagebrush, and wheatgrass bunchgrass cover types. The transition matrix also indicates that the loss of the interior ponderosa pine cover type was mostly attributable to a conversion into the grand fir/white fir cover type, and to a lesser degree, the interior Douglas-fir cover type.

Central Idaho Mountains ERU

We detected an increase of cover type richness within the Central Idaho Mountains ERU between the historical and current periods (table 3.127). Although three endemic cover types (bitterbrush/bluebunch wheatgrass, native forb, and whitebark pine/subalpine larch) were not detected, five additional cover types appeared during the current period. Three of the five new cover types detected in the current period were anthropogenic (croplands, exotic forbs/annual grass, and urban), while the remaining two were the mountain hemlock (*Tsuga mertensiana*) and western redcedar/western hemlock cover types. Ecologically significant trends relative to class and the Central Idaho Mountains ERU were detected for 55 and 36 percent of the cover types, respectively. Similarly, the departures of 39 percent of the cover types from their median historical ranges were ecologically significant.

The Central Idaho Mountains ERU was dominated by the areal declines of the wheatgrass bunchgrass and interior Douglas-fir cover types, and the increased areal extent of the croplands, Engelmann spruce/subalpine fir, grand fir/white fir, and shrub or herb/tree regen cover types (table 3.127; Jones 1996). Approximately 53 percent of the Douglas-fir type was converted primarily to the shrub or herb/tree regen, lodgepole pine, Engelmann spruce/subalpine fir, and grand fir/white fir cover types. Similarly, the substantial areal decline of the wheatgrass bunchgrass cover type was primarily the result of conversions into the mountain big sagebrush (34%), big sagebrush (20%), or croplands (19%) cover types.

Columbia Plateau ERU

Between the historical and current periods, five additional cover types were documented, while three were not detected within the Columbia Plateau ERU (table 3.128). The three cover types eliminated included trace amounts of the native forb, western white pine, and whitebark pine/subalpine larch cover types. The five cover types that appeared between the historical and current periods included three anthropogenic cover types (croplands, exotics/annual grass, and urban) and trace amounts of the mountain hemlock and western redcedar/western hemlock cover types.

We detected ecologically significant trends relative to class and the Columbia Plateau ERU for 46 and 20 percent of the cover types, respectively (table

Table 3.125—Summary of broad-scale cover type trends within the Basin.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	Basin Change[3]	Departure Class[4]
	Percent						
Alpine Tundra	0.16	0.16	0.16	0.16	-0.18	0	1
Barren	0.24	0.24	0.24	0.24	0	0	3
Big Sagebrush	24.54	16.36	24.54	16.43	-33.04*	-8.11*	2*
Bitterbrush / Bluebunch Wheatgrass	0.31	0.16	0.31	0.20	-33.87	-0.10	3
Chokecherry / Serviceberry / Rose	0.04	0.04	0.05	0.03	-8.88	T[5]	1
Cottonwood / Willow	0.05	0.03	0.05	0.02	-63.71*	-0.03	1
Cropland / Hay / Pasture	0	0	0	16.06	NA[6]	16.06*	5*
Engelmann Spruce / Subalpine Fir	4.00	3.27	4.00	4.66	16.68	0.67	5*
Exotic Forbs / Annual Grass	0	0	0	2.06	NA	2.06*	5*
Fescue-Bunchgrass	8.17	6.43	8.17	2.82	-65.53*	-5.36*	1*
Grand Fir / White Fir	0.46	0.46	1.71	4.91	964.64*	4.45*	5*
Interior Douglas-fir	6.47	6.47	8.38	8.23	27.22*	1.76*	4*
Interior Ponderosa Pine	13.63	13.04	13.70	10.08	-26.06*	-3.55*	1*
Juniper / Sagebrush	0.82	0.55	0.82	2.15	163.17*	1.34*	5*
Juniper Woodlands	0.11	0.09	0.11	0.14	36.42*	0.04	5
Limber Pine	0.04	0.03	0.04	0.05	34.32*	0.01	5
Lodgepole Pine	7.60	5.13	7.60	7.25	-4.64	-0.35	3
Low Sagebrush	1.82	1.41	1.82	1.90	4.30	0.08	5
Mixed-Conifer Woodlands	0.94	0.94	1.52	0.49	-47.41*	-0.44	1
Mountain Big Sagebrush	7.72	7.17	7.72	5.12	-33.74*	-2.61*	1*
Mountain Hemlock	0.15	0.13	0.17	0.23	53.36*	0.08	5
Mountain Mahogany	0.07	0.07	0.34	0.35	406.48*	0.28	5
Native Forb	0.10	0.10	0.33	0.01	-91.71*	-0.09	1
Oregon White Oak	0.01	0.01	0.01	0.01	0	0	4
Pacific Ponderosa Pine	0.10	0.10	0.13	0.19	80.16*	0.08	5
Pacific Silver Fir / Mountain Hemlock	0.02	0.02	0.38	0.40	1733.33*	0.37	5
Red Fir	0	0	0.03	0	0	0	2
Salt Desert Shrub	2.21	1.46	2.21	1.47	-33.79*	-0.75	2*
Shrub or Herb / Tree Regen	3.63	3.63	4.34	4.90	34.89*	1.27*	5*
Sierra Nevada Mixed-Conifer	0.04	0.04	0.06	T	-92.12*	-0.03	1
Urban	0	0	0	0.16	NA	0.16	5
Water	0.94	0.94	0.94	0.93	-0.16	T	1
Western Larch	3.65	3.56	3.66	2.35	-35.75*	-1.30*	1*
Western Redcedar / Western Hemlock	0.07	0.07	0.49	0.67	853.48*	0.60	5
Western White Pine	1.79	1.77	2.43	0.08	-95.54*	-1.71*	1*
Wheatgrass Bunchgrass	6.61	6.61	14.74	2.11	-68.05*	-4.49*	1*
Whitebark Pine	1.33	1.33	1.58	0.81	-38.75*	-0.52	1*
Whitebark Pine / Subalpine Larch	0.27	0.27	0.70	0.01	-94.59*	-0.25	1

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]Basin change = percent change of the Basin attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]T = Trace amount ≤ 0.01%.

[6]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

Table 3.126—Summary of broad-scale cover type trends within the Blue Mountains Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	..... Percent						
Alpine Tundra	0.28	0.28	0.28	0.28	0	0	3
Big Sagebrush	8.55	6.79	8.55	6.79	-20.64*	-1.77*	1*
Bitterbrush / Bluebunch Wheatgrass	T[5]	T	T	0	-100.00*	0	1
Cottonwood / Willow	0.02	0.01	0.02	0	-100.00*	-0.02	1
Cropland / Hay / Pasture	0	0	0	17.40	NA[6]	17.40*	5*
Engelmann Spruce / Subalpine Fir	1.11	0.98	1.29	2.01	81.32*	0.90	5*
Exotic Forbs / Annual Grass	0	0	0	1.44	NA	1.44*	5*
Fescue-Bunchgrass	18.61	12.32	18.61	5.76	-69.03*	-12.84*	1*
Grand Fir / White Fir	0.95	0.95	1.47	11.05	1067.17*	10.10*	5*
Interior Douglas-fir	3.35	3.35	11.64	10.12	202.06	6.77	3
Interior Ponderosa Pine	30.59	28.54	30.59	19.05	-37.73*	-11.54*	1*
Juniper / Sagebrush	0.63	0.39	0.63	2.16	243.43*	1.53*	5*
Lodgepole Pine	2.36	1.76	2.36	2.58	9.16	0.22	5*
Low Sagebrush	0.10	0.08	0.10	0.10	0	0	4
Mixed-Conifer Woodlands	2.07	2.07	4.01	0.92	-55.42*	-1.15*	1*
Mountain Big Sagebrush	11.66	9.93	11.66	6.07	-47.89*	-5.58*	1*
Mountain Mahogany	0.08	0.08	0.61	0.39	376.51	0.31	3
Native Forb	0.02	0.02	0.37	0.09	318.98	0.07	3
Salt Desert Shrub	0.76	0.71	0.80	0.55	-28.09*	-0.21	1
Shrub or Herb / Tree Regen	9.32	7.37	10.03	10.58	13.51	1.26*	5*
Urban	0	0	0	0.15	NA	0.15	5
Water	0.28	0.28	0.28	0.28	0	0	3
Western Larch	0.38	0.38	1.33	0	-100.00*	-0.38	1
Western White Pine	0	0	0.67	0	0	0	2
Wheatgrass Bunchgrass	6.31	6.31	7.82	1.54	-75.59*	-4.77*	1*
Whitebark Pine	0.88	0.75	0.88	0.27	-69.04*	-0.61	1
Whitebark Pine / Subalpine Larch	0.09	0.09	0.24	0	-100.00*	-0.09	1

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]T = Trace amount ≤ 0.01%.

[6]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

Table 3.127—Summary of broad-scale cover type trends within the Central Idaho Mountains Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Alpine Tundra	0.20	0.20	0.20	0.20	0	0	3
Barren	0.50	0.50	0.50	0.50	0	0	3
Big Sagebrush	4.51	4.51	5.15	4.72	4.54	0.20	3
Bitterbrush / Bluebunch Wheatgrass	T[5]	T	T	0	-100.00*	T	1
Chokecherry / Serviceberry / Rose	0.02	0.02	0.02	0.01	-8.18	T	1
Cottonwood / Willow	0.05	0.04	0.06	0.04	-13.53	-0.01	1
Cropland / Hay / Pasture	0	0	0	5.46	NA[6]	5.46*	5*
Engelmann Spruce / Subalpine Fir	9.36	6.90	9.36	13.39	43.03*	4.03*	5*
Exotic Forbs / Annual Grass	0	0	0	1.69	NA	1.69*	5*
Fescue-Bunchgrass	9.84	6.94	9.84	7.36	-25.24	-2.49	3
Grand Fir / White Fir	1.67	1.67	2.40	7.10	325.50*	5.43*	5*
Interior Douglas-fir	17.26	12.20	17.26	8.18	-52.60*	-9.08*	1*
Interior Ponderosa Pine	14.14	14.14	17.61	11.38	-19.51*	-2.76*	1*
Juniper / Sagebrush	0.08	0.06	0.08	0.19	126.16*	0.11	5
Juniper Woodlands	0.03	0.03	0.07	0.08	174.74*	0.05	5
Limber Pine	0.27	0.22	0.27	0.36	34.42*	0.09	5
Lodgepole Pine	11.14	9.09	11.14	12.25	10.02	1.12*	5*
Low Sagebrush	1.10	1.10	1.27	1.51	36.65*	0.40	5*
Mixed-Conifer Woodlands	2.73	2.73	3.51	0.08	-97.05*	-2.65*	1*
Mountain Big Sagebrush	6.44	6.44	9.33	6.52	1.19	0.08	2
Mountain Hemlock	0	0	T	0.01	NA	0.01	5
Mountain Mahogany	0.11	0.11	0.29	0.31	191.89*	0.20	5
Native Forb	0.05	0.05	0.11	0	-100.00*	-0.05	1
Salt Desert Shrub	0.89	0.53	0.89	0.53	-39.67*	-0.35	2
Shrub or Herb / Tree Regen	5.13	5.13	5.69	9.31	81.65*	4.18*	5*
Urban	0	0	0	0.03	NA	0.03	5
Water	0.20	0.20	0.20	0.20	0	0	3
Western Larch	0.37	0.37	3.65	0.83	125.86	0.46	3
Western Redcedar / Western Hemlock	0	0	0.30	1.10	NA	1.10*	5*
Western White Pine	T	T	2.58	0.14	11483.33*	0.14	2
Wheatgrass Bunchgrass	7.88	2.98	7.88	1.40	-82.19*	-6.48*	1*
Whitebark Pine	4.75	4.52	4.89	3.62	-23.93*	-1.14*	1*
Whitebark Pine / Subalpine Larch	0.71	0.71	3.05	0	-100.00*	-0.71	1

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]T = Trace amount ≤ 0.01%.

[6]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

Table 3.128—Summary of broad-scale cover type trends within the Columbia Plateau Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Alpine Tundra	T[5]	T	T	T	0	0	3
Big Sagebrush	39.60	27.43	39.60	21.30	-46.22*	-18.30*	1*
Bitterbrush / Bluebunch Wheatgrass	0.62	0.31	0.62	0.48	-22.70	-0.14	3
Chokecherry / Serviceberry / Rose	0.01	0.01	0.01	0.01	101.92*	0.01	4
Cottonwood / Willow	0.12	0.06	0.12	0.07	-36.05	-0.04	3
Cropland / Hay / Pasture	0	0	0	44.46	NA[6]	44.46*	5*
Engelmann Spruce / Subalpine Fir	0.09	0.08	0.12	0.02	-79.82*	-0.07	1
Exotic Forbs / Annual Grass	0	0	0	2.46	NA	2.46*	5*
Fescue-Bunchgrass	13.72	12.56	13.72	1.47	-89.27*	-12.24*	1*
Grand Fir / White Fir	0.32	0.32	0.61	2.21	595.28*	1.89	5*
Interior Douglas-fir	0.42	0.42	1.97	1.10	158.64	0.67	3
Interior Ponderosa Pine	7.36	7.36	8.16	7.63	3.59	0.26	3
Juniper / Sagebrush	2.74	1.58	2.74	7.14	160.80*	4.40*	5*
Juniper Woodlands	0.07	0.05	0.07	0.07	0	0	4
Lodgepole Pine	0.49	0.40	0.51	0.36	-27.15*	-0.13	1
Low Sagebrush	0.03	0.03	0.11	0.03	0	0	2
Mixed-Conifer Woodlands	0.29	0.29	0.48	0.33	14.50	0.04	3
Mountain Big Sagebrush	7.77	7.27	7.77	1.61	-79.32*	-6.16*	1*
Mountain Hemlock	0	0	0.01	0.01	NA	0.01	3
Mountain Mahogany	0.09	0.09	0.52	0.61	551.82*	0.52	5
Native Forb	0.17	0.17	1.23	0	-100.00*	-0.17	1
Pacific Ponderosa Pine	0.01	0.01	0.01	0.02	23.53*	T	5
Pacific Silver Fir / Mountain Hemlock	0	0	0.06	0	0	0	2
Red Fir	0	0	0.08	0	0	0	2
Salt Desert Shrub	0.43	0.23	0.43	T	-99.77*	-0.43	1
Shrub or Herb / Tree Regen	1.77	1.18	1.77	1.47	-17.34	-0.31	3
Sierra Nevada Mixed-Conifer	0	0	0.01	0	0	0	2
Urban	0	0	0	0.28	NA	0.28	5
Water	0.62	0.62	0.62	0.62	0	0	3
Western Larch	0.26	0.26	0.72	0.54	105.18	0.28	3
Western Redcedar / Western Hemlock	0	0	0.11	0.15	NA	0.15	5
Western White Pine	0.57	0.34	0.57	0	-100.00*	-0.57	1
Wheatgrass Bunchgrass	21.26	21.26	32.91	5.23	-75.39*	-16.03*	1*
Whitebark Pine	0.01	0.01	0.01	0.01	-44.68 *	T	1
Whitebark Pine / Subalpine Larch	T	T	T	0	-100.00*	T	1

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]T = Trace amount ≤ 0.01%.

[6]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

3.128). Similarly, 8 of 35 cover types had significant departures from their median historical ranges. Conversely, 10 cover types (alpine tundra, bitterbrush/bluebunch wheatgrass, cottonwood/willow, interior Douglas-fir, interior ponderosa pine, mixed-conifer woodlands, mountain hemlock, shrub or herb/tree regen, water, and western larch) occurred within their median historical ranges during the current period.

Cover type transitions within the Columbia Plateau ERU were dominated by the agricultural conversion of 46 percent of the big sagebrush, 79 percent of the wheatgrass bunchgrass, and 91 percent of the fescue-bunchgrass cover types (Jones 1996). In fact, the croplands cover type composed nearly 45 percent of the Columbia Plateau ERU during the current period. The decline in mountain big sagebrush was primarily attributable to encroachment by western juniper and the associated conversion to the juniper/sagebrush cover type. This transition was most notable in the southern portion of the Columbia Plateau ERU (maps 3.45 and 3.46).

Lower Clark Fork ERU

The richness of cover types within the Lower Clark Fork ERU increased between the historical and current periods (table 3.129). Although two cover types (mixed-conifer woodlands and whitebark pine/subalpine larch) were not detected during this period, five new types (croplands, exotics/annual grass, urban, mountain hemlock, and western redcedar/western hemlock) appeared within the Lower Clark Fork ERU.

We detected ecologically significant trends for 41 and 36 percent of the cover types relative to class and the Lower Clark Fork ERU, respectively (table 3.129). Only three cover types (Engelmann spruce/subalpine fir, interior Douglas-fir, and western larch) occurred within their median historical ranges during the current period. Although we detected substantial departures for the other 19 cover types, only 8 of them were ecologically significant.

The compositional changes of cover types that affected the Lower Clark Fork ERU to the greatest extent involved areal increases of the grand fir/white fir and shrub or herb/tree regen cover types, and areal declines of the interior ponderosa pine and western white pine cover types. The areal extent of the grand fir/white fir cover type increased by more than 5,700 percent and dominated the ERU during the current period. Conversely, the western white pine cover type was nearly eliminated, as its coverage in the Lower Clark Fork ERU declined from approximately 27 percent to near zero. Cover type transitions were dominated by the nearly total conversion of the western white pine cover type to the grand fir/white fir, western larch, and shrub or herb/tree regen cover types, and the conversion of 66 percent of the interior ponderosa pine cover type to the grand fir/white fir type (Jones 1996).

Northern Cascades ERU

The richness of cover types within the Northern Cascades ERU increased between the historical and current periods (table 3.130). During this period, three anthropogenic cover types appeared (cropland, exotic forbs/annual grass, and urban), while the salt desert shrub cover type was not detected.

We detected ecologically significant trends with respect to class and the Northern Cascades ERU for 55 and 39 percent of the cover types, respectively (table 3.130). Of the 33 cover types detected within the ERU, only the chokecherry/serviceberry/rose (*Prunus virginiana/Amelanchier alnifolia/Rosa* spp.), interior ponderosa pine, water, and whitebark pine/subalpine larch cover types occurred within their median historical ranges during the current period. However, more than 50 percent of the substantial departures from the median historical range were not ecologically significant.

The compositional changes of cover types in the Northern Cascades ERU were dominated by the areal decline of the Engelmann spruce/subalpine fir, interior ponderosa pine, western larch, and whitebark pine cover types, and the areal increase

Map 3.45—Historical distribution of western juniper in the Basin, based on the historical extent of the juniper-sagebrush and juniper woodland cover types in the Basin.

Map 3.46—Current distribution of western juniper in the Basin, based on the current period extent of the juniper-sagebrush and juniper woodland cover types in the Basin.

Table 3.129—Summary of broad-scale cover type trends within the Lower Clark Fork Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Cropland / Hay / Pasture	0	0	0	3.24	NA[5]	3.24*	5*
Engelmann Spruce / Subalpine Fir	7.81	5.80	7.81	6.19	-20.67	-1.61	3
Exotic Forbs / Annual Grass	0	0	0	T[6]	NA	T	5
Fescue-Bunchgrass	1.11	0.66	1.11	0.13	-88.34*	-0.98*	1*
Grand Fir / White Fir	0.40	0.40	8.03	23.05	5734.83*	22.66*	5*
Interior Douglas-fir	4.71	4.71	15.58	8.45	79.33	3.74	3
Interior Ponderosa Pine	21.14	16.96	21.14	7.11	-66.36*	-14.03*	1*
Lodgepole Pine	14.02	7.72	14.02	13.34	-4.85	-0.68	4
Mixed-Conifer Woodlands	0.03	0.01	0.03	0	-100.00*	-0.03	1
Mountain Big Sagebrush	0	0	0.11	0	0	0	2
Mountain Hemlock	0	0	0.28	1.04	NA	1.04*	5*
Native Forb	0	0	0.04	0	0	0	2
Salt Desert Shrub	0	0	T	0	0	0	2
Shrub or Herb / Tree Regen	1.76	1.76	8.24	11.92	576.95*	10.16*	5*
Urban	0	0	0	0.15	NA	0.15	5
Water	0.84	0.84	0.84	0.83	-1.32	-0.01	1
Western Larch	20.38	17.16	20.38	19.66	-3.51	-0.72	3
Western Redcedar / Western Hemlock	0	0	2.38	4.38	NA	4.38*	5*
Western White Pine	26.89	14.36	26.89	0.04	-99.86*	-26.86*	1*
Wheatgrass Bunchgrass	0.38	0.37	0.38	0.16	-58.65*	-0.23	1
Whitebark Pine	0.42	0.42	0.56	0.06	-86.08*	-0.37	1
Whitebark Pine / Subalpine Larch	0.06	0.05	0.06	0	-100.00*	-0.06	1

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable since the cover type did not exist during the historical period.

[6]T = Trace amount ≤ 0.01%.

*Ecologically significant changes.

Table 3.130—Summary of broad-scale cover type trends within the Northern Cascades Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Alpine Tundra	0.95	0.95	0.95	0.94	-0.82	-0.01	1
Big Sagebrush	3.38	3.31	3.64	0.68	-79.81*	-2.70*	1*
Bitterbrush / Bluebunch Wheatgrass	1.22	0.63	1.22	0.62	-49.36*	-0.60	1*
Chokecherry / Serviceberry / Rose	0.28	0.28	0.30	0.29	4.23	0.01	3
Cropland / Hay / Pasture	0	0	0	6.24	NA[5]	6.24*	5*
Engelmann Spruce / Subalpine Fir	8.94	5.10	8.94	4.66	-47.88*	-4.28*	1*
Exotic Forbs / Annual Grass	0	0	0	0.20	NA	0.20	5
Fescue-Bunchgrass	3.53	2.77	3.53	1.50	-57.52*	-2.03*	1*
Grand Fir / White Fir	0.18	0.18	4.31	4.04	2150.28*	3.86*	4*
Interior Douglas-fir	17.98	15.41	17.98	18.22	1.32	0.24	5
Interior Ponderosa Pine	23.65	15.31	23.65	17.86	-24.49	-5.79	3
Juniper / Sagebrush	0.01	0.01	0.20	0.89	7534.19*	0.88	5
Juniper Woodlands	0.01	T	0.01	0.01	0	0	4
Lodgepole Pine	16.82	11.49	16.82	22.21	32.04*	5.39*	5*
Low Sagebrush	0	0	0.02	0	0	0	2
Mixed-Conifer Woodlands	1.16	1.16	1.56	1.15	-1.01	-0.01	1
Mountain Big Sagebrush	2.59	1.05	2.59	0.28	-88.99*	-2.30*	1*
Mountain Hemlock	2.36	1.99	2.75	3.61	52.64*	1.24*	5*
Mountain Mahogany	0	0	0.04	0.04	NA	0.04	4
Native Forb	0	0	0.03	0	0	0	2
Pacific Ponderosa Pine	1.12	0.91	1.12	1.40	25.44*	0.28	5*
Pacific Silver Fir / Mountain Hemlock	0.43	0.43	6.32	8.48	1895.18*	8.06*	5*
Salt Desert Shrub	T[6]	0	T	0	-100.00*	-0.00	2
Shrub or Herb / Tree Regen	5.05	5.05	7.44	3.93	-22.24*	-1.12*	1*
Sierra Nevada Mixed-Conifer	0.10	0.10	0.48	0.01	-92.00*	-0.09	1
Urban	0	0	0	0.11	NA	0.11	5
Water	1.05	1.05	1.05	1.05	0	0	3
Western Larch	3.00	3.00	6.37	T	-99.87*	-3.00*	1*
Western Redcedar / Western Hemlock	0.77	0.77	4.42	0.28	-63.46*	-0.49	1
Western White Pine	0	0	1.91	0	0	0	2
Wheatgrass Bunchgrass	2.04	1.95	2.60	0.70	-65.71*	-1.34*	1*
Whitebark Pine	3.18	2.87	3.18	0.18	-94.36*	-3.00*	1*
Whitebark Pine / Subalpine Larch	0.12	0.12	0.40	0.33	165.63	0.21	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable since the cover type did not exist during the historical period.

[6]Trace = Trace amount ≤ 0.01%.

*Ecologically significant changes.

of the croplands, lodgepole pine, and Pacific silver fir (*Abies amabilis*)/mountain hemlock cover types. The transition matrix (Jones 1996) indicates that the Engelmann spruce/subalpine fir cover type converted primarily to the Pacific silver fir/mountain hemlock and lodgepole pine cover types; the interior ponderosa pine cover type converted to either grand fir/white fir or interior Douglas-fir cover types; the western larch cover type converted into interior Douglas-fir cover type; and the whitebark pine cover type converted into Engelmann spruce/subalpine fir cover type. Similarly, the areal increase of the croplands cover type occurred primarily at the expense of the big sagebrush and fescue-bunchgrass cover types.

Northern Glaciated Mountains ERU

Cover type richness increased between the historical and current periods in the Northern Glaciated Mountains ERU (table 3.131). Five additional cover types appeared (croplands, exotics/annual grass, urban, mountain hemlock, and western redcedar/western hemlock), while the whitebark pine/subalpine larch cover type was not detected in the current period. In addition to the whitebark pine/subalpine larch cover type, nearly all of the big sagebrush and cottonwood/willow cover types were converted to other types between the historical and current periods.

Ecologically significant trends relative to class and the Northern Glaciated Mountains occurred in 46 percent of the cover types (table 3.131). Of the 28 cover types detected in the ERU, the areal extents of only the barren, bitterbrush/bluebunch wheatgrass, Engelmann spruce/subalpine fir, mixed-conifer woodlands, and mountain hemlock cover types occurred within their median historical ranges. Although we detected substantial departures from their median historical ranges for most cover types, only 54 percent of the departures were ecologically significant relative to the composition of types within the Northern Glaciated Mountains ERU.

The composition of the Northern Glaciated Mountains ERU was affected predominantly by the areal increase of the croplands, grand fir/white fir, and interior Douglas-fir cover types, and areal declines of the fescue-bunchgrass, interior ponderosa pine, and western larch cover types (table 3.131; Jones 1996). The transition matrix indicated that agricultural development was largely responsible for the areal declines of the big sagebrush, fescue-bunchgrass, and interior ponderosa pine cover types. Similarly, 46 percent of the western larch and 33 percent of the interior ponderosa pine cover types were converted to either grand fir/white fir or interior Douglas-fir cover types.

Northern Great Basin ERU

The richness of cover types did not vary between the historical and current periods within the Northern Great Basin ERU (table 3.132). However, three cover types appeared (croplands, exotic forbs/annual grass, and grand fir/white fir), while three cover types (native forb, Sierra Nevada mixed-conifer, and western larch) were converted to other types during that time interval.

We detected ecologically significant class trends for 10 cover types (table 3.132). However, ecologically significant changes relative to the Northern Great Basin ERU occurred due to the changes of five cover types (big sagebrush, croplands, exotic forbs/annual grass, juniper/sagebrush, and mountain big sagebrush). The current period areal extent of most (84%) cover types departed substantially from their median historical ranges. However, only the departures of five cover types (croplands, exotic forbs/annual grass, fescue-bunchgrass, juniper/sagebrush, and mountain big sagebrush) were ecologically significant.

The compositional changes of the Northern Great Basin ERU were dominated by the areal increases in the cropland, exotic forbs/annual grass, and juniper/sagebrush cover types, and the areal declines of the big sagebrush, mountain big sagebrush, and salt desert shrub cover types (table 3.132; Jones 1996). Agricultural development was

largely responsible for the substantial decline of the salt desert shrub cover type, and relatively smaller declines of the wheatgrass bunchgrass and fescue-bunchgrass cover types. The increase of the exotic forbs/annual grass cover type occurred predominantly in the big sagebrush cover type, and to a lesser extent in the mountain big sagebrush cover type. The decline in mountain big sagebrush was primarily attributable to encroachment by western juniper and the conversion to the juniper/sagebrush cover type.

Owyhee Uplands ERU

The richness of cover types within the Owyhee Uplands ERU increased between the historical and current periods (table 3.133). Three anthropogenic cover types appeared (cropland, exotic forbs/annual grass, and urban), while two cover types (lodgepole pine and native forb) disappeared during this time interval.

We detected ecologically significant trends of 38 and 10 percent of the cover types relative to class and the Owyhee Uplands ERU, respectively (table 3.133). Although the areal extents of 22 of the 29 cover types occurred outside their median historical ranges during the current period, the departures of only six cover types were ecologically significant.

The composition of the Owyhee Uplands ERU was affected to the greatest extent by the areal decline of the big sagebrush cover type, and the areal increases of the croplands and exotic forbs/annual grass cover types (table 3.133; Jones 1996). Not surprisingly, the transition matrix indicates that agricultural development and the large increase in exotic forbs/annual grass cover type were responsible for the substantial reduction in area of the big sagebrush cover type. Although we observed a 21 percent decline of the big sagebrush cover type across 11 percent of the Owyhee Uplands ERU, the big sagebrush type continued to occur within its median historical range during the current period.

Snake Headwaters ERU

The richness of cover types within the Snake Headwaters ERU decreased between the historical and current periods (table 3.134). Although three anthropogenic cover types (croplands, exotic forbs/annual grass, and urban) appeared, four endemic cover types (chokecherry/serviceberry/rose, cottonwood/willow, mixed-conifer woodlands, and native forb) were not detected in the current period.

Of the 28 cover types observed within the Snake Headwaters ERU, we detected ecologically significant trends for 46 and 32 percent of the types relative to class and the Snake Headwaters ERU, respectively (table 3.134). Although we observed substantial departures from the median historical range in all but five cover types, these departures were ecologically significant for only 36 percent of the cover types.

The composition of cover types within the Snake Headwaters ERU was affected predominantly by the areal increases of the croplands and interior Douglas-fir cover types; and the areal declines of the big sagebrush and lodgepole pine cover types, and to a lesser degree, the mountain big sagebrush, and shrub or herb/tree regen cover types (table 3.134; Jones 1996). The areal increase of the interior Douglas-fir cover type was derived mostly from the lodgepole pine, mountain big sagebrush, shrub or herb tree/regen, and Engelmann spruce/subalpine fir cover types. The 67 percent loss of the lodgepole pine cover type was attributable to gains in the interior Douglas-fir and Engelmann spruce/subalpine fir cover types. Nearly all of the big sagebrush and mountain big sagebrush cover types were eliminated within the Snake Headwaters ERU. Agricultural conversion was responsible for the 84 percent areal decline of the big sagebrush cover type, whereas encroaching Douglas-fir converted 89 percent of the mountain big sagebrush cover type.

Table 3.131—Summary of broad-scale cover type trends within the Northern Glaciated Mountains Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Barren	0.01	0.01	0.01	0.01	0	0	3
Big Sagebrush	3.34	2.99	3.34	0.06	-98.19*	-3.28*	1*
Bitterbrush / Bluebunch Wheatgrass	0.60	0.30	0.60	0.40	-33.33	-0.20	3
Cottonwood / Willow	0.11	0.07	0.11	T[5]	-98.77*	-0.11	1
Cropland / Hay / Pasture	0	0	0	11.75	NA[6]	11.75*	5*
Engelmann Spruce / Subalpine Fir	7.41	6.70	7.41	7.19	-2.94	-0.22	3
Exotic Forbs / Annual Grass	0	0	0	0.09	NA	0.09	5
Fescue-Bunchgrass	7.08	3.33	7.08	0.83	-88.27*	-6.25*	1*
Grand Fir / White Fir	0.52	0.52	3.76	8.96	1638.60*	8.44*	5*
Interior Douglas-fir	7.94	7.94	13.26	15.61	96.74*	7.68*	5*
Interior Ponderosa Pine	20.51	20.48	21.89	13.93	-32.07*	-6.58*	1*
Juniper / Sagebrush	0	0	T	T	0	T	5
Lodgepole Pine	14.30	7.62	14.30	13.55	-5.28	-0.75	4*
Low Sagebrush	0	0	T	0	0	0	2
Mixed-Conifer Woodlands	0.25	0.25	1.69	1.33	435.90	1.09	3
Mountain Big Sagebrush	2.07	1.46	2.07	0.84	-59.25*	-1.23*	1*
Mountain Hemlock	0	0	0.02	0.01	NA	0.01	3
Native Forb	0	0	0.33	0	0	0	2
Pacific Silver Fir / Mountain Hemlock	0	0	0.01	0	0	0	2
Shrub or Herb / Tree Regen	4.94	4.94	6.81	7.61	54.09*	2.67*	5*
Urban	0	0	0	0.29	NA	0.29	5
Water	2.36	2.36	2.36	2.36	-0.25	-0.01	1
Western Larch	19.17	12.70	19.17	10.34	-46.09*	-8.84*	1*
Western Redcedar / Western Hemlock	0	0	0.59	2.08	NA	2.08*	5*
Western White Pine	3.80	3.80	8.94	0.48	-87.27*	-3.32*	1*
Wheatgrass Bunchgrass	2.25	2.25	2.58	0.70	-68.84*	-1.55*	1*
Whitebark Pine	2.14	2.14	2.73	1.45	-31.99*	-0.68	1*
Whitebark Pine / Subalpine Larch	1.21	1.19	1.26	0	-100.00*	-1.21*	1*

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]T = Trace amount ≤ 0.01%.

[6]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

Table 3.132—Summary of broad-scale cover type trends within the Northern Great Basin Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	..... Percent						
Alpine Tundra	0.05	0.05	0.05	0.05	0	0	3
Big Sagebrush	61.04	37.57	61.04	58.71	-3.81	-2.32*	4
Chokecherry / Serviceberry / Rose	T[5]	T	T	T	0	0	3
Cropland / Hay / Pasture	0	0	0	2.35	NA[6]	2.35*	5*
Engelmann Spruce / Subalpine Fir	0.01	0.01	0.07	0.02	165.28	0.01	3
Exotic Forbs / Annual Grass	0	0	0	2.30	NA	2.30*	5*
Fescue-Bunchgrass	1.07	1.07	1.84	0.27	-74.95*	-0.80	1*
Grand Fir / White Fir	0	0	0.30	0.85	NA	0.85	5
Interior Douglas-fir	0.03	0.03	1.56	1.27	4737.64	1.25	3
Interior Ponderosa Pine	7.30	5.56	7.30	6.24	-14.57	-1.06	3
Juniper / Sagebrush	0.44	0.44	0.57	2.05	363.22*	1.60*	5*
Juniper Woodlands	0.05	0.04	0.05	0.05	0	0	4
Lodgepole Pine	1.67	1.30	1.67	1.49	-10.84	-0.18	3
Low Sagebrush	3.55	2.55	3.55	3.66	2.95	0.11	5
Mixed-Conifer Woodlands	0.20	0.18	0.25	0.26	30.51*	0.06	5
Mountain Big Sagebrush	5.31	4.13	5.31	2.73	-48.58*	-2.58*	1*
Mountain Hemlock	0	0	0.01	0	0	0	2
Mountain Mahogany	0.01	0.01	0.15	0.17	1363.87*	0.16	5
Native Forb	T	T	0.02	0	-100.00*	T	1
Pacific Ponderosa Pine	0.08	0.08	0.25	0.37	355.67*	0.29	5
Pacific Silver Fir / Mountain Hemlock	0	0	0.10	0	0	0	2
Red Fir	0	0	0.11	0	0	0	2
Salt Desert Shrub	13.15	9.16	13.15	10.35	-21.29	-2.80	3
Shrub or Herb / Tree Regen	1.06	0.97	1.08	1.01	-4.95	-0.05	3
Sierra Nevada Mixed-Conifer	0.09	0.09	0.13	0	-100.00*	-0.09	1
Water	2.24	2.24	2.24	2.24	0	0	3
Western Larch	0.19	0.11	0.19	0	-100.00*	-0.19	1
Western Redcedar / Western Hemlock	0	0	0.05	0	0	0	2
Western White Pine	0	0	0.08	0	0	0	2
Wheatgrass Bunchgrass	0.66	0.66	27.13	0.52	-21.58*	-0.14	1
Whitebark Pine	0.14	0.03	0.14	0.15	6.70	0.01	5
Whitebark Pine / Subalpine Larch	0	0	0.13	0	0	0	2

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]T = Trace amount ≤ 0.01%.

[6]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

Table 3.133—Summary of broad-scale cover type trends within the Owyhee Uplands Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	..... Percent						
Alpine Tundra	0.09	0.09	0.09	0.09	0	0	3
Big Sagebrush	52.03	31.03	52.03	41.20	-20.82	-10.83	3
Bitterbrush / Bluebunch Wheatgrass	0.51	0.28	0.51	0.28	-44.02*	-0.22	2
Chokecherry / Serviceberry / Rose	T[5]	T	T	T	0	0	3
Cottonwood / Willow	T	0	T	T	0	0	3
Cropland / Hay / Pasture	0	0	0	11.76	NA[6]	11.76*	5*
Engelmann Spruce / Subalpine Fir	0	0	0.02	0.03	NA	0.03	5
Exotic Forbs / Annual Grass	0	0	0	3.11	NA	3.11*	5*
Fescue-Bunchgrass	2.33	2.33	4.93	1.99	-14.70	-0.34	1*
Grand Fir / White Fir	0	0	0.04	0.04	NA	0.04	5
Interior Douglas-fir	0.04	0.04	0.31	0.46	972.73*	0.42	5
Interior Ponderosa Pine	0.47	0.47	0.86	0.35	-24.12*	-0.11	1
Juniper / Sagebrush	0.68	0.38	0.68	1.52	124.22*	0.84	5*
Juniper Woodlands	0.40	0.35	0.40	0.63	57.57*	0.23	5
Lodgepole Pine	0.01	0.01	0.04	0	-100.00*	-0.01	1
Low Sagebrush	8.57	6.37	8.57	8.90	3.78	0.32	5
Mixed-Conifer Woodlands	0.06	0.06	0.22	T	-97.71*	-0.06	1
Mountain Big Sagebrush	21.98	19.33	21.98	20.86	-5.09	-1.12	3
Mountain Mahogany	0.02	0.02	0.69	0.66	3653.67*	0.65	4
Native Forb	0.27	0.16	0.27	0	-100.00*	-0.27	1
Salt Desert Shrub	6.08	4.15	6.08	4.22	-30.52*	-1.85*	2*
Shrub or Herb / Tree Regen	0.50	0.21	0.50	0.42	-14.75	-0.07	3
Urban	0	0	0	0.16	NA	0.16	5
Water	0.13	0.13	0.13	0.13	0	0	3
Western Larch	0	0	0.03	0	0	0	2
Western White Pine	0	0	0.02	0	0	0	2
Wheatgrass Bunchgrass	2.79	2.79	26.29	2.13	-23.77*	-0.66	1*
Whitebark Pine	0	0	0.01	0.02	NA	0.02	5
Whitebark Pine / Subalpine Larch	0	0	0.02	0	0	0	2

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]T = Trace amount ≤ 0.01%.

[6]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

Table 3.134—Summary of broad-scale cover type trends within the Snake Headwaters Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Alpine Tundra	0.96	0.96	0.96	0.96	0	0	3
Barren	0.05	0.05	0.05	0.05	0	0	3
Big Sagebrush	7.72	6.89	7.72	0.08	-98.92*	-7.64*	1*
Bitterbrush / Bluebunch Wheatgrass	T[5]	0	T	0.01	100.00*	T	5
Chokecherry / Serviceberry / Rose	0.09	0.09	0.17	0	-100.00*	-0.09	1
Cottonwood / Willow	0.07	0.06	0.09	0	-100.00*	-0.07	1
Cropland / Hay / Pasture	0	0	0	8.65	NA[6]	8.65*	5*
Engelmann Spruce / Subalpine Fir	11.10	10.73	12.16	11.93	7.55	0.84	3
Exotic Forbs / Annual Grass	0	0	0	1.47	NA	1.47*	5*
Fescue-Bunchgrass	6.45	4.25	6.45	4.80	-25.63	-1.65	3
Grand Fir / White Fir	0	0	T	0	0	0	2
Interior Douglas-fir	12.45	12.45	24.28	29.20	134.44*	16.74*	5*
Interior Ponderosa Pine	0.21	0.21	0.54	0.22	1.80	T	2
Juniper / Sagebrush	0.03	0.03	0.08	0.22	544.12*	0.19	5
Lodgepole Pine	24.16	14.59	24.16	8.06	-66.63*	-16.10*	1*
Low Sagebrush	0.01	0.01	0.05	0.01	0	0	2
Mixed-Conifer Woodlands	0.99	0.99	1.79	0	-100.00*	-0.99*	1*
Mountain Big Sagebrush	5.55	0.39	5.55	0.17	-96.94*	-5.38*	1*
Mountain Mahogany	0.20	0.20	0.35	0.39	100.00*	0.20	5
Native Forb	0.19	0.03	0.19	0	-100.00*	-0.19	1
Shrub or Herb / Tree Regen	9.25	4.91	9.25	3.31	-64.16*	-5.93*	1*
Urban	0	0	0	0.13	NA	0.13	5
Water	0.79	0.79	0.79	0.79	0	0	3
Western Larch	0	0	T	0	0	0	2
Western White Pine	0	0	T	0	0	0	2
Wheatgrass Bunchgrass	2.82	2.82	3.74	1.52	-45.98*	-1.29*	1*
Whitebark Pine	1.24	1.24	4.66	1.04	-16.15	-0.20	1*
Whitebark Pine / Subalpine Larch	0	0	0.80	0	0	0	2

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]T = Trace amount ≤ 0.01%.

[6]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

Southern Cascades ERU

Overall, the richness of cover types increased within the Southern Cascades ERU between the historical and current periods (table 3.135). Four cover types appeared (croplands, exotic forbs/annual grass, urban, and mountain mahogany), while three cover types disappeared (cottonwood/willow, salt desert shrub, and Sierra Nevada mixed-conifer) during this time interval. In addition, nearly all of the western larch cover type was eliminated between the historical and current periods.

We detected ecologically significant trends relative to class and the Southern Cascades ERU with 41 and 22 percent of the cover types, respectively (table 3.135). Seven cover types (alpine tundra, barren, chokecherry/serviceberry/rose, Engelmann spruce/subalpine fir, mixed-conifer woodlands, shrub or herb/tree regen, and Pacific silver fir/mountain hemlock) occurred within their median historical ranges during the current period. Although we observed substantial departures from the median historical ranges for most cover types, only the departures of 30 percent of the cover types were ecologically significant relative to the composition of the Southern Cascades ERU.

The composition of the Southern Cascades ERU was predominantly affected by the decline of the interior ponderosa pine cover type, and the increases of the cropland, interior Douglas-fir, and grand fir/white fir cover types (table 3.135; Jones 1996). The transition matrix indicates that approximately 30 percent of the interior ponderosa pine cover type transitioned into interior Douglas-fir and grand fir/white fir cover types. The transitions of non-forest cover types were dominated by the agricultural conversion of the big sagebrush cover type.

Upper Clark Fork ERU

The richness of cover types within the Upper Clark Fork ERU increased between the historical and current periods (table 3.136). Three additional cover types appeared (croplands, exotic forbs/annual grass, urban), while two cover types (juniper/sagebrush and whitebark pine/subalpine larch) were not detected during the current period. The western larch cover type was nearly eliminated during this period as well.

We observed ecologically significant trends relative to class and the Upper Clark Fork ERU with 46 and 37 percent of the cover types, respectively (table 3.136). Seven of 26 cover types occurred within their median historical ranges during the current period. The departures of 39 percent of the cover types were ecologically significant.

The composition of the Upper Clark Fork ERU was most affected by the areal increases of the cropland and Engelmann spruce/subalpine fir cover types, and the areal declines of the wheatgrass bunchgrass, fescue-bunchgrass, and interior Douglas-fir cover types (table 3.136; Jones 1996). The transition matrix indicates that approximately 18 percent of the fescue-bunchgrass and 69 percent of the wheatgrass bunchgrass cover types were converted by agricultural development between the historical and current periods. An additional 47 percent of the fescue-bunchgrass cover type was eliminated by the encroachment of interior ponderosa pine and interior Douglas-fir cover types. Changes in forest cover types were dominated by transitions of the lodgepole pine and interior Douglas-fir cover types into the Engelmann spruce/subalpine fir cover type.

Upper Klamath ERU

Although the richness of cover types within the Upper Klamath ERU did not change between the historical and current periods, the composition of cover types changed substantially (table 3.137). Three anthropogenic cover types appeared (cropland, exotic forbs/annual grass, and urban), while three endemic cover types (salt desert shrub, western larch, and whitebark pine/subalpine larch) were not detected in the current period.

We detected ecologically significant trends relative to class and the Upper Klamath ERU for 49 and 30 percent of the cover types, respectively (table 3.137). During the current period, the areal extent of only six cover types (alpine tundra, barren,

chokecherry/serviceberry/rose, Engelmann spruce/subalpine fir, mixed-conifer woodlands, and shrub or herb/tree regen) occurred within their median historical ranges. Although we observed substantial departures of most cover types from their median historical ranges, only the departures of 33 percent of the cover types were ecologically significant.

Upper Klamath ERU composition was predominantly affected by the areal increases of the cropland, interior Douglas-fir, and juniper/sagebrush cover types; and the areal declines of the fescue-bunchgrass, interior ponderosa pine, and mountain big sagebrush cover types (table 3.137; Jones 1996). The transition matrix indicates that the 95 percent decline of the fescue-bunchgrass cover type that we observed was the result of transitions to the interior ponderosa pine (94%), croplands (33%), and mixed-conifer woodlands (17%) cover types (Jones 1996). Nearly 25 percent of the interior ponderosa pine cover type changed into the interior Douglas-fir cover type. Although somewhat less significant with respect to the Upper Klamath ERU, the transition matrix indicates that approximately 56 percent of the mountain big sagebrush and 99 percent of the low sagebrush (*Artemisia arbuscula*) cover types changed into the juniper/sagebrush cover type.

Upper Snake ERU

The richness of cover types within the Upper Snake ERU increased between the historical and current periods (table 3.138). Three anthropogenic cover types appeared (cropland, exotic forbs/annual grass, and urban), and two endemic cover types (mixed-conifer woodlands and native forb) were not detected during the current period.

We detected ecologically significant trends relative to class and the Upper Snake ERU with 35 and 23 percent of the cover types, respectively (table 3.138). Although only 6 of 26 cover types occurred within their median historical range during the current period, most departures were not ecologically significant. Ecologically significant departures were evident with 27 percent of the cover types.

The composition of cover types within the Upper Snake ERU was primarily influenced by the changes of three cover types (table 3.138; Jones 1996). A significant decline of the big sagebrush cover type occurred across 42 percent of the ERU, whereas areal increases of the croplands and exotic forbs/annual grass cover types affected nearly 43 percent of the ERU. Forty-one percent of the areal decline of the big sagebrush cover type was a result of agricultural development. Lesser amounts of the big sagebrush cover type were converted into the exotic forbs/annual grass (10%) and wheatgrass bunchgrass (5%) cover types. Virtually all of the areal increase of the croplands cover type occurred at the expense of the big sagebrush cover type.

Cover type discussion

Differing geographic scales did not seem to substantially affect cover type trends within our assessment area. That is, the cover type trends observed within the 13 ERUs generally reflected the trends that occurred within the Basin as a whole. Furthermore, with the exception of the bitterbrush/bluebunch wheatgrass, Engelmann spruce/subalpine fir, lodgepole pine, and shrub or herb/tree regen cover types, there was little variability of the cover type departure classes among the 13 ERUs. Although the departure classes of the bitterbrush/bluebunch wheatgrass, Engelmann spruce/subalpine fir, and lodgepole pine varied among the ERUs, the ERUs that seemed to have the most conflicting trends were those whose departures were not ecologically significant. For example, the departure classes of the lodgepole pine cover type indicated that it occurred within or above its median historical range for the majority of ERUs. Conversely, the areal extent of lodgepole pine cover type within the Columbia Plateau, Snake Headwaters, and Upper Snake ERUs was well below its median historical ranges. However, only the observed departure class of the Snake Headwaters ERU was ecologically significant. The shrub or herb/tree

Table 3.135—Summary of broad-scale cover type trends within the Southern Cascades Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Alpine Tundra	0.26	0.26	0.26	0.26	0	0	3
Barren	0.05	0.05	0.05	0.05	0	0	3
Big Sagebrush	4.67	2.55	4.67	1.35	-71.17*	-3.32*	1*
Bitterbrush / Bluebunch Wheatgrass	0.24	0.11	0.24	0.26	8.83	0.02	5
Chokecherry / Serviceberry / Rose	0.08	0.08	0.08	0.08	0	0	3
Cottonwood / Willow	0.24	0.10	0.24	0	-100.00*	-0.24	1
Cropland / Hay / Pasture	0	0	0	5.94	NA[5]	5.94*	5*
Engelmann Spruce / Subalpine Fir	4.95	2.11	4.95	2.54	-48.62	-2.41	3
Exotic Forbs / Annual Grass	0	0	0	0.28	NA	0.28	5
Fescue-Bunchgrass	2.56	2.56	4.27	0.73	-71.43*	-1.83*	1*
Grand Fir / White Fir	0.07	0.07	3.33	3.98	5460.20*	3.91*	5*
Interior Douglas-fir	19.38	13.71	19.38	26.28	35.57*	6.90*	5*
Interior Ponderosa Pine	35.32	24.82	35.32	24.78	-29.84*	-10.54*	1*
Juniper / Sagebrush	3.64	1.03	3.64	3.59	-1.18	-0.04	4
Juniper Woodlands	0.01	0	0.01	0.01	0	0	4
Lodgepole Pine	12.72	10.93	12.72	15.20	19.47	2.48*	5*
Low Sagebrush	0	0	0.02	0	0	0	2
Mixed-Conifer Woodlands	1.62	0.92	1.62	1.20	-26.10	-0.42	3
Mountain Big Sagebrush	1.42	1.42	4.37	0.95	-33.67*	-0.48	1*
Mountain Hemlock	0.93	0.51	0.97	0.48	-48.46*	-0.45	1
Mountain Mahogany	0	0	0.01	0.01	NA	0.01	4
Native Forb	0	0	0.03	0	0	0	2
Oregon White Oak	0.29	0.26	0.29	0.29	0	0	4
Pacific Ponderosa Pine	0.11	0.11	0.34	0.49	331.15*	0.38	5
Pacific Silver Fir / Mountain Hemlock	0.06	0.06	2.91	0.92	1334.32	0.86	3
Red Fir	0	0	0.42	0	0	0	2
Salt Desert Shrub	0.14	0.01	0.14	0	-100.00*	-0.14	1
Shrub or Herb / Tree Regen	2.36	2.36	8.26	5.46	131.92	3.11	3
Sierra Nevada Mixed-Conifer	0.38	0.16	0.38	0	-100.00*	-0.38	1
Urban	0	0	0	0.19	NA	0.19	5
Water	2.53	2.53	2.53	2.52	-0.28	-0.01	1
Western Larch	2.26	2.26	5.61	0.04	-98.41*	-2.22*	1*
Western Redcedar / Western Hemlock	1.49	1.49	3.22	1.21	-18.75	-0.28	1*
Western White Pine	0.09	0.09	1.02	0.04	-49.94*	-0.04	1
Wheatgrass Bunchgrass	1.12	1.12	3.35	0.42	-62.82*	-0.70	1*
Whitebark Pine	0.68	0.68	1.05	0.11	-83.15*	-0.57	1
Whitebark Pine / Subalpine Larch	0	0	0.03	0	0	0	2

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

Table 3.136—Summary of broad-scale cover type trends within the Upper Clark Fork Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Alpine Tundra	0.03	0.03	0.03	0.03	0	0	3
Barren	4.06	4.06	4.06	4.06	0	0	3
Big Sagebrush	0.02	0.02	0.14	0.02	-20.18*	T[5]	1
Cottonwood / Willow	0	0	0.03	0	0	0	2
Cropland / Hay / Pasture	0	0	0	8.80	NA[6]	8.80*	5*
Engelmann Spruce / Subalpine Fir	6.74	6.32	8.17	15.78	134.20*	9.04*	5*
Exotic Forbs / Annual Grass	0	0	0	0.67	NA	0.67	5
Fescue-Bunchgrass	14.30	5.06	14.30	3.92	-72.62*	-10.38*	1*
Grand Fir / White Fir	0.04	0.04	1.14	0.91	1982.30	0.86	3
Interior Douglas-fir	16.10	15.31	16.49	10.94	-32.05*	-5.16*	1*
Interior Ponderosa Pine	14.69	14.69	19.34	17.18	16.95	2.49	3
Juniper / Sagebrush	0.09	0.03	0.09	0	-100.00*	-0.09	1
Lodgepole Pine	24.60	14.94	24.60	25.94	5.45	1.34*	5*
Low Sagebrush	0	0	T	T	0	T	4
Mixed-Conifer Woodlands	2.75	2.63	3.13	0.34	-87.82*	-2.42*	1*
Mountain Big Sagebrush	1.37	1.37	3.49	1.07	-21.91*	-0.30	1*
Mountain Mahogany	0	0	0.03	0.03	NA	0.03	3
Native Forb	0.11	0.03	0.11	0.01	-92.01*	-0.10	1
Shrub or Herb / Tree Regen	4.64	4.64	7.91	6.47	39.30	1.82	3
Urban	0	0	0	0.22	NA	0.22	5
Water	0.10	0.10	0.10	0.10	0	0	3
Western Larch	2.15	2.15	4.07	0.01	-99.60*	-2.14*	1*
Western White Pine	0	0	2.53	0.01	NA	0.01	2
Wheatgrass Bunchgrass	5.46	5.41	5.46	1.49	-72.65*	-3.97*	1*
Whitebark Pine	1.65	1.65	3.69	0.46	-72.11*	-1.19*	1*
Whitebark Pine / Subalpine Larch	0.21	0.21	0.42	0	-100.00*	-0.21	1

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]T = Trace amount ≤ 0.01%.

[6]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

Table 3.137—Summary of broad-scale cover type trends within the Upper Klamath Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Alpine Tundra	0.04	0.04	0.04	0.04	0	0	3
Barren	0.12	0.12	0.12	0.12	0	0	3
Big Sagebrush	1.39	1.05	1.39	1.39	0	0	4
Bitterbrush / Bluebunch Wheatgrass	0.04	0.03	0.04	0.04	0	0	4
Chokecherry / Serviceberry / Rose	0.01	0.01	0.01	0.01	0	0	3
Cropland / Hay / Pasture	0	0	0	6.83	NA[5]	6.83*	5*
Engelmann Spruce / Subalpine Fir	1.48	0.72	1.48	1.29	-13.25	-0.20	3
Exotic Forbs / Annual Grass	0	0	0	0.34	NA	0.34	5
Fescue-Bunchgrass	14.33	10.68	14.33	0.70	-95.09*	-13.63*	1*
Grand Fir / White Fir	0.09	0.09	0.92	3.32	3643.81*	3.24*	5*
Interior Douglas-fir	1.59	1.59	8.15	15.19	857.59*	13.60*	5*
Interior Ponderosa Pine	48.62	40.02	48.62	38.24	-21.34*	-10.37*	1*
Juniper / Sagebrush	2.17	2.17	2.94	6.10	180.99*	3.93*	5*
Juniper Woodlands	0.43	0.35	0.43	0.43	0	0	4
Lodgepole Pine	6.47	5.53	6.47	6.88	6.37	0.41	5*
Low Sagebrush	1.24	0.25	1.24	0.02	-98.46*	-1.22*	1*
Mixed-Conifer Woodlands	1.07	1.07	4.02	2.89	169.82	1.82	3
Mountain Big Sagebrush	4.90	4.44	4.90	0.71	-85.49*	-4.19*	1*
Mountain Hemlock	0.79	0.27	0.79	0.16	-80.00*	-0.63	1
Native Forb	0	0	0.01	0	0	0	2
Pacific Ponderosa Pine	1.59	1.59	2.16	3.06	92.43*	1.47*	5*
Pacific Silver Fir / Mountain Hemlock	0.05	0.05	0.65	0.07	37.40*	0.02	2
Salt Desert Shrub	1.07	0.17	1.07	0	-100.00*	-1.07*	1*
Shrub or Herb / Tree Regen	3.51	3.51	5.19	4.80	36.89	1.29	3
Sierra Nevada Mixed-Conifer	0.64	0.64	1.09	0.10	-85.14*	-0.55	1
Urban	0	0	0	0.21	NA	0.21	5
Water	5.12	5.12	5.12	5.11	-0.12	-0.01	1
Western Larch	0.63	0.63	1.16	0	-100.00*	-0.63	1
Western Redcedar / Western Hemlock	0.04	0.04	0.29	0.03	-28.60*	-0.01	1
Western White Pine	0	0	0.43	0	0	0	2
Wheatgrass Bunchgrass	0.26	0.26	0.79	0.28	7.34	0.02	2
Whitebark Pine	0.86	0.70	0.88	0.67	-22.79*	-0.20	1
Whitebark Pine / Subalpine Larch	0.03	0.03	0.61	0	-100.00*	-0.03	1

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

Table 3.138—Summary of broad-scale cover type trends within the Upper Snake Ecological Reporting Unit.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Alpine Tundra	0.02	0.02	0.02	0.02	0	0	3
Big Sagebrush	72.81	47.47	72.81	31.00	-57.43*	-41.81*	1*
Bitterbrush / Bluebunch Wheatgrass	0.09	0.05	0.09	0.08	-10.42	-0.01	3
Chokecherry / Serviceberry / Rose	0.28	0.28	0.38	0.27	-3.15	-0.01	1
Cropland / Hay / Pasture	0	0	0	32.52	NA[5]	32.52*	5*
Engelmann Spruce / Subalpine Fir	0.21	0.11	0.21	0.01	-97.14*	-0.20	1
Exotic Forbs / Annual Grass	0	0	0	10.04	NA	10.04*	5*
Fescue-Bunchgrass	3.41	2.69	3.41	3.04	-10.63	-0.36	3
Grand Fir / White Fir	0	0	0.04	0	0	0	2
Interior Douglas-fir	0.46	0.46	0.87	0.58	26.92	0.12	3
Interior Ponderosa Pine	0.21	0.21	0.41	0.28	31.95	0.07	3
Juniper / Sagebrush	0.55	0.55	0.71	2.15	292.99*	1.60*	5*
Juniper Woodlands	0.34	0.25	0.34	0.34	0	0	4
Lodgepole Pine	0.11	0.11	0.21	0.09	-13.96	-0.01	1
Low Sagebrush	3.46	2.60	3.46	3.50	1.36	0.05	5
Mixed-Conifer Woodlands	0.05	0.05	0.28	0	-100.00*	-0.05	1
Mountain Big Sagebrush	5.95	4.91	5.95	3.14	-47.28*	-2.81*	1*
Mountain Mahogany	0.34	0.34	0.75	0.88	156.39*	0.54	5
Native Forb	0.21	0.14	0.21	0	-100.00*	-0.21	1
Salt Desert Shrub	2.65	0.84	2.65	0.48	-81.76*	-2.16*	1*
Shrub or Herb / Tree Regen	0.53	0.48	0.74	0.27	-49.73*	-0.26	1
Urban	0	0	0	0.19	NA	0.19	5
Water	0.04	0.04	0.04	0.04	0	0	3
Western Larch	0	0	0.02	0	0	0	2
Western White Pine	0	0	0.01	0	0	0	2
Wheatgrass Bunchgrass	5.34	5.34	31.55	5.76	7.88	0.42	2*

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the cover type.

[3]ERU change = percent change of the Ecological Reporting Unit (ERU) attributable to the cover type change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable since the cover type did not exist during the historical period.

*Ecologically significant changes.

regen cover type occurred well above its median historical range in four ERUs, within its median historical range in six ERUs, and well below its median historical range in three ERUs.

Agricultural development significantly changed the composition of cover types within the Basin, and within all of the 13 ERUs. Approximately 16 percent of the Basin was converted to the croplands cover type. Even the least impacted ERUs (for example, the Lower Clark Fork and Northern Great Basin ERUs) lost 2 to 3 percent of their area to agricultural uses. Conversely, agricultural development occurred across 33 and 45 percent of the Upper Snake and Columbia Plateau ERUs, respectively. Not surprisingly, most of the agricultural conversions occurred within non-forest cover types, and were largely responsible for the significant areal declines of the endemic grassland and forb cover types (that is, the wheatgrass bunchgrass, fescue-bunchgrass, and native forb cover types) and also for a large proportion of the observed declines in many shrubland cover types (for example, the big sagebrush, mountain big sagebrush, and salt desert shrub cover types).

Within forest environments, cover type compositional changes were predominantly related to the replacement of cover types dominated by shade-intolerant species with resistance to fire, insects, and diseases, by cover types dominated by shade-tolerant species with higher susceptibilities to fires, insects, and diseases. With few exceptions, we observed significantly declining trends for the cottonwood/willow, interior ponderosa pine, western larch, western white pine, whitebark pine/subalpine larch, and whitebark pine cover types throughout the Basin. Conversely, we commonly detected significant increases for the grand fir/white fir, interior Douglas-fir, and western redcedar/western hemlock cover types. These trends were most likely brought about by fire suppression and timber harvesting activities. Fire suppression increased the establishment and development of forest stands that were composed of shade-tolerant species. Conversely, past silvicultural practices commonly targeted the early-seral shade-intolerant species for removal from forest stands.

We detected 37 instances in which a cover type disappeared from an ERU between the historical and current periods. Twelve cover types were involved. Although these cover types disappeared from our broad-scale coverage of the current period, we are not suggesting that they no longer occurred in that region; instead, we are saying that their areal declines within an ERU were to the extent that the cover types no longer represented a dominant component of a 1-square kilometer pixel. In all likelihood, a finer-grained analysis would have detected their presence in the landscape (Henderson-Sellers and others 1985, Meentemeyer and Box 1987). The cover types that experienced the largest declines include whitebark pine/subalpine larch (lost from 7 ERUs), native forb (lost from 6 ERUs), and western larch (lost from 5 ERUs). These cover types were often rare within an ERU during the historical period. In most instances (76%), the historical area of the lost cover type had composed less than 0.5 percent of an ERU (mean = 1.10%, sd = 4.40). However, the western white pine cover type was eliminated from the Lower Clark Fork ERU even though it composed nearly 27 percent of the region during the historical period. Four of the 12 cover types (native forb, Sierra Nevada mixed-conifer, western white pine, and whitebark pine/subalpine larch), which were frequently lost from various ERU landscapes, have experienced at least 90 percent declines within the Basin as a whole.

We compared the trends of our broad-scale forest and woodland cover types within ERUs to the trends of mid-scale forest and woodland cover types reported by Hessburg and others (1996a). As expected, there were some discrepancies between the two data sets. However, considering that the two analyses were conducted at different resolutions (1-km^2 and 4-ha for broad-scale and mid-scale analyses, respectively), and that the trends were assessed across different time periods (approximately 100 to 150 years versus the past 30 to 70 years for broad-scale and mid-scale, respectively), the observed trends were quite comparable. The most common discrepancies between the two analyses included instances where trends were detected at both the broadscale and midscale, but the trends were only significant at the broadscale. These sorts of discrepancies occurred most

frequently with the grand fir/white fir, lodgepole pine, and western larch cover types within the Central Idaho Mountains, Lower Clark Fork, and Southern Cascades ERUs. Conflicting trends (that is, the broad-scale and mid-scale analyses detected opposite trends) most commonly occurred with the Engelmann spruce/subalpine fir and interior ponderosa pine cover types.

Coarse-grained analyses commonly underestimated cover types occurring in small- to medium-sized patches that did not dominate the spectral response of a particular pixel (Quattrochi and Pelletier 1991). As previously noted, we experienced problems accurately depicting the presence of the aspen, herbaceous wetlands, and shrub wetlands cover types. Our broad-scale mapping of vegetation types also underestimated the extent of plant communities dominated by exotic species. For example, many of the exotic broadleaf forbs (for example, knapweeds, yellow starthistle, and leafy spurge) could have existed in patches too small to dominate a 1-square-kilometer pixel. In addition, we were more likely to detect large patches of communities dominated by exotic annual grasses (for example, cheatgrass and medusahead) where they existed as a monoculture. Where exotic grasses composed portions of the understory shrubland community, the spectral image was typically classified as a shrub cover type (for example, big sagebrush, or mountain big sagebrush). Lastly, even if a patch was large enough to be detected, remote sensing techniques only had a limited capability to differentiate endemic species from exotic species. Examples of broad-scale native cover type conversions to the exotic forbs/annual grass cover type, which we likely failed to document in this analysis and were supported by finer-scale information, include:

1) wheatgrass bunchgrass cover type in the Blue Mountains and Columbia Plateau ERUs to the exotic forbs/annual grass cover type (particularly by yellow starthistle)(Talbott 1987), and
2) fescue-bunchgrass and interior ponderosa pine cover types in the Northern Glaciated Mountains ERU to the exotic forbs/annual grass cover type (particularly by diffuse and spotted knapweed) (Talbott 1987).

Many cover types often incurred substantial class changes, but because they composed relatively minor proportions of a region, their changes did not significantly affect the overall composition of the region. However, that is not to say that these changes did not have significant effects on other components of the ecosystem, or on various ecosystem functions. Rare vegetation communities may contain unique phenotypes and genotypes that may be important for individual, population, and species fitness and consequently, evolutionary processes.

Our historical simulation of cover types suggests that the composition of cover types within an ERU was dynamic. Each ERU contained two to four cover types for which we detected substantial trends between the historical and current periods, even though these cover types still occurred within their median historical range during the current period. Thus, substantial changes of at least some broad-scale cover types seemed to have been the norm, rather than the exception, prior to Euro-American settlement within the Basin. The cover types that appeared to be most dynamic across a region include Engelmann spruce/subalpine fir, interior Douglas-fir, interior ponderosa pine, shrub or herb/tree regen, mixed-conifer woodlands, western larch, fescue-bunchgrass, and bitterbrush/bluebunch wheatgrass.

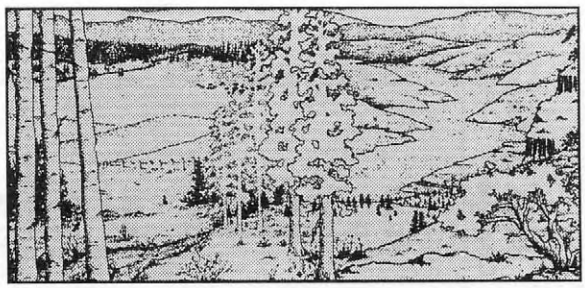
Inherent to any scale of analysis is the need to summarize data to some geographic unit. For our analysis of broad-scale cover types, we chose to summarize composition and trends at the ERU and Basin levels. We do not imply that the trends we observed would necessarily occur at other analytical scales. Our transition analyses indicate that trends for a specific cover type could differ appreciably within ERUs. This was because the pixels of a specific cover type could change in different ways within an ERU between the historical to the current period (that is, the pixels could stay the same or convert into another cover type). Given this level of variability for specific cover types at the ERU level, we expect that trends for specific cover types at a finer scale would likewise be variable and might be inconsistent with ERU trends.

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REGIONAL AND ECOLOGICAL REPORTING UNIT TERRESTRIAL COMMUNITY TRENDS



We reported the changes of the broad-scale terrestrial communities for the Basin as a whole, as well as by the 13 Ecological Reporting Units of the Basin.

The Basin

Richness of terrestrial communities increased by three anthropogenic types (agricultural, exotic herbland, and urban) between the historical and current periods. During the current period, agricultural was the third most dominant community type within the Basin. Out of 21[2] terrestrial communities, alpine, rock/barren, and water did not change between historical and current periods (table 3.139).

We detected significant changes with respect to class for 11 of 21 community types (table 3.139). Ecologically significant negative trends were evident in six terrestrial communities (upland herbland, upland shrubland, early-seral lower montane forest, late-seral lower montane single-layer forest, late-seral lower montane multi-layer forest, and late-seral subalpine multi-layer forest). The early-seral lower montane forest and late-seral lower montane single-layer forest communities declined by more than 75 percent. Conversely, significant positive trends occurred in five terrestrial communities (early-seral subalpine forests, mid-seral lower montane forest, mid-seral montane forest, late-seral subalpine single-layer forest, and upland woodland).

Ecologically significant changes relative to the Basin were apparent with seven terrestrial communities (table 3.139). The agricultural, exotic herbland, mid-seral montane forest, and mid-seral lower montane forest communities increased across substantial areas within the Basin, whereas late-seral lower montane single-layer forest, upland herbland, and upland shrubland communities declined across substantial areas. The decrease in upland shrubland and upland herbland communities accounted for nearly a 21 percent change of the Basin as a whole. Conversions to the agricultural community occurred across 16 percent of the Basin.

The transitions of upland herbland and upland shrubland communities into the agricultural type dominated the changes that occurred in the Basin (table 3.140). Other dominating changes involved the transitions of early- and late-seral forest communities into mid-seral forest communities, which occurred across 9.2 percent of the Basin. Although pixels of upland herbland and upland shrubland transitioned to each other, the net transition favored the upland shrubland community.

[2] There are 24 terrestrial community types found within the Basin, but we were able to assess only 21 of them. Patterns were not assessed for the three riparian community types due to the fact that these types generally occurred in scattered, relatively small- to medium-sized patches, and tended to be underestimated as mapping resolution increased. The historical vegetation layer was developed at a coarser resolution than the current period vegetation layer, creating different biases. Therefore, changes of riparian communities between historical and current periods could not be accurately assessed (see table 3.9 and appendix 3-B for descriptions of terrestrial community types).

Table 3.139—Changes of broad-scale terrestrial communities between historical and current periods within the Basin.

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	Basin Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	16.06	NA[5]	16.06*	5*
Alpine	0.16	0.16	0.16	0.16	-0.18	0	3
Early-seral Lower Montane Forest	1.10	1.10	2.73	0.26	-76.75*	-0.85	1
Early-seral Montane Forest	8.67	7.73	8.67	7.94	-8.40	-0.73	3
Early-seral Subalpine Forest	1.21	0.77	1.21	1.80	48.20*	0.58	5*
Exotic Herbland	0	0	0	2.06	NA	2.06*	5*
Late-seral Lower Montane Multi-layer Forest	2.16	1.72	2.16	1.42	-34.55*	-0.75	1*
Late-seral Lower Montane Single-layer Forest	5.56	4.77	5.56	1.08	-80.61*	-4.48*	1*
Late-seral Montane Multi-layer Forest	3.80	3.80	6.63	3.38	-11.18	-0.43	1*
Late-seral Montane Single-layer Forest	0.78	0.78	1.38	0.85	8.38	0.07	2
Late-seral Subalpine Multi-layer Forest	1.23	1.23	2.46	0.45	-63.83*	-0.79	1*
Late-seral Subalpine Single-layer Forest	0.57	0.21	0.57	0.78	36.32*	0.21	5*
Mid-seral Lower Montane Forest	4.91	3.93	4.91	7.52	53.03*	2.60*	5*
Mid-seral Montane Forest	10.48	10.17	11.95	16.62	58.58*	6.14*	5*
Mid-seral Subalpine Forest	2.72	2.22	2.72	2.70	-1.02	-0.03	4
Rock/Barren	0.24	0.24	0.24	0.24	0	0	3
Upland Herbland	14.88	14.88	21.48	4.94	-66.82*	-9.94*	1*
Upland Shrubland	36.71	26.97	36.71	25.50	-30.53*	-11.21*	1*
Upland Woodland	1.91	1.91	2.22	2.85	49.49*	0.94	5*
Urban	0	0	0	0.16	NA	0.16	5
Water	0.94	0.94	0.94	0.94	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]Basin change = percent change of the Basin attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

*Ecologically significant changes.

Table 3.140—Dominant transitions[1] of terrestrial communities within the Basin.

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of Basin Area (%)[3]**
Early-seral Montane Forest	Mid-seral Montane Forest	3.9
Late-seral Lower Montane Single-layer Forest	Mid-seral Montane Forest	1.4
Late-seral Lower Montane Single-layer Forest	Mid-seral Lower Montane Forest	1.8
Late-seral Montane Multi-layer Forest	Mid-seral Montane Forest	2.1
Mid-seral Lower Montane Forest	Mid-seral Montane Forest	1.2
Mid-seral Montane Forest	Early-seral Montane Forest	2.2
Upland Herbland	Agricultural	6.6
Upland Herbland	Mid-seral Lower Montane Forest	1.3
Upland Herbland	Upland Shrubland	2.1
Upland Shrubland	Agricultural	9.0
Upland Shrubland	Exotic Herbland	1.1
Upland Shrubland	Upland Herbland	1.0
Upland Shrubland	Upland Woodland	1.3

[1]Dominant transitions were those affecting at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of Basin Area (percent) = proporation of landscape affected; area of the landscape in which a terrestrial community changed into another terrestrial community.

The areal extent of all but four (alpine, rock/barren, water, and early-seral montane forest) terrestrial communities occurred outside of their median 75 percent historical range (tables 3.139 and 3.140). However, the departure indices for the mid-seral subalpine forest, late-seral montane single-layer forest, late-seral montane multi-layer forest, and urban communities were not ecologically significant.

A significant shift among the areal extent of early-, mid-, and late-seral forest communities occurred between historical and current time periods. The distribution of mid-seral forest communities increased at the expense of both early- and late-seral forest communities. Late-seral and early-seral forest communities had net declines across 6 and 1 percent of the Basin, respectively (table 3.139). However, as a group, the areal extent of mid-seral forest communities increased across nearly 9 percent of the Basin.

Blue Mountains ERU

During the current period, the agricultural community type was the most dominant type within the Blue Mountains ERU (table 3.141). Of the 20 terrestrial communities we observed in the Blue Mountains ERU, only the alpine and water communities did not change between historical and current periods.

We failed to detect significant changes with respect to class for 50 percent of the terrestrial communities that occurred within the Blue Mountains ERU (table 3.141). Six communities declined significantly (early-seral lower montane forest, late-seral lower montane single-layer forest, late-seral subalpine single-layer forest, mid-seral subalpine forest, upland herbland, and upland shrubland). The late-seral lower montane single-layer forest and mid-seral subalpine forest communities declined by more

than 80 percent. Conversely, significant positive trends occurred within four of the terrestrial communities (early-seral subalpine forest, late-seral montane multi-layer forest, mid-seral lower montane forest, and mid-seral montane forest). The mid-seral montane forest, late-seral montane multi-layer forest, and early-seral subalpine forest communities increased by more than 200, 300, and 600 percent, respectively. Although, the early-seral montane forest, late-seral montane single-layer forest, and late-seral subalpine multi-layer forest communities increased substantially, their trends were not ecologically significant.

Ecologically significant changes relative to the Blue Mountains ERU were apparent in 9 of 20 terrestrial communities (table 3.141). Three communities decreased across significant proportions of the ERU (upland shrubland, upland herbland, and late-seral lower montane single-layer forest), whereas significant increases in area were evident with the agricultural, exotic herbland, early-seral subalpine forest, late-seral montane multi-layer forest, mid-seral lower montane, and mid-seral montane forest communities. The decline of the upland herbland and late-seral lower montane single-layer forest communities occurred across 18 and 15 percent of the Blue Mountains ERU, respectively. Conversely, approximately 17 percent of the ERU was converted to the agricultural community type.

The areal extent of most (60%) terrestrial communities occurred outside of their median 75 percent historical range (table 3.141). Although the urban community type occurred above its historical range, its departure was not ecologically significant.

The areal reduction of the upland shrubland and upland herbland communities was dominated by agricultural conversion (table 3.142). Finer-resolution information, however (Skovlin and Thomas 1995), suggests that substantial areal reduction of the upland shrubland and upland herbland communities was attributable to encroachment by western juniper (that is, the upland woodland community). Virtually all (96%) of the late-seral lower montane single-layer forest type was transformed: 27 percent changed to the mid-seral lower montane forest, 26 percent changed to the mid-seral montane forest, and 22 percent changed to the late-seral montane multi-layer forest community types (Jones 1996). Conversely, the increase in late-seral montane multi-layer and mid-seral forest communities occurred predominantly at the expense of the late-seral lower montane single-layer and mid-seral forest communities.

As a group, the composition of late-seral forest communities declined from 23 to 15 percent of the Blue Mountains ERU (a 35% decline). However, late-seral single-layer forest communities decreased, whereas late-seral multi-layer forest communities increased (table 3.141). The increases in both early- and mid-seral forest communities were ecologically significant.

Central Idaho Mountains ERU

The richness of terrestrial communities of the current period was greater than the historical period due to the addition of three anthropogenic communities (agricultural, exotic herbland, and urban; table 3.143). Of the 21 terrestrial communities occurring within the Central Idaho Mountains ERU, 7 communities occurred within their median 75 percent historical range during the current period (alpine, late-seral montane multi-layer forest, late-seral lower montane multi-layer forest, mid-seral montane forest, rock/barren, upland shrubland, and water). Ecologically significant trends occurred for 10 and 11 community types with respect to class and ERU, respectively. The areal extent of the early-seral lower montane forest, late-seral lower montane single-layer forest, upland herbland, and upland woodland communities decreased by more than 50 percent. In terms of ERU change, the loss of upland herbland communities and the conversion to agriculture affected the largest proportion of the Central Idaho Mountains ERU (9% and 6%, respectively).

Table 3.141—Changes of broad-scale terrestrial communities between historical and current periods within the Blue Mountains Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	17.40	NA[5]	17.40*	5*
Alpine	0.28	0.28	0.28	0.28	0	0	3
Early-seral Lower Montane Forest	1.08	1.08	6.40	0.36	-66.73*	-0.72	1*
Early-seral Montane Forest	9.89	9.89	14.15	12.06	21.93	2.17	3
Early-seral Subalpine Forest	0.17	0.17	0.55	1.27	651.30*	1.10*	5*
Exotic Herbland	0	0	0	1.44	NA	1.44*	5*
Late-seral Lower Montane Multi-layer Forest	4.00	2.85	4.00	3.38	-15.59	-0.62	3
Late-seral Lower Montane Single-layer Forest	15.47	11.18	15.47	0.59	-96.21*	-14.88*	1*
Late-seral Montane Multi-layer Forest	2.10	2.10	3.96	9.31	342.38*	7.20*	5*
Late-seral Montane Single-layer Forest	0.54	0.54	1.44	1.00	86.04	0.46	3
Late-seral Subalpine Multi-layer Forest	0.38	0.38	0.89	0.55	44.05	0.17	3
Late-seral Subalpine Single-layer Forest	0.51	0.08	0.51	0.27	-46.91*	-0.24	3
Mid-seral Lower Montane Forest	10.04	6.40	10.04	14.72	46.68*	4.69*	5*
Mid-seral Montane Forest	3.83	3.83	8.23	11.97	212.33*	8.13*	5*
Mid-seral Subalpine Forest	1.02	0.72	1.02	0.19	-81.40*	-0.83	1*
Upland Herbland	24.94	20.36	24.94	7.40	-70.35*	-17.55*	1*
Upland Shrubland	21.15	18.20	21.15	13.90	-34.29*	-7.25*	1*
Upland Woodland	2.70	2.70	4.44	3.09	14.29	0.39	3
Urban	0	0	0	0.15	NA	0.15	5
Water	0.28	0.28	0.28	0.28	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum =maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

*Ecologically significant changes.

Table 3.142—Dominant transitions[1] of terrestrial communities within the Blue Mountains Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Early-seral Montane Forest	Mid-seral Montane Forest	1.7
Early-seral Montane Forest	Mid-seral Lower Montane Forest	2.0
Late-seral Lower Montane Multi-layer Forest	Mid-seral Lower Montane Forest	1.1
Late-seral Lower Montane Single-layer Forest	Mid-seral Lower Montane Forest	4.3
Late-seral Lower Montane Single-layer Forest	Mid-seral Montane Forest	4.1
Late-seral Lower Montane Single-layer Forest	Late-Seral Montane Multi-layer Forest	3.5
Late-seral Lower Montane Single-layer Forest	Early-seral Montane Forest	1.4
Late-seral Lower Montane Single-layer Forest	Late-seral Lower Montane Multi-layer Forest	1.3
Mid-seral Lower Montane Forest	Late-seral Montane Multi-layer Forest	2.5
Mid-seral Lower Montane Forest	Mid-seral Montane Forest	2.5
Mid-seral Lower Montane Forest	Early-seral Montane Forest	1.0
Mid-seral Montane Forest	Early-seral Montane Forest	1.3
Upland Herbland	Agricultural	10.7
Upland Herbland	Early-seral Montane Forest	2.3
Upland Herbland	Mid-seral Lower Montane Forest	2.4
Upland Herbland	Upland Shrubland	1.5
Upland Herbland	Upland Woodland	1.3
Upland Shrubland	Agricultural	5.6
Upland Shrubland	Mid-seral Lower Montane Forest	1.6
Upland Shrubland	Upland Woodland	1.1
Upland Woodland	Upland Herbland	1.5

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of ERU Area (percent) = proportion of landscape affected; area of the ERU in which a terrestrial community changed into another terrestrial community.

Table 3.143—Changes of broad-scale terrestrial communities between historical and current periods within the Central Idaho Mountains Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	5.46	NA[5]	5.46*	5*
Alpine	0.20	0.20	0.20	0.20	0	0	3
Early-seral Lower Montane Forest	2.01	2.01	3.48	0.54	-73.25*	-1.47*	1*
Early-seral Montane Forest	12.82	10.58	12.82	14.99	16.96	2.17*	5*
Early-seral Subalpine Forest	3.47	1.91	3.47	6.76	94.53*	3.28*	5*
Exotic Herbland	0	0	0	1.69	NA	1.69*	5*
Late-seral Lower Montane Multi-layer Forest	2.74	1.65	2.74	1.96	-28.45	-0.78	3
Late-seral Lower Montane Single-layer Forest	3.56	3.56	6.96	0.42	-88.31*	-3.14*	1*
Late-seral Montane Multi-layer Forest	3.30	3.30	8.16	6.34	91.95*	3.04*	3
Late-seral Montane Single-layer Forest	1.56	1.56	2.22	0.86	-45.05*	-0.70	1*
Late-seral Subalpine Multi-layer Forest	1.95	1.95	6.65	1.94	-0.31	-0.01	1
Late-seral Subalpine Single-layer Forest	2.62	0.64	2.62	3.46	32.26*	0.84	5*
Mid-seral Lower Montane Forest	5.84	5.01	5.84	8.47	45.06*	2.63*	5*
Mid-seral Montane Forest	17.88	13.98	18.36	16.73	-6.42	-1.15	3
Mid-seral Subalpine Forest	6.79	5.31	6.79	4.86	-28.42*	-1.93*	1*
Rock/Barren	0.50	0.50	0.50	0.50	0	0	3
Upland Herbland	17.78	9.98	17.78	8.76	-50.71*	-9.01*	1*
Upland Shrubland	13.07	13.07	16.52	13.61	4.08	0.53	3
Upland Woodland	3.11	3.11	3.88	0.71	-77.21*	-2.40*	1*
Urban	0	0	0	0.03	NA	0.03	5
Water	0.20	0.20	0.20	0.20	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

*Ecologically significant changes.

Although substantial class and ERU changes occurred with the late-seral lower montane multi-layer forest and mid-seral montane forest communities, respectively, these changes were not ecologically significant. On the other hand, even though the current period areal extent of the late-seral subalpine multi-layer forest and urban community types occurred outside of their median historical ranges, these departures were not ecologically significant.

The 51 percent areal decline of the upland herbland community was attributed primarily to increases in upland shrubland, agricultural, and mid-seral lower montane forest communities (table 3.144, Jones 1996). The decline in late-seral lower montane single-layer forest communities largely occurred due to transitions into mid-seral montane forest and late-seral montane multi-layer forest communities. Similarly, disturbances converted the mid-seral subalpine forest community to the early-seral subalpine forest community, converted the mid-seral montane forest community to the early-seral subalpine community, and converted the upland woodland community to the upland herbland community. Conversely, successional processes were most likely responsible for the conversions of the early-seral lower montane forest community to the early-seral montane forest, mid-seral montane forest, and mid-seral lower montane forest communities.

Columbia Plateau ERU

We detected 20 broad-scale terrestrial communities within the Columbia Plateau ERU (table 3.145). However, the alpine and late-seral subalpine single-layer forest communities had always been extremely rare in that they never occupied more than a trace amount of the landscape. The current period areal extent of five community types (alpine, early-seral subalpine forest, late-seral montane multi-layer forest, late-seral montane single-layer forest, and water) occurred within their median 75 percent historical ranges. Ecologically significant trends were detected for 10 and 8 communities with respect to class and ERU, respectively. Five communities (early-seral lower montane forest, late-seral lower montane single-layer forest, late-seral subalpine multi-layer forest, mid-seral subalpine forest, and upland herbland) declined by more than 75 percent. Conversely, four communities (late-seral montane single-layer forest, mid-seral montane forest, mid-seral lower montane forest, and upland woodland) increased by more than 100 percent. The areal declines of the upland herbland and upland shrubland communities occurred across approximately 53 percent of the Columbia Plateau ERU. Conversely, approximately 45 percent of the ERU was converted to the agricultural community.

Although we detected substantial class changes of the early-seral subalpine forest, late-seral montane multi-layer forest, and late-seral montane single-layer forest communities, these changes were not ecologically significant (table 3.145). Similarly, the 35 percent increase of the late-seral subalpine single-layer forest community was not deemed significant, as the current period area did not amount to more than a trace amount of the ERU. Using similar logic, we concluded that although the current period areal extent of the late-seral subalpine single-layer forest and urban communities occurred above their median historical ranges, we did not regard these changes as significant.

The dominant causal factor for the loss of upland herbland and upland shrubland communities in the Columbia Plateau ERU was conversion to the agricultural type (table 3.146; Jones 1996). Approximately 94 percent of the late-seral lower montane single-layer forest community was altered by the loss of larger diameter trees and/or an increase in stocking levels of montane species. These forests converted predominantly to mid-seral lower montane (46%), late-seral lower montane multi-layer (18%), or mid-seral montane forest (15%) community types. The encroachment of the upland woodland community (primarily western juniper) into the upland shrubland community occurred across 4 percent of the ERU, and was restricted primarily to the southern portion of this ERU.

Table 3.144—Dominant transitions[1] of terrestrial communities within the Central Idaho Mountains Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Early-seral Montane Forest	Mid-seral Montane Forest	3.8
Early-seral Montane Forest	Mid-seral Subalpine Forest	1.2
Late-seral Montane Multi-layer Forest	Mid-seral Montane Forest	1.0
Mid-seral Lower Montane Forest	Mid-seral Montane Forest	1.5
Mid-seral Montane Forest	Early-seral Montane Forest	4.5
Mid-seral Montane Forest	Early-seral Subalpine Forest	1.5
Mid-seral Montane Forest	Late-seral Montane Multi-layer Forest	1.8
Mid-seral Montane Forest	Mid-seral Lower Montane Forest	1.3
Mid-seral Montane Forest	Mid-seral Subalpine Forest	1.5
Mid-seral Subalpine Forest	Early-seral Montane Forest	1.3
Mid-seral Subalpine Forest	Early-seral Subalpine Forest	2.1
Mid-seral Subalpine Forest	Mid-seral Montane Forest	1.1
Upland Herbland	Agricultural	3.1
Upland Herbland	Early-seral Montane Forest	1.3
Upland Herbland	Mid-seral Lower Montane Forest	1.9
Upland Herbland	Upland Shrubland	4.9
Upland Shrubland	Agricultural	2.5
Upland Woodland	Upland Herbland	2.7

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of ERU Area (percent) = proportion of landscape affected; area of the ERU in which a terrestrial community changed into another terrestrial community.

Lower Clark Fork ERU

Nineteen community types were detected within the Lower Clark Fork ERU (table 3.147). However, the exotic herbland community type only occupied a trace amount of the region during the current period, and the upland shrubland community appeared across 0.1 percent of the region during the historical simulations, but did not appear during the historical or current periods. Relative to the historical period, the current period had three additional anthropogenic community types (agricultural, exotic herbland, and urban). Conversely, three community types (late-seral lower montane multi-layer forest, late-seral lower montane single-layer forest, and upland woodland) were no longer evident during the current period. Thus, the richness of terrestrial communities stayed the same between historical and current periods.

Ecologically significant trends relative to class and ERU were apparent with 11 and 9 community types, respectively (table 3.147). Three terrestrial communities (late-seral lower montane multi-layer

Table 3.145—Changes of broad-scale terrestrial communities between historical and current periods within the Columbia Plateau Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	44.46	NA[5]	44.46*	5*
Alpine	T[6]	0	0	T	0	0	3
Early-seral Lower Montane Forest	0.63	0.63	2.04	0.10	-84.06*	-0.53	1*
Early-seral Montane Forest	2.22	1.98	2.39	1.58	-28.71*	-0.64	1*
Early-seral Subalpine Forest	0.02	0.01	0.02	0.02	-28.64	-0.01	3
Exotic Herbland	0	0	0	2.46	NA	2.46*	5*
Late-seral Lower Montane Multi-layer Forest	1.02	0.69	1.02	1.21	18.55	0.19	5*
Late-seral Lower Montane Single-layer Forest	3.13	2.83	3.13	0.19	-93.93*	-2.94*	1*
Late-seral Montane Multi-layer Forest	0.47	0.47	1.19	0.65	38.15	0.18	3
Late-seral Montane Single-layer Forest	0.04	0.04	0.41	0.13	230.15	0.09	3
Late-seral Subalpine Multi-layer Forest	0.02	0.02	0.05	0.01	-78.42*	-0.02	1*
Late-seral Subalpine Single-layer Forest	T	0	0	T	35.48	0	5
Mid-seral Lower Montane Forest	2.60	2.08	2.60	6.14	136.40*	3.54*	5*
Mid-seral Montane Forest	1.12	1.12	1.89	3.47	210.23*	2.35*	5*
Mid-seral Subalpine Forest	0.05	0.04	0.06	T	-91.48*	-0.05	1*
Upland Herbland	35.15	35.15	46.66	6.71	-80.92*	-28.44*	1*
Upland Shrubland	48.55	35.97	48.55	24.03	-50.50*	-24.51*	1*
Upland Woodland	3.10	2.08	3.10	7.54	143.41*	4.44*	5*
Urban	0	0	0	0.28	NA	0.28	5
Water	0.62	0.62	0.62	0.62	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

[6]T = Trace amount ≤ 0.01%.

*Ecologically significant changes.

Table 3.146—Dominant transitions[1] of terrestrial communities within the Columbia Plateau Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Early-seral Montane Forest	Mid-seral Montane Forest	1.0
Late-seral Lower Montane Single-layer Forest	Mid-seral Lower Montane Forest	1.5
Upland Herbland	Agricultural	23.0
Upland Herbland	Mid-seral Lower Montane Forest	1.2
Upland Herbland	Upland Shrubland	4.2
Upland Shrubland	Agricultural	23.0
Upland Shrubland	Upland Woodland	3.9

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of ERU Area (percent) = proportion of landscape affected; area of the ERU in which a terrestrial community changed into another terrestrial community.

forest, late-seral lower montane single-layer forest, and upland woodland) were lost completely, and the areal extent of four other community types (early-seral lower montane forest, late-seral montane multi-layer forest, late-seral subalpine multi-layer forest, and upland herbland) declined by more than 80 percent.

Successionally, forest communities have transitioned to mid-seral forests. As a whole, late-seral forest communities decreased from 25 to 2 percent of the Lower Clark Fork ERU (a 93% decline), while early-seral forest communities declined 53 percent. Both single- and multi-layer late-seral forest declined. Mid-seral communities, as a whole, increased by 106 percent. The areal extent of two of the three mid-seral forest communities (mid-seral montane forest and mid-seral subalpine forest) increased by more than 100 percent. In fact, the increase of the mid-seral montane forest community occurred across 36 percent of the landscape.

Although substantial areal declines occurred with the early-seral subalpine forest and late-seral subalpine single-layer forest communities these changes were not ecologically significant (table 3.147). Similarly, we did not regard the substantial departures of the exotic herbland, upland shrubland, and urban communities as ecologically significant.

The areal extent of the mid-seral montane forest community increased (table 3.148) largely due to the loss of the late-seral lower montane single-layer forest and mid-seral lower montane forest communities (Jones 1996). In addition, virtually all of the late-seral lower montane single-layer forest type changed to either mid-seral montane or mid-seral lower montane forest communities. Similarly, virtually all of the late-seral lower montane multi-layer forest community was converted to predominantly mid-seral montane or mid-seral lower montane forest communities. A comparable process was evident in subalpine forest communities, where a 95 percent decline of the late-seral subalpine multi-layer forest type was attributable to a subsequent increase of both early- and mid-seral montane forest and subalpine forest communities. Rangeland communities were dominated by the 100 percent conversion of the upland woodland community to the upland herbland community, and the alteration of 87 percent of the upland herbland community by either agricultural development or encroachment by lower montane forest communities.

Table 3.147—Changes of broad-scale terrestrial communities between historical and current periods within the Lower Clark Fork Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	3.24	NA[5]	3.24*	5*
Early-seral Lower Montane Forest	3.77	1.72	3.77	0.03	-99.12*	-3.74*	1*
Early-seral Montane Forest	26.24	13.91	26.24	15.10	-42.46*	-11.14*	2*
Early-seral Subalpine Forest	5.64	0.49	5.64	1.50	-73.35	-4.14	3
Exotic Herbland	0	0	0	T[6]	T	T	5
Late-seral Lower Montane Multi-layer Forest	3.57	3.57	4.30	0	-100.00*	-3.57*	1*
Late-seral Lower Montane Single-layer Forest	6.93	5.32	6.93	0	-100.00*	-6.93*	1*
Late-seral Montane Multi-layer Forest	12.74	12.74	21.46	1.19	-90.70*	-11.56*	1*
Late-seral Montane Single-layer Forest	0.57	0.57	8.63	0.46	-20.01*	-0.11	1*
Late-seral Subalpine Multi-layer Forest	0.75	0.75	3.59	0.04	-95.05*	-0.71	1*
Late-seral Subalpine Single-layer Forest	0.10	0.02	0.10	0.06	-38.44	-0.04	3
Mid-seral Lower Montane Forest	6.86	5.65	7.34	7.08	3.18	0.22	3
Mid-seral Montane Forest	28.61	28.59	38.01	64.11	124.08*	35.50*	5*
Mid-seral Subalpine Forest	1.81	1.81	4.72	5.69	214.49*	3.88*	5*
Upland Herbland	1.49	1.07	1.49	0.29	-80.69*	-1.20*	1*
Upland Shrubland	0	0.09	0.11	0	0	0	1
Upland Woodland	0.03	0.01	0.03	0	-100.00*	-0.03	1*
Urban	0	0	0	0.15	NA	0.15	5
Water	0.84	0.84	0.84	0.84	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

[6]T = Trace amount; estimated to be a trace amount based on reconnaissance.

*Ecologically significant changes.

Table 3.148—Dominant transitions[1] of terrestrial communities within the Lower Clark Fork Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Early-seral Lower Montane Forest	Mid-seral Montane Forest	2.3
Early-seral Montane Forest	Mid-seral Montane Forest	18.7
Early-seral Montane Forest	Mid-seral Subalpine Forest	1.0
Early-seral Subalpine Forest	Early-seral Montane Forest	1.4
Early-seral Subalpine Forest	Mid-seral Montane Forest	1.5
Early-seral Subalpine Forest	Mid-seral Subalpine Forest	2.0
Late-seral Lower Montane Multi-layer Forest	Mid-seral Montane Forest	2.2
Late-seral Lower Montane Single-layer Forest	Mid-seral Lower Montane Forest	2.0
Late-seral Lower Montane Single-layer Forest	Mid-seral Montane Forest	3.9
Late-seral Montane Multi-layer Forest	Early-seral Montane Forest	2.0
Late-seral Montane Multi-layer Forest	Mid-seral Montane Forest	9.4
Mid-seral Lower Montane Forest	Mid-seral Montane Forest	4.2
Mid-seral Montane Forest	Early-seral Montane Forest	5.1
Mid-seral Montane Forest	Mid-seral Subalpine Forest	1.5

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of the ERU Area (percent) = proportion of landscape affected; the area of the ERU in which a terrestrial community changed into another terrestrial community.

Northern Cascades ERU

The richness of terrestrial communities increased by three anthropogenic types between historical and current periods (table 3.149). Of 20 terrestrial communities, we observed ecologically significant trends with 11 and 10 communities relative to class and ERU, respectively. The seven community types that had significant declining class trends lost nearly 60 percent or more of their respective areas. The areal decline of the late-seral lower montane single-layer forest community (96%) was the most extensive landscape change within the Northern Cascades ERU.

Although the early-seral lower montane forest community increased by more than 200 percent across 1.2 percent of the Northern Cascades ERU, the change was not ecologically significant (table 3.149). Similarly, the increase of the late-seral montane multi-layer forest across nearly 1.3 percent of the ERU did not deviate substantially from historical conditions. Conversely, although the exotic herbland and urban community types deviated substantially from their median historical ranges, these changes were not ecologically significant.

Virtually all of the decline in the late-seral lower montane single-layer forest community was due to transitions to predominantly younger stands of mid-seral lower montane and mid-seral montane forest communities (table 3.150, Jones 1996). Other forest communities were also dominated by changes to younger forests. An increase of the early-seral montane forest community occurred largely at the expense of mid-seral montane and mid-seral subalpine forest communities. However, the increase in the mid-seral lower montane forest community was derived from both ends of the

Table 3.149—Changes of broad-scale terrestrial communities between historical and current periods within the Northern Cascades Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	6.24	NA[5]	6.24*	5*
Alpine	0.95	0.95	0.95	0.95	0	0	3
Early-seral Lower Montane Forest	0.53	0.53	3.03	1.70	222.20	1.17	3
Early-seral Montane Forest	12.53	12.53	15.93	23.45	87.15*	10.92*	5*
Early-seral Subalpine Forest	1.10	1.10	2.52	3.82	248.41*	2.72*	5*
Exotic Herbland	0	0	0	0.20	NA	0.20	5
Late-seral Lower Montane Multi-layer Forest	4.17	3.00	4.42	1.43	-65.79*	-2.75*	1*
Late-seral Lower Montane Single-layer Forest	12.01	4.78	12.01	0.52	-95.65*	-11.48*	1*
Late-seral Montane Multi-layer Forest	7.75	7.75	16.48	9.02	16.42	1.27	3
Late-seral Montane Single-layer Forest	1.49	1.04	1.89	1.42	-4.96	-0.07	3
Late-seral Subalpine Multi-layer Forest	2.11	2.11	4.19	0.53	-75.00*	-1.58*	1*
Late-seral Subalpine Single-layer Forest	0.37	0.37	0.61	0.15	-59.38*	-0.22	1*
Mid-seral Lower Montane Forest	8.06	5.48	8.06	15.61	93.66*	7.55*	5*
Mid-seral Montane Forest	22.56	22.56	24.51	23.28	3.22	0.73	3
Mid-seral Subalpine Forest	11.03	4.75	11.03	4.28	-61.19*	-6.75*	1*
Upland Herbland	5.56	4.88	5.56	2.20	-60.52*	-3.37*	1*
Upland Shrubland	7.47	5.44	7.47	1.92	-74.37*	-5.56*	1*
Upland Woodland	1.18	1.18	1.72	2.05	73.60*	0.87	5*
Urban	0	0	0	0.11	NA	0.11	5
Water	1.05	1.05	1.05	1.05	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

*Ecologically significant changes.

Table 3.150—Dominant transitions[1] of terrestrial communities within the Northern Cascades Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Early-seral Montane Forest	Late-seral Montane Multi-layer Forest	1.4
Early-seral Montane Forest	Mid-seral Lower Montane Forest	2.2
Early-seral Montane Forest	Mid-seral Montane Forest	4.0
Late-seral Lower Montane Multi-layer Forest	Mid-seral Lower Montane Forest	2.0
Late-seral Lower Montane Single-layer Forest	Late-seral Montane Multi-layer Forest	1.4
Late-seral Lower Montane Single-layer Forest	Mid-seral Lower Montane Forest	5.2
Late-seral Lower Montane Single-layer Forest	Mid-seral Montane Forest	2.4
Late-seral Montane Multi-layer Forest	Mid-seral Montane Forest	3.1
Late-seral Montane Multi-layer Forest	Early-seral Montane Forest	2.9
Mid-seral Lower Montane Forest	Mid-seral Montane Forest	1.6
Mid-seral Montane Forest	Early-seral Montane Forest	8.7
Mid-seral Montane Forest	Late-seral Montane Multi-layer Forest	2.5
Mid-seral Montane Forest	Mid-seral Subalpine Forest	1.9
Mid-seral Subalpine Forest	Early-seral Montane Forest	4.4
Mid-seral Subalpine Forest	Early-seral Subalpine Forest	2.3
Mid-seral Subalpine Forest	Late-seral Montane Multi-layer Forest	1.0
Mid-seral Subalpine Forest	Mid-seral Montane Forest	2.0
Upland Herbland	Agricultural	3.3
Upland Shrubland	Agricultural	2.9
Upland Shrubland	Mid-seral Lower Montane Forest	1.4

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of the ERU Area (percent) = proportion of landscape affected; the area of the ERU in which a terrestrial community changed into another terrestrial community.

successional pathway— mostly originating from the late-seral lower montane single-layer forest and early-seral montane forest communities, and to a lesser degree, the upland shrubland communities. With respect to rangeland communities, the 6 percent of the Northern Cascades ERU that was converted to agriculture was largely derived from the upland shrubland and upland herbland communities. The majority of the 74 percent loss of the upland shrubland community from the historic to the current period was attributable to conversion to the agricultural (38%), mid-seral lower montane forest (19%), and upland woodland (12%) communities.

As a group, late-seral forest communities decreased from 28 to 13 percent of the ERU (a 54% decline; table 3.149). We detected significant declines in both single- and multi-layer late-seral forest communities. Conversely, both early- and mid-seral forest communities increased.

Northern Glaciated Mountains ERU

The richness of terrestrial communities increased by three anthropogenic types (agricultural, exotic herbland, and urban) between the historical and current periods (table 3.151). Of the 20 terrestrial communities that occurred in the Northern Glaciated Mountains ERU, the areal extent of only three (rock/barren, upland woodland, and water) existed within their median historical ranges during the current period. Ecologically significant trends were detected for 14 and 13 community types with respect to class and ERU, respectively. The areal extent of eight community types decreased by more than 75 percent. The late-seral montane single-layer forest, late-seral lower montane single-layer forest, and late-seral subalpine multi-layer forest communities were nearly eliminated from the Northern Glaciated Mountains ERU between historical and current periods. Conversely, three communities (late-seral subalpine single-layer forest, mid-seral montane forest, and upland woodland) increased by more than 100 percent.

Successionally, forest communities have transitioned to mid-seral forests within the Northern Glaciated Mountains ERU. With the exception of the late-seral subalpine single-layer forest (which increased), all late-seral forest communities declined by more than 90 percent (table 3.151). Over all, the areal extent of late-seral forest communities declined from 29 to 3 percent of the Northern Glaciated Mountains ERU. Conversely, ecologically significant increases were detected for all mid-seral forest communities, which in total, encompassed approximately 34 percent more land area of the ERU in the current period than in the historical period. Thus, mid-seral forest communities increased at the expense of early- and late-seral forest communities.

Although the upland woodland community increased by more than 400 percent, the change was not ecologically significant (table 3.151). Conversely, the areal increases of the current period exotic herbland and urban communities, which occurred at levels well above their historical ranges, were also not ecologically significant.

The Northern Glaciated Mountains ERU was dominated by transitions toward more homogeneous mid-seral forests. The nearly one-third of the ERU which was converted to the mid-seral montane forest community, originated mostly from the early-seral montane forest and late-seral montane multi-layer forest communities (table 3.152, Jones 1996). Large-diameter trees were removed from late-seral montane forest communities, while younger forests developed more complex structures. The 91 percent areal decline of the late-seral montane multi-layer forest community was dominated by transitions to mid-seral montane (72%) or early-seral montane forest (16%) communities. Almost all of the late-seral subalpine multi-layer forest community type was similarly converted to younger forest communities. Single-layer lower montane and montane forest communities were nearly eliminated as a result of conversions to mid-seral or early-seral communities. Agricultural conversions dominated the transitions of rangeland communities, affecting 12 percent of the Northern Glaciated Mountains ERU. Most of the agricultural development occurred within the upland herbland and upland shrubland communities.

Northern Great Basin ERU

The richness of terrestrial communities increased from 16 to 18 types between the historical and current periods (table 3.153). The two additional communities detected in the current period included two anthropogenic types (agricultural and exotic herbland).

Ecologically significant class and ERU trends were detected for seven and four communities, respectively (table 3.153). Most of the early-seral lower montane forest and upland herbland communities (89 and 55%, respectively) were converted to other communities between the historical and current periods. Conversely, the areal extent of four communities (late-seral montane multi-layer forest, late-seral montane single-layer forest, late-seral subalpine multi-layer forest, and upland woodland) increased by more than 200 percent. However, of these communities, only the increasing trends of the late-seral montane multi-layer forest

Table 3.151—Changes of broad-scale terrestrial communities between historical and current periods within the Northern Glaciated Mountains Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	11.75	NA[5]	11.75*	5*
Early-seral Lower Montane Forest	2.13	2.13	3.85	0.32	-85.22*	-1.82*	1*
Early-seral Montane Forest	17.79	13.40	17.79	11.42	-35.80*	-6.37*	1*
Early-seral Subalpine Forest	2.27	1.45	2.27	1.30	-42.98*	-0.98	1*
Exotic Herbland	0	0	0	0.09	NA	0.09	5
Late-seral Lower Montane Multi-layer Forest	3.08	3.08	3.97	0.11	-96.41*	-2.97*	1*
Late-seral Lower Montane Single-layer Forest	7.95	6.50	7.95	0.05	-99.31*	-7.90*	1*
Late-seral Montane Multi-layer Forest	12.10	11.44	14.83	1.14	-90.55*	-10.96*	1*
Late-seral Montane Single-layer Forest	1.96	1.96	2.70	0.01	-99.27*	-1.94*	1*
Late-seral Subalpine Multi-layer Forest	3.34	3.34	4.74	0.05	-98.58*	-3.29*	1*
Late-seral Subalpine Single-layer Forest	0.56	0.34	0.56	1.41	153.72*	0.86	5*
Mid-seral Lower Montane Forest	7.34	6.60	7.93	13.45	83.30*	6.11*	5*
Mid-seral Montane Forest	18.81	18.81	25.30	46.05	144.85*	27.24*	5*
Mid-seral Subalpine Forest	4.58	3.96	4.58	5.90	28.63*	1.31*	5*
Rock/Barren	0.01	0	0	0.01	0	0	3
Upland Herbland	9.33	6.20	9.33	1.53	-83.59*	-7.80*	1*
Upland Shrubland	6.01	4.78	6.01	1.30	-78.35*	-4.71*	1*
Upland Woodland	0.25	0.25	1.69	1.34	437.03	1.09	3
Urban	0	0	0	0.29	NA	0.29	5
Water	2.36	2.36	2.36	2.36	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

*Ecologically significant changes.

Table 3.152—Dominant transitions[1] of terrestrial communities within the Northern Glaciated Mountains Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Early-seral Montane Forest	Agricultural	1.5
Early-seral Montane Forest	Mid-seral Lower Montane Forest	1.3
Early-seral Montane Forest	Mid-seral Montane Forest	10.3
Late-seral Lower Montane Multi-layer Forest	Mid-seral Lower Montane Forest	1.1
Late-seral Lower Montane Multi-layer Forest	Mid-seral Montane Forest	1.4
Late-seral Lower Montane Single-layer Forest	Mid-seral Lower Montane Forest	3.2
Late-seral Lower Montane Single-layer Forest	Mid-seral Montane Forest	3.4
Late-seral Montane Multi-layer Forest	Early-seral Montane Forest	2.1
Late-seral Montane Multi-layer Forest	Mid-seral Montane Forest	8.7
Late-seral Montane Single-layer Forest	Mid-seral Montane Forest	1.4
Late Seral Subalpine Multi-layer Forest	Mid-seral Montane Forest	1.2
Late Seral Subalpine Multi-layer Forest	Mid-seral Subalpine Forest	1.1
Mid-seral Lower Montane Forest	Mid-seral Montane Forest	3.1
Mid-seral Montane Forest	Early-seral Montane Forest	2.9
Mid-seral Montane Forest	Mid-seral Subalpine Forest	1.0
Mid-seral Subalpine Forest	Mid-seral Montane Forest	1.2
Upland Herbland	Agricultural	4.2
Upland Herbland	Mid-seral Lower Montane Forest	2.4
Upland Herbland	Upland Woodland	1.2
Upland Shrubland	Agricultural	3.8

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of ERU Area (percent) = proportion of landscape affected; the area of the ERU in which a terrestrial community changed into another terrestrial community.

and upland woodland community types were ecologically significant relative to the Northern Great Basin ERU.

The areal extent of 5 of 19 current period terrestrial communities occurred within their median historical ranges (alpine, late-seral lower montane single-layer forest, late-seral subalpine multi-layer forest, upland shrubland, and water). Thus, although the late-seral lower montane single-layer forest and late-seral subalpine multi-layer forest experienced substantial class changes, these changes were not ecologically significant (that is, they appeared to occur within the HRV for these types). Similarly, the decline of the upland shrubland community across 7 percent of the ERU was within the HRV.

Landscape changes in terrestrial communities within the Northern Great Basin ERU were dominated by the areal decline of the upland shrubland community (table 3.154, Jones 1996). Agricultural development, exotic plant invasions, and the encroachment of the upland woodland community were the primary causal factors in the decline of the upland shrubland community. Less

Table 3.153—Changes of broad-scale terrestrial communities between historical and current periods within the Northern Great Basin Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	2.35	NA[5]	2.35*	5*
Alpine	0.05	0.05	0.05	0.05	0	0	3
Early-seral Lower Montane Forest	0.20	0.20	1.36	0.02	-89.28*	-0.18	1*
Early-seral Montane Forest	1.73	1.73	1.97	1.06	-38.76*	-0.67	1*
Early-seral Subalpine Forest	T[6]	0	0.04	0	0	0	2
Exotic Herbland	0	0	0	0.30	NA	2.30*	5*
Late-seral Lower Montane Multi-layer Forest	1.03	0.52	1.03	1.21	17.40	0.18	5*
Late-seral Lower Montane Single-layer Forest	3.69	2.33	3.69	2.78	-24.69	-0.91	3
Late-seral Montane Multi-layer Forest	0.09	0.09	0.86	2.41	2552.81*	2.32*	5*
Late-seral Montane Single-layer Forest	T	0	0.24	0.26	10541.67*	0.25	5*
Late-seral Subalpine Multi-layer Forest	T	0	0.10	0.02	247.92	0.01	3
Late-seral Subalpine Single-layer Forest	0.14	0.02	0.14	0.15	6.70	0.01	5
Mid-seral Lower Montane Forest	2.46	1.34	2.46	2.60	5.52	0.14	5*
Mid-seral Montane Forest	1.21	1.21	1.80	0.90	-25.24*	-0.31	1*
Mid-seral Subalpine Forest	T	0.02	0.09	0	0	0	1
Upland Herbland	1.73	1.73	28.93	0.79	-54.54*	-0.95	1*
Upland Shrubland	83.07	53.81	83.07	75.63	-8.95	-7.44	3
Upland Woodland	0.69	0.69	0.84	2.35	241.20*	1.66*	5*
Water	2.24	2.24	2.24	2.24	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

[6]T = Trace amount ≤ 0.01%.

*Ecologically significant changes.

Table 3.154—Dominant transitions[1] of terrestrial communities within the Northern Great Basin Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Upland Shrubland	Agricultural	2.6
Upland Shrubland	Exotic Herbland	1.7
Upland Shrubland	Upland Woodland	1.6

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]*Historical Period = circa 1850 to 1900; Current Period = circa 1991.*

[3]Proportion of ERU Area (percent) = proportion of landscape affected; the area of the ERU in which a terrestrial community changed into another terrestrial community.

extensive declines were detected in the upland herbland and late-seral lower montane single-layer forest communities. Sixty-four percent of the areal decline of the upland herbland community was attributable to the encroachment of the upland woodland and lower montane forest communities, and to a lesser degree, to conversion to the upland shrubland, exotic herbland, or agricultural community types.

Successional processes were largely responsible for the loss of 25 percent of the late-seral lower montane single-layer forest community. The areal decline of the late-seral lower montane single-layer forest type was dominated by the development of the structurally more complex late-seral montane multi-layer forest and late-seral lower montane multi-layer forest communities. Similarly, the increase of the late-seral montane multi-layer forest type was primarily a result of the successional development of early- and mid-seral montane forest, as well as the late-seral lower montane single-layer forest communities.

As a group, late-seral forest communities increased from 5 to 7 percent of the Northern Great Basin ERU (table 3.153). The net increase was dominated by a significant increase in late-seral multi-layer forest types as late-seral single-layer forest types declined. Although the area of early-seral and mid-seral forest communities declined, the ERU trends were not significant.

Owyhee Uplands ERU

The richness of terrestrial communities in the Owyhee Uplands ERU increased from 13 to 20 types between the historical and current periods (table 3.155). The seven additional communities included three anthropogenic types (agricultural, exotic herbland, and urban) and three subalpine forest communities. However, of the seven, only the agricultural and exotic herbland communities composed a substantial proportion of the Owyhee Uplands ERU during the current period.

Ecologically significant class and ERU trends were detected for eight and four communities, respectively (table 3.155). The dominant changes affecting the composition of the Owyhee Uplands ERU included agricultural conversion and decline of the upland shrubland community across 12 and 13 percent of the landscape, respectively. Six of the 20 community types (alpine, early-seral montane forest, late-seral montane multi-layer forest, mid-seral subalpine forest, upland shrubland, and water) occurred within their median historical ranges during the current period. Although substantial departures were documented for the early-seral subalpine forest, late-seral subalpine multi-layer forest, late-seral subalpine single-layer forest, and urban communities, their departures were not ecologically significant.

Table 3.155—Changes of broad-scale terrestrial communities between historical and current periods within the Owyhee Uplands Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	11.76	NA[5]	11.76*	5*
Alpine	0.09	0.09	0.09	0.09	0	0	3
Early-seral Lower Montane Forest	0.09	0.09	0.23	0.02	-72.82*	-0.06	1*
Early-seral Montane Forest	0.50	0.30	0.50	0.43	-13.14	-0.07	3
Early-seral Subalpine Forest	0	0	0.02	0.02	NA	0.02	4
Exotic Herbland	0	0	0	3.11	NA	3.11*	5*
Late-seral Lower Montane Multi-layer Forest	0.02	0.02	0.07	0.01	-46.34*	-0.01	1*
Late-seral Lower Montane Single-layer Forest	0.17	0.17	0.36	0.01	-96.24*	-0.16	1*
Late-seral Montane Multi-layer Forest	0.01	0.01	0.09	0.02	165.79	0.01	3
Late-seral Montane Single-layer Forest	0.01	0.01	0.02	0.08	592.04*	0.07	5*
Late-seral Subalpine Multi-layer Forest	0	0.01	0.01	T[6]	NA	0	1
Late-seral Subalpine Single-layer Forest	0	0	0	0.02	NA	0.02	5
Mid-seral Lower Montane Forest	0.19	0.19	0.28	0.31	62.73*	0.12	5*
Mid-seral Montane Forest	0.03	0.03	0.28	0.39	1306.50*	0.36	5*
Mid-seral Subalpine Forest	0	0	0.03	0.01	NA	0.01	3
Upland Herbland	5.40	5.40	31.35	4.12	-23.73*	-1.28*	1*
Upland Shrubland	89.18	61.96	89.18	76.12	-14.64	-13.06	3
Upland Woodland	1.13	0.94	1.13	2.15	89.56*	1.02*	5*
Urban	0	0	0	0.16	NA	0.16	5
Water	0.13	0.13	0.13	0.13	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

[6]T = Trace amount ≤ 0.01%.

*Ecologically significant changes.

Table 3.156—Dominant transitions[1] of terrestrial communities within the Owyhee Uplands Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Upland Herbland	Upland Shrubland	2.9
Upland Shrubland	Agricultural	9.7
Upland Shrubland	Exotic Herbland	2.6
Upland Shrubland	Upland Herbland	2.4
Upland Shrubland	Upland Woodland	1.1

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of ERU Area (percent) = proportion of landscape affected; the area of the ERU in which a terrestrial community changed into another terrestrial community.

Terrestrial community transitions within the Owyhee Uplands ERU were dominated by the agricultural conversion of 12 percent of the area, most of which occurred within the upland shrubland community (table 3.156, Jones 1996). Lesser declines in the upland shrubland community were attributable to the invasion of exotic plants, and the encroachment of the upland woodland community (primarily western juniper). Upland shrublands and upland herblands transitioned to each other from the historical to the current period, but the net transition reflected a conversion of upland herbland to upland shrubland. The areal decline of the late-seral lower montane single-layer forest community was largely attributable to disturbances that resulted in their conversion to early- and mid-seral montane forest communities. In addition, the areal decline of the early-seral lower montane forest community was a result of transitions of montane and lower montane forest communities or early-seral montane forest community to mid-seral communities.

Snake Headwaters ERU

The richness of terrestrial communities increased between the historical and current periods (table 3.157). Three anthropogenic types occurred in the current period, but not in the historical period. Conversely, the early-seral lower montane forest and late-seral lower montane multi-layer forest communities occurred historically, but not during the current period.

Of the 21 community types detected within the Snake Headwaters ERU, ecologically significant trends relative to class and ERU were observed for 11 and 9 communities, respectively. Areal declines in the late-seral montane multi-layer forest, late-seral subalpine multi-layer forest, upland shrubland, and upland woodland communities exceeded 75 percent between historical and current periods. Conversely, the early-seral subalpine forest and late-seral lower montane single-layer forest communities increased by more than 1,000 percent.

The areal extent of 5 of the 21 terrestrial community types occurred within their median historical ranges during the current period (alpine, early-seral montane forest, late-seral lower montane single-layer forest, rock/barren, and water; table 3.157). The substantial departures that occurred with the mid-seral lower montane forest and urban communities were not ecologically significant.

The decline of the upland shrubland community type across about 13 percent of the ERU represented the most extensive landscape change in the

Table 3.157—Changes of broad-scale terrestrial communities between historical and current periods within the Snake Headwaters Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	8.65	NA[5]	8.65*	5*
Alpine	0.96	0.96	0.96	0.96	0	0	3
Early-seral Lower Montane Forest	0.02	0.02	0.15	0	-100.00*	-0.02	1*
Early-seral Montane Forest	13.17	9.72	13.17	11.27	-14.45	-1.90	3
Early-seral Subalpine Forest	0.38	0.38	3.41	4.23	1008.89*	3.85*	5*
Exotic Herbland	0	0	0	1.47	NA	1.47*	5*
Late-seral Lower Montane Multi-layer Forest	0.02	0.02	0.05	0	-100.00*	-0.02	1*
Late-seral Lower Montane Single-layer Forest	T[6]	0	0.22	0.05	1092.11	0.04	3
Late-seral Montane Multi-layer Forest	7.72	7.72	13.79	0.59	-92.32*	-7.12*	1*
Late-seral Montane Single-layer Forest	1.23	1.23	1.88	1.85	50.61*	0.62	4*
Late-seral Subalpine Multi-layer Forest	6.18	6.18	7.21	0.65	-89.49*	-5.53*	1*
Late-seral Subalpine Single-layer Forest	0.63	0.34	0.63	0.88	39.51*	0.25	5*
Mid-seral Lower Montane Forest	0.17	0.13	0.17	0.17	-2.19	0	4
Mid-seral Montane Forest	23.75	17.97	23.75	26.86	13.11	3.11*	5*
Mid-seral Subalpine Forest	5.14	4.27	6.87	7.21	40.31*	2.07*	5*
Rock/Barren	0.05	0.05	0.05	0.05	0	0	3
Upland Herbland	9.46	8.05	9.46	6.32	-33.20*	-3.14*	1*
Upland Shrubland	13.57	7.85	13.57	0.66	-95.10*	-12.91*	1*
Upland Woodland	1.03	1.03	1.86	0.22	-78.67*	-0.81	1*
Urban	0	0	0	0.13	NA	0.13	5
Water	0.79	0.79	0.79	0.79	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

[6]T = Trace amount ≤ 0.01%.

*Ecologically significant changes.

Snake Headwaters ERU. Nearly one-half of the decline of the upland shrubland community was a result of agricultural development (table 3.158, Jones 1996). The remainder of the decline was attributable primarily to the encroachment of the mid-seral montane forest community. Changes in forested communities were dominated by transitions toward younger, less structurally complex communities. A 92 percent areal decline of the late-seral montane multi-layer forest community was dominated by changes to early- and mid-seral montane forest communities, and to a lesser degree, to the mid-seral subalpine forest community. Likewise, the decline of 90 percent of the late-seral subalpine multi-layer forest community was a result of transitions to both early- and mid-seral subalpine forest, and early- and mid-seral montane forest communities.

The distribution of forest communities became more centered around middle-aged forests. As a whole, late-seral forest communities decreased from approximately 16 to 4 percent and mid-seral forests increased from 29 to 34 percent of the Snake Headwaters ERU (table 3.157).

Southern Cascades ERU

The richness of terrestrial communities within the Southern Cascades ERU increased by three anthropogenic communities (agricultural, exotic herbland, and urban) between the historical and current periods (table 3.159). During this time interval, ecologically significant class and ERU trends occurred for 9 and 10 communities, respectively. The trends of the late-seral montane single-layer forest and late-seral lower montane single-layer forest communities dominated the landscape changes that occurred across the Southern Cascades ERU. The late-seral montane single-layer forest community increased, whereas the late-seral lower montane single-layer forest community decreased across approximately 8 percent of the ERU.

Six of 21 communities occurred within their median historical ranges during the current period (alpine, early-seral montane forest, late-seral subalpine single-layer forest, upland woodland, rock/barren, and water; table 3.159). Although substantial areal changes occurred with the early-seral montane forest and late-seral subalpine single-layer forest communities, the changes were not ecologically significant. Similarly, although the current areal extent of the exotic herbland and urban communities occurred well above historical conditions, the increases were not ecologically significant.

Terrestrial community transitions within the Southern Cascades ERU were dominated by increases in both late-seral montane single-layer forest and late-seral montane multi-layer forest communities that affected nearly 9 and 8 percent of the ERU, respectively (table 3.160, Jones 1996). The increase of the late-seral montane single-layer forest community type was derived predominantly from the late-seral lower montane single-layer forest, mid-seral montane forest, and mid-seral lower montane forest communities, whereas the increase in the late-seral montane multi-layer forest community type occurred at the expense of the mid-seral subalpine forest, and early-, and mid-seral montane forest communities. The 8.5 percent areal decline of the late-seral lower montane single-layer forest community was primarily attributable to a transition to the mid-seral lower montane forest type. Successional processes were largely responsible for the observed decreases in mid-seral subalpine forest and mid-seral montane forest communities. Nearly one-half of the mid-seral subalpine forest community changed into the late-seral montane multi-layer forest community, although 24 percent was converted into the early-seral montane forest community. The decline of the mid-seral montane forest community was dominated by an increase of the late-seral montane multi-layer forest community. In rangeland communities, agricultural conversion was the greatest causal factor in the detected loss of upland shrubland and upland herbland from the historical to the current period.

Table 3.158—Dominant transitions[1] of terrestrial communities within the Snake Headwaters Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Early-seral Montane Forest	Mid-seral Montane Forest	5.9
Late-seral Montane Multi-layer Forest	Early-seral Montane Forest	1.6
Late-seral Montane Multi-layer Forest	Mid-seral Montane Forest	3.3
Late-seral Subalpine Multi-layer Forest	Early-seral Montane Forest	1.0
Late-seral Subalpine Multi-layer Forest	Mid-seral Subalpine Forest	1.5
Late-seral Subalpine Multi-layer Forest	Early-seral Subalpine Forest	1.5
Late-seral Subalpine Multi-layer Forest	Mid-seral Montane Forest	1.7
Mid-seral Montane Forest	Early-seral Montane Forest	5.2
Mid-seral Montane Forest	Mid-seral Subalpine Forest	2.8
Mid-seral Subalpine Forest	Mid-seral Montane Forest	1.2
Mid-seral Subalpine Forest	Early-seral Subalpine Forest	1.4
Upland Herbland	Agricultural	1.9
Upland Shrubland	Agricultural	6.7
Upland Shrubland	Mid-seral Montane Forest	4.0
Upland Woodland	Upland Herbland	1.0

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of ERU Area (percent) = proportion of landscape affected; the area of the ERU in which a terrestrial community changed into another terrestrial community.

As a group, late-seral forest communities increased from approximately 30 to 35 percent of the Southern Cascades ERU (table 3.159). The net change of late-seral forest communities was dominated by the increase of multi-layer communities, as the decline of single-layer communities was insignificant. The areal extent of early-seral forest communities also increased, whereas the area of mid-seral forest communities decreased.

Upper Clark Fork ERU

The richness of terrestrial communities increased from 18 to 19 community types in the Upper Clark Fork ERU between the historical and current periods (table 3.161). During this time interval, three anthropogenic communities (agricultural, exotic herbland, and urban) were added, while two communities (late-seral montane single-layer forest and late-seral lower montane single-layer forest) were eliminated.

Of the 21 communities detected within the Upper Clark Fork ERU, the areal extent of only the alpine, rock/barren, and water community types occurred within their median historical ranges during the current period (table 3.161). The majority of the terrestrial communities had ecologically significant class (62%) and ERU trends (62%). Seven of 9 communities that had significantly declining class trends decreased by more than 80 percent.

Table 3.159—Changes of broad-scale terrestrial communities between historical and current periods within the Southern Cascades Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	5.94	NA[5]	5.94*	5*
Alpine	0.26	0.26	0.26	0.26	0	0	3
Early-seral Lower Montane Forest	0.89	0.89	5.51	0.26	-70.17*	-0.62	1*
Early-seral Montane Forest	10.61	10.61	17.09	13.35	25.84	2.74	3
Early-seral Subalpine Forest	0.51	0.51	0.74	1.37	169.00*	0.86	5*
Exotic Herbland	0	0	0	0.28	NA	0.28	5
Late-seral Lower Montane Multi-layer Forest	5.35	3.72	6.10	3.02	-43.51*	-2.33*	1*
Late-seral Lower Montane Single-layer Forest	16.15	7.96	16.15	7.67	-52.53*	-8.48*	1*
Late-seral Montane Multi-layer Forest	5.97	5.97	12.34	13.31	122.90*	7.34*	5*
Late-seral Montane Single-layer Forest	1.50	1.25	1.78	9.72	549.28*	8.22*	5*
Late-seral Subalpine Multi-layer Forest	1.03	1.03	1.95	0.95	-7.64	-0.08	1*
Late-seral Subalpine Single-layer Forest	0.06	0.06	0.20	0.10	55.59	0.04	3
Mid-seral Lower Montane Forest	13.05	6.67	13.05	14.32	9.77	1.27*	5*
Mid-seral Montane Forest	20.73	18.43	20.73	16.76	-19.17	-3.97*	1*
Mid-seral Subalpine Forest	4.95	1.65	4.95	0.72	-85.55*	-4.24*	1*
Rock/Barren	0.05	0.05	0.05	0.05	0	0	3
Upland Herbland	3.67	3.67	7.63	1.15	-68.81*	-2.53*	1*
Upland Shrubland	6.56	6.56	7.44	2.64	-59.72*	-3.92*	1*
Upland Woodland	5.56	2.28	5.56	5.09	-8.38	-0.47	3
Urban	0	0	0	0.19	NA	0.19	5
Water	2.53	2.53	2.53	2.53	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

*Ecologically significant changes.

Table 3.160—Dominant transitions[1] of terrestrial communities within the Southern Cascades Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Early-seral Montane Forest	Late-seral Montane Multi-layer Forest	2.6
Early-seral Montane Forest	Mid-seral Montane Forest	3.9
Early-seral Montane Forest	Mid-seral Lower Montane Forest	1.3
Late-seral Lower Montane Multi-layer Forest	Late-seral Lower Montane Single-layer Forest	1.1
Late-seral Lower Montane Multi-layer Forest	Mid-seral Lower Montane Forest	1.9
Late-seral Lower Montane Single-layer Forest	Early-seral Montane Forest	1.1
Late-seral Lower Montane Single-layer Forest	Late-seral Lower Montane Multi-layer Forest	1.3
Late-seral Lower Montane Single-layer Forest	Late-seral Montane Multi-layer Forest	1.1
Late-seral Lower Montane Single-layer Forest	Late-seral Montane Single-layer Forest	2.5
Late-seral Lower Montane Single-layer Forest	Mid-seral Lower Montane Forest	5.7
Late-seral Lower Montane Single-layer Forest	Mid-seral Montane Forest	1.6
Late-seral Montane Multi-layer Forest	Early-seral Montane Forest	1.3
Late-seral Montane Multi-layer Forest	Late-seral Montane Single-layer Forest	1.2
Late-seral Montane Multi-layer Forest	Mid-seral Montane Forest	1.8
Mid-seral Lower Montane Forest	Early-seral Montane Forest	2.1
Mid-seral Lower Montane Forest	Late-seral Lower Montane Multi-layer Forest	1.1
Mid-seral Lower Montane Forest	Late-seral Lower Montane Single-layer Forest	2.1
Mid-seral Lower Montane Forest	Late-seral Montane Single-layer Forest	2.1
Mid-seral Lower Montane Forest	Mid-seral Montane Forest	1.0
Mid-seral Montane Forest	Early-seral Montane Forest	4.5
Mid-seral Montane Forest	Late-seral Lower Montane Single-layer Forest	1.2
Mid-seral Montane Forest	Late-seral Montane Multi-layer Forest	4.8
Mid-seral Montane Forest	Late-seral Montane Single-layer Forest	2.0
Mid-seral Subalpine Forest	Early-seral Montane Forest	1.1
Mid-seral Subalpine Forest	Late-seral Montane Multi-layer Forest	2.1
Upland Herbland	Agricultural	1.1
Upland Shrubland	Agricultural	4.0

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of ERU Area (percent) = proportion of landscape affected; the area of the ERU in which a terrestrial community changed into another terrestrial community.

With the exception of the late-seral subalpine single-layer forest community, all of the late-seral forest communities declined by more than 90 percent (table 3.161). As a group, the areal extent of late-seral forest communities declined from approximately 15 to 1 percent of the Upper Clark Fork ERU. Conversely, the mid-seral lower montane forest and mid-seral subalpine forest communities increased by more than 175 percent.

The structures of broad-scale forest communities became more homogenized between the historical and current periods. A net loss of early- and late-seral forest communities affected 7 and 15 percent of the ERU, respectively. Conversely, the net increase of mid-seral forest communities encompassed nearly 28 percent of the Upper Clark Fork ERU.

The decline of the upland herbland community was the most extensive regional change in the Upper Clark Fork ERU from the historical to the current period (table 3.161). Agricultural conversion and encroaching lower montane and montane forest communities were each responsible for nearly a 33 percent areal reduction of the upland herbland community type (table 3.162, Jones 1996). Net transitions to mid-seral subalpine, mid-seral lower montane, and mid-seral montane forest communities were somewhat less extensive, occurring on approximately 7, 11, and 6 percent of the ERU, respectively. The areal extent of the mid-seral lower montane forest community increased by the encroachment into the upland herbland community, and the loss of large-diameter trees from the late-seral lower montane single-layer forest community. The mid-seral subalpine forest community increased via transitions from early- and mid-seral montane forest communities. The increase of the mid-seral montane forest community type was derived predominantly from the successional development of the early-seral montane forest community, as well as from the loss of large-diameter trees in the late-seral montane multi-layer forest community.

Upper Klamath ERU

The richness of terrestrial communities increased from 18 to 20 communities between the historical and current periods (table 3.163). During this time interval, three anthropogenic communities (agricultural, exotic herbland, and urban) developed, while the mid-seral subalpine community was eliminated.

Of the 21 terrestrial communities detected within the Upper Klamath ERU, 4 types (alpine, late-seral lower montane single-layer forest, rock/barren, and water) occurred within their median historical ranges during the current period (table 3.163). Ecologically significant class and ERU trends were detected for 12 and 11 terrestrial communities, respectively. The early-seral lower montane forest community was virtually eliminated, while the areal extent of three other communities (early-seral subalpine forest, upland herbland, and upland shrubland) declined by at least 75 percent. Conversely, the areal extent of the late-seral montane single-layer forest, late-seral montane multi-layer forest, and upland woodland communities increased greatly. Overall, forest communities aged, as we detected net areal declines of early-seral (2%) and mid-seral (18%) forest communities, while late-seral forest communities covered an additional 27 percent of the Upper Klamath ERU between the historical and current periods.

Although the late-seral lower montane single-layer forest community declined across 3 percent of the Upper Klamath ERU, its areal extent during the current period continued to exist within its median historical range (table 3.163). Consequently, the change was not ecologically significant. Similarly, the substantial departures that were detected with the exotic herbland, late-seral subalpine single-layer forest, and urban communities were also not ecologically significant, as none of these communities constituted substantial proportions of the Upper Klamath ERU.

Table 3.161—Changes of broad-scale terrestrial communities between historical and current periods within the Upper Clark Fork Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	8.80	NA[5]	8.80*	5*
Alpine	0.03	0.03	0.03	0.03	0	0	3
Early-seral Lower Montane Forest	2.09	2.09	5.18	0.23	-88.98*	-1.86*	1*
Early-seral Montane Forest	13.92	13.92	15.92	8.51	-38.91*	-5.42*	1*
Early-seral Subalpine Forest	2.27	1.61	2.27	2.96	30.08*	0.68	5*
Exotic Herbland	0	0	0	0.67	NA	0.67	5
Late-seral Lower Montane Multi-layer Forest	3.14	1.68	3.14	0.10	-96.81*	-3.04*	1*
Late-seral Lower Montane Single-layer Forest	3.45	3.45	6.98	0	-100.00*	-3.45*	1*
Late-seral Montane Multi-layer Forest	4.55	4.55	12.48	0.32	-93.01*	-4.23*	1*
Late-seral Montane Single-layer Forest	2.16	1.35	2.16	0	-100.00*	-2.16*	1*
Late-seral Subalpine Multi-layer Forest	1.85	1.85	5.11	0.10	-94.35*	-1.75*	1*
Late-seral Subalpine Single-layer Forest	0.39	0.24	0.39	0.46	17.79	0.07	5
Mid-seral Lower Montane Forest	6.01	5.21	6.19	16.85	180.64*	10.85*	5*
Mid-seral Montane Forest	26.90	18.97	26.90	35.45	31.76*	8.54*	5*
Mid-seral Subalpine Forest	4.09	3.88	5.06	12.72	210.97*	8.63*	5*
Rock/Barren	4.06	4.06	4.06	4.06	0	0	3
Upland Herbland	19.87	10.55	19.87	5.42	-72.73*	-14.45*	1*
Upland Shrubland	1.39	1.39	3.65	1.12	-19.68	-0.27	1*
Upland Woodland	2.84	2.67	3.18	0.34	-88.21*	-2.51*	1*
Urban	0	0	0	0.22	NA	0.22	5
Water	0.10	0.10	0.10	0.10	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

*Ecologically significant changes.

Table 3.162—Dominant transitions[1] of terrestrial communities within the Upper Clark Fork Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Early-seral Lower Montane Forest	Mid-seral Lower Montane Forest	1.1
Early-seral Montane Forest	Mid-seral Montane Forest	8.0
Early-seral Montane Forest	Mid-seral Subalpine Forest	2.8
Late-seral Lower Montane Multi-layer Forest	Mid-seral Lower Montane Forest	2.3
Late-seral Lower Montane Single-layer Forest	Mid-seral Lower Montane Forest	2.2
Late-seral Montane Multi-layer Forest	Mid-seral Montane Forest	2.5
Mid-seral Lower Montane Forest	Mid-seral Montane Forest	1.5
Mid-seral Montane Forest	Early-seral Montane Forest	2.5
Mid-seral Montane Forest	Mid-seral Lower Montane Forest	1.7
Mid-seral Montane Forest	Mid-seral Subalpine Forest	5.9
Mid-seral Subalpine Forest	Mid-seral Montane Forest	1.5
Upland Herbland	Agricultural	6.4
Upland Herbland	Early-seral Montane Forest	1.3
Upland Herbland	Mid-seral Lower Montane Forest	4.6
Upland Herbland	Mid-seral Montane Forest	2.2
Upland Herbland	Upland Shrubland	1.0
Upland Shrubland	Agricultural	1.0
Upland Woodland	Upland Herbland	1.8

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of ERU Area (percent) = proportion of landscape affected; the area of the ERU in which a terrestrial community changed into another terrestrial community.

Terrestrial community transitions within the Upper Klamath ERU were dominated by the progression of young to older forests, and the development of more complex structures (for example, single-layer to multi-layer stands). Species composition also changed substantially. The increase of late-seral montane forest communities was dominated by the conversion of the lower montane forest community types (table 3.164, Jones 1996). More specifically, the increase of the late-seral montane multi-layer forest community was derived largely from late-seral lower montane single-layer forest and mid-seral lower montane forest communities, and to a lesser degree, by the development of the mid-seral montane forest community. Similarly, the increase of the late-seral montane single-layer forest community was dominated by the development of mid-seral lower montane forest and late-seral lower montane single-layer forest communities. More complex structures also developed in lower montane forest communities.

The rangeland communities (upland herbland and upland shrubland) transitioned predominantly to agricultural, upland woodland, or lower montane forest communities. Of the 93 percent decline of the upland herbland community, 34 percent was attributable to transition to lower montane forest communities, 32 percent to transition to agricultural communities, and 19 percent to transition to upland woodland communities.

Table 3.163—Changes of broad-scale terrestrial communities between historical and current periods within the Upper Klamath Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	6.83	NA[5]	6.83*	5*
Alpine	0.04	0.04	0.04	0.04	0	0	3
Early-seral Lower Montane Forest	1.58	1.58	11.84	0.01	-99.60*	-1.57*	1*
Early-seral Montane Forest	5.53	5.53	10.02	5.00	-9.63	-0.53	1*
Early-seral Subalpine Forest	0.30	0.30	0.47	0.08	-75.01*	-0.23	1*
Exotic Herbland	0	0	0	0.34	NA	0.34	5
Late-seral Lower Montane Multi-layer Forest	8.18	2.88	8.18	15.22	85.97*	7.04*	5*
Late-seral Lower Montane Single-layer Forest	22.30	16.47	23.11	19.23	-13.77	-3.07	3
Late-seral Montane Multi-layer Forest	0.98	0.98	4.48	16.82	1610.28*	15.84*	5*
Late-seral Montane Single-layer Forest	0.03	0.03	1.04	6.92	27125.98*	6.89*	5*
Late-seral Subalpine Multi-layer Forest	0.74	0.74	1.03	1.38	85.46*	0.63	5*
Late-seral Subalpine Single-layer Forest	0.60	0.12	0.60	0.66	10.63	0.06	5
Mid-seral Lower Montane Forest	18.14	8.65	18.14	6.85	-62.24*	-11.29*	1*
Mid-seral Montane Forest	6.48	6.48	8.39	1.66	-74.36*	-4.82*	1*
Mid-seral Subalpine Forest	1.52	0.88	1.52	0	-100.00*	-1.52*	1*
Rock/Barren	0.12	0.12	0.12	0.12	0	0	3
Upland Herbland	14.59	11.40	14.59	0.98	-93.26*	-13.61*	1*
Upland Shrubland	8.64	6.13	8.64	2.17	-74.89*	-6.47*	1*
Upland Woodland	3.67	3.67	7.13	9.42	156.48*	5.75*	5*
Urban	0	0	0	0.21	NA	0.21	5
Water	5.12	5.12	5.12	5.12	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

*Ecologically significant changes.

Table 3.164—Dominant transitions[1] of terrestrial communities within the Upper Klamath Ecological Reporting Unit (ERU).

Terrestrial Community		
Historical Period[2]	**Current Period**	**Proportion of ERU Area (%)[3]**
Early-seral Montane Forest	Late-seral Montane Multi-layer Forest	2.3
Late-seral Lower Montane Multi-layer Forest	Late-seral Lower Montane Single-layer Forest	2.7
Late-seral Lower Montane Multi-layer Forest	Late-seral Montane Multi-layer Forest	1.3
Late-seral Lower Montane Single-layer Forest	Late-seral Lower Montane Multi-layer Forest	6.1
Late-seral Lower Montane Single-layer Forest	Late-seral Montane Multi-layer Forest	4.3
Late-seral Lower Montane Single-layer Forest	Late-seral Montane Single-layer Forest	2.3
Late-seral Lower Montane Single-layer Forest	Mid-seral Lower Montane Forest	2.2
Mid-seral Lower Montane Forest	Early-seral Montane Forest	1.7
Mid-seral Lower Montane Forest	Late-seral Lower Montane Multi-layer Forest	3.9
Mid-seral Lower Montane Forest	Late-seral Lower Montane Single-layer Forest	4.7
Mid-seral Lower Montane Forest	Late-seral Montane Multi-layer Forest	3.2
Mid-seral Lower Montane Forest	Late-seral Montane Single-layer Forest	3.0
Mid-seral Montane Forest	Late-seral Montane Multi-layer Forest	3.5
Upland Herbland	Agricultural	4.7
Upland Herbland	Late-seral Lower Montane Multi-layer Forest	2.4
Upland Herbland	Late-seral Lower Montane Single-layer Forest	2.6
Upland Herbland	Mid-seral Lower Montane Forest	1.3
Upland Herbland	Upland Woodland	2.8
Upland Shrubland	Agricultural	1.3
Upland Shrubland	Late-seral Lower Montane Single-layer Forest	1.1
Upland Shrubland	Upland Woodland	4.0

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of ERU Area (percent) = proportion of landscape affected; the area of the ERU in which a terrestrial community changed into another terrestrial community.

Upper Snake ERU

The richness of terrestrial communities declined from 16 to 14 communities between historical and current periods (table 3.165). Although three anthropogenic communities (agricultural, exotic herbland, and urban) developed during this time interval, five endemic community types (early-seral lower montane forest, early-seral subalpine forest, late-seral montane multi-layer forest, late-seral lower montane multi-layer forest, and late-seral subalpine multi-layer forest) were eliminated. Ecologically significant class and ERU trends occurred between historical and current periods for 10 and 4 communities, respectively (table 3.165). Although five community types were not detected in the current period, their loss represented only a minor compositional change in the Upper Snake ERU. Changes of two communities dominated the compositional alteration of the ERU. Approximately 33 percent of the landscape transitioned to the agricultural community, whereas the ERU extent of the upland shrubland community declined 46 percent.

Table 3.165—Changes of broad-scale terrestrial communities between historical and current periods within the Upper Snake Ecological Reporting Unit (ERU).

Cover Type	Historical Area[1]	Historical Minimum	Historical Maximum	Current Area	Class Change[2]	ERU Change[3]	Departure Class[4]
	Percent						
Agricultural	0	0	0	32.52	NA[5]	32.52*	5*
Alpine	0.02	0.02	0.02	0.02	0	0	3
Early-seral Lower Montane Forest	0.03	0.03	0.11	0	-100.00*	-0.03	1*
Early-seral Montane Forest	0.61	0.57	0.99	0.28	-54.59*	-0.33	1*
Early-seral Subalpine Forest	0.01	0	0.01	0	-100.00*	-0.01	1*
Exotic Herbland	0	0	0	10.04	NA	10.04*	5*
Late-seral Lower Montane Multi-layer Forest	0.02	0.01	0.03	0	-100.00*	-0.02	1*
Late-seral Lower Montane Single-layer Forest	0.04	0.04	0.19	0.08	73.08	0.03	3
Late-seral Montane Multi-layer Forest	0.11	0.11	0.45	0	-100.00*	-0.11	1*
Late-seral Montane Single-layer Forest	0.10	0.03	0.10	0.04	-54.48	-0.05	3
Late-seral Subalpine Multi-layer Forest	0.04	0.04	0.08	0	-100.00*	-0.04	1*
Mid-seral Lower Montane Forest	0.11	0.09	0.13	0.20	81.66*	0.09	5*
Mid-seral Montane Forest	0.29	0.29	0.72	0.62	117.51	0.34	3
Mid-seral Subalpine Forest	0.16	0.04	0.16	0.01	-96.29*	-0.15	1*
Upland Herbland	8.95	8.95	34.41	8.80	-1.64	-0.15	1
Upland Shrubland	85.57	57.09	85.57	39.35	-54.01*	-46.22*	1*
Upland Woodland	0.93	0.93	1.28	2.49	166.89*	1.56*	5*
Urban	0	0	0	0.19	NA	0.19	5
Water	0.04	0.04	0.04	0.04	0	0	3

[1]Historical Area = circa 1850 to 1900 (initiated model simulation); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current Area = circa 1991.

[2]Class change = percent change relative to the terrestrial community.

[3]ERU change = percent change of the ERU attributable to the terrestrial community change.

[4]Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges. Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[5]NA = Not Applicable; the terrestrial community did not exist during the historical period.

*Ecologically significant changes.

Table 3.166—Dominant transitions[1] of terrestrial communities within the Upper Snake Ecological Reporting Unit.

Terrestrial Community		
Historical Period[2]	Current Period	Proportion of ERU Area (%)[3]
Upland Herbland	Agricultural	4.5
Upland Shrubland	Agricultural	31.8
Upland Shrubland	Exotic Herbland	7.3
Upland Shrubland	Upland Herbland	5.9
Upland Shrubland	Upland Woodland	1.6

[1]Dominant transitions affected at least 1 percent of the landscape.

[2]Historical Period = circa 1850 to 1900; Current Period = circa 1991.

[3]Proportion of ERU Area (percent) = proportion of landscape affected; the area of the ERU in which a terrestrial community changed into another terrestrial community.

Of the 19 terrestrial communities that were detected within the Upper Snake ERU, 5 (alpine, late-seral montane single-layer forest, late-seral lower montane single-layer forest, mid-seral montane forest, and water) occurred within their median historical range during the current period (table 3.165). Three of these communities had substantial class trends: a 55 percent decline for late-seral montane single-layer forest, a 73 percent increase for late-seral lower montane single-layer forest, and a 118 percent increase for mid-seral montane forest.

Terrestrial community transitions within the Upper Snake ERU were dominated by the 46 percent decline of the upland shrubland community, and the conversion of a large proportion (33%) of the ERU to agriculture (table 3.166; Jones 1996). In addition to agricultural conversion, the upland shrubland community was also extensively invaded by exotics.

Terrestrial communities discussion

As expected, the changes of broad-scale terrestrial community types did not occur uniformly throughout the Basin. Because of its geographic extent and variation in geologic history and climatic regimes, the diversity of biophysical environments within the Basin is inherently complex (see the Biophysical, Chapter 2 of this document for further details). Consequently, so too are the variations of disturbance regimes (both natural and human-influenced)(Long and others 1996), and subsequent composition of potential vegetation types (Hann and others 1997). However, the vegetation changes that we observed within the Upper Klamath ERU were very dissimilar to those observed for the Basin. Among the 13 ERUs, the greatest variation in trends of a single community type occurred with the mid-seral subalpine forest community. The current area of this community occurred well below its median historical range within four ERUs, well above its median historical range in eight ERUs, and occurred within its median historical range in one ERU.

Other terrestrial communities having a relatively wide variation of departure indices among the ERUs included the early-seral montane forest, early-seral subalpine forest, late-seral multi-layer forest, late-seral montane single-layer forest, and upland woodland community types. Conversely, there was virtually no variation of departure indices of nine terrestrial communities (agricultural, alpine, early-seral lower montane forest, exotic herbland, mid-seral lower montane forest, rock/barren, upland herbland, urban, and water) among the 13 ERUs and the Basin.

In Basin rangeland communities, the substantial loss of the upland herbland and upland shrubland community types, attributable to the transition to agriculture, was detected in all ERUs except the Lower Clark Fork. A substantial extent of upland shrubland and upland herbland also transitioned to upland woodland. This was typically attributable to fire suppression, but was often accelerated by excessive livestock grazing pressure. This transition was most prevalent in the Blue Mountains, Columbia Plateau, Northern Glaciated Mountains, Northern Great Basin, Owyhee Uplands, Upper Klamath, and Upper Snake ERUs, specifically in areas characterized by a mixture of forest and rangeland communities with extensive ecotonal areas, or the presence of a historical woodland component.

Over the last 100 to 150 years, disturbances within forest communities favored the development of mid-seral forest communities at the expense of both late-seral forest, and to a lesser degree, early-seral forest communities. A net increase of mid-seral forest communities, and net declines of early- and late-seral forest communities were detected Basin-wide, as well as within the Lower Clark Fork, Upper Clark Fork, and Northern Glaciated Mountains ERUs. These changes were most likely a consequence of both fire suppression and timber harvest activities throughout the Basin. Timber harvest activities reduced the areal extent of late-seral forest communities, while fire suppression activities limited the recruitment of early-seral forest communities. Apparently, harvest activities that resulted in early-seral forest communities did not keep pace with the successional rates of change in younger stands. Consequently, the middle-age forests dominated the distribution of seral communities within current period forested environments more than they had historically.

Over all, the relative magnitude of change we detected in the lower montane forest communities was greater than that observed within the subalpine forest communities. Natural disturbance frequencies within the lower montane communities were typically greater than those of subalpine environments (Long and others 1996). Successional rates of change occurred more slowly in subalpine environments. Consequently, the effects of altering disturbance regimes accrued much faster in lower montane environments. In addition, human settlement patterns tended to concentrate in lower-elevation, more hospitable environments. Thus, the direct and indirect effects of human occupancy also tended to be oriented around lower montane communities. In the Basin, agricultural development, livestock grazing, fire suppression, and timber harvest have all had significantly greater impacts over relatively longer time periods on lower montane forests than on subalpine forests.

We were able to make some comparisons at the ERU level of our broad-scale vegetation trends to the mid-scale vegetation trends reported by Hessburg and others (1996a). Classifications used in the mid-scale assessment that approximated some of our terrestrial communities or our further aggregation of terrestrial communities, included three physiognomic types (woodland, shrubland, and herbland), the ponderosa pine cover type, and three forest structural classes (stand initiation, old multi-story, and old single-story). These mid-scale classifications were comparable to (1) our upland woodland, upland shrubland, and upland herbland terrestrial communities, and (2) our aggregations of four lower montane forest communities, three early-seral forest communities, three late-seral multi-layer forest communities, and three late-seral single-layer forest communities. As with our analyses of cover types, there were some discrepancies between the two data sets. Again, considering that the two analyses were conducted at different resolutions and that trends were assessed across different time periods, the conclusions were remarkably similar.

The most frequent discrepancies involved vegetation communities for which the broad-scale analysis generated significant trends, whereas the mid-scale assessment did not. These discrepancies commonly occurred with Hessburg and others' (1996a) forest structural types within the Lower Clark Fork, Upper Clark Fork and Northern Glaciated

Mountains ERUs, and the woodland and shrubland physiognomic types within the Northern Cascades, Northern Glaciated Mountains, Upper Clark Fork, and Upper Klamath ERUs. With respect to forest structural types, we likely detected trends because our assessment period included the occurrence of the expansive wildfires that occurred throughout the Lower Clark Fork, Upper Clark Fork, and Northern Glaciated Mountains ERUs during the early-1900s—prior to the assessment period used in the mid-scale assessment.

The apparent discrepancies with the woodland and shrubland physiognomic types might have been attributable to differences in the resolution and/or the time periods for which trends were assessed. Conflicting trends (that is, trends in which the broad-scale and mid-scale assessments detected opposite tendencies) most commonly involved the upland herbland terrestrial community and herbland physiognomic types. We detected significant declines of the upland herbland community within 12 of 13 ERUs, whereas Hessburg and others (1996a) detected positive trends of the herbland physiognomic type within five ERUs, and no significant change of this type within four ERUs.

We speculate that these differences in trend should not have been unexpected, however, because (1) the mid-scale herbland physiognomic types included exotics and irrigated pasture cover types, whereas the broad-scale upland herbland community excluded these cover types, and (2) early literature pertinent to the Basin (for example, Griffiths 1902) indicated that the herbland component was already in low vigor by the turn of the century, and attributed the condition to excessive livestock grazing pressure. Our speculation was that appreciable upland herbland had transitioned to other communities prior to the mid-scale analysis assessment period. Therefore, the baseline status of the herbland community for the mid-scale analysis was different than for the broad-scale analysis. Conflicting trends also occurred for the old multistory structural class and the late-seral multi-layer forest communities in the Blue Mountains ERU; the stand initiation structural class and early-seral forest communities in the Central Idaho Mountains ERU; the woodland physiognomic type and the upland woodland community in the Snake Headwaters ERU; and the ponderosa pine cover type and lower montane forest communities in the Southern Cascades and Upper Clark Fork ERUs. We were unable to establish rational hypotheses regarding the factors responsible for these conflicting trends.

We commonly detected substantial trends of terrestrial communities between historical and current periods that apparently fell within the expected range of historical variation. Thus, as we observed in our analysis of cover types, major compositional changes of at least some broad-scale communities were apparently the norm, rather than the exception. Only by grounding observed changes to some historical range of conditions, could the ecological consequences of change be fully understood.

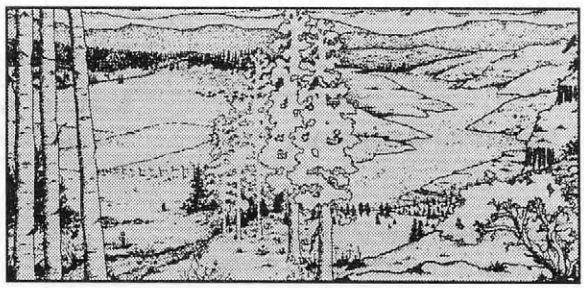
For our analysis of broad-scale terrestrial communities, we chose to summarize broad-scale community composition and trends at the ERU and Basin levels. As stated in the previous "Regional Cover Type Trends" subsection, we do not imply that trends we observed would occur at other scales. In fact, we detected spatial variation of vegetation changes at the ERU level, which were not consistent with those observed for the Basin as a whole. Our transition analyses indicate that trends for a specific terrestrial community could differ appreciably within and amongst ERUs. This was because the pixels of a specific terrestrial community could change in different ways from the historical to the current period (that is, the pixels could stay the same or convert into another terrestrial community). Consequently, the trends observed at the ERU level should not be interpreted as meaning a consistent trend occurred everywhere throughout the ERU where a particular community exists. Given this level of variability for specific terrestrial communities at the ERU level, we expect that trends for specific terrestrial communities at a finer scale would likewise be variable and might be inconsistent with ERU trends.

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REGIONAL AND ECOLOGICAL REPORTING UNIT BROAD-SCALE LANDSCAPE TRENDS



Regional Broad-Scale Landscape Departure

Eight of 12 terrestrial community groups (early-seral lower montane forest, late-seral lower montane forest, early-seral montane forest, late-seral montane forest, mid-seral subalpine forest, late-seral subalpine forest, upland herbland, and upland shrubland) were below their historical range (that is, Departure Class 1) in a high percentage of the subbasins in which they existed. The remaining four terrestrial community groups (mid-seral lower montane forest, mid-seral montane forest, early-seral subalpine forest, and upland woodland) were above their historical range (that is, Departure Class 5) in a high percentage of the subbasins in which they existed (tables 3.7, 3.9, and 3.167). The average frequency of subbasin membership in Class 1 and Class 5 departures was 48 and 28 percent, respectively. During the current period, community groups existed within their 75 percent median historical range (that is, Departure Class 3) in few subbasins. The average frequency of subbasins containing community groups within their 75 percent median historical range was only 14 percent. The greatest deviation from historical ranges occurred in the early- and late-seral lower montane forests — nearly 80 percent of the subbasins contained areas of these community groups at levels below their historical ranges (that is, Class 1 departures).

Early-seral Lower Montane Forest

Nearly all the subbasins (94%) that contained the early-seral lower montane forest terrestrial community group showed extents that were below their median 75 percent historical range (table 3.167, map 3.47). However, the Northern Cascades ERU was the exception in that it was largely dominated by subbasins in which the areal extent of the early-seral lower montane forest community group was within or above its median historical range. Five isolated subbasins (or a frequency of 4%) contained this community group within its 75 percent median historical range. These subbasins were in the Northern Cascades, Northern Glaciated Mountains, Columbia Plateau, and Central Idaho Mountains ERUs (table 3.168; map 3.47).

Within the Basin, five patches of eight subbasins (7 % of the subbasins) had the early-seral lower montane forest community group within or above its median historical range (table 3.169; map 3.47). Two of these patches existed as isolated individual subbasins; one each in the Blue Mountains and Central Idaho Mountains ERUs. The other three patches were clustered in the northwest portion of the Basin, two occurred in the Northern Cascades ERU, and one on the western edge of the Northern Glaciated Mountains ERU. The largest patch (three subbasins) occurred within the Northern Cascades ERU. Consequently, species whose fitness is closely correlated with the areal extent of the early-seral lower montane forest community group are likely doing well in the northwestern portion of the Basin relative to other areas within the Basin.

Table 3.167—Summary of subbasin frequency distribution by current terrestrial community group departures.

Terrestrial Community Group	Number of Subbasins[1]	Departure Class[2]				
		1	2	3	4	5
		Percent				
Early-seral Lower Montane Forest	117	79	15	4	1	2
Late-seral Lower Montane Forest	125	78	8	7	0	6
Mid-seral Lower Montane Forest	125	23	5	10	3	58
Early-seral Montane Forest	136	44	7	18	4	28
Late-seral Montane Forest	127	59	4	9	1	27
Mid-seral Montane Forest	133	19	3	19	2	57
Early-seral Subalpine Forest	75	21	3	20	0	56
Late-seral Subalpine Forest	91	63	9	12	0	16
Mid-seral Subalpine Forest	90	38	9	20	3	30
Upland Herbland	145	66	15	12	0	7
Upland Shrubland	129	47	14	22	8	9
Upland Woodland	104	34	7	13	6	40
Average[3]	NA[4]	47.6	8.3	13.8	2.3	28.0

[1]Subbasins (4th field HUCs) having at least 1 percent composition of the terrestrial community group during historical or current periods.

[2]*Departure class = index of current areal extent of broad-scale cover types with respect to their historical ranges.* Classes: (1) is < historical minimum; (2) is ≥ historical minimum but < median 75% historical range; (3) is within median 75% historical range; (4) is >median 75% historical range and ≤ historical maximum; (5) is > historical maximum.

[3]Average subbasin frequency distribution across 12 terrestrial community group departure classes.

[4]Not Applicable.

Mid-seral Lower Montane Forest

The Basin was dominated by subbasins (61%) in which the mid-seral lower montane community group occurred above its 75 percent median historical range (table 3.167, map 3.48). Subbasins having Class 5 departures were located in Washington, Oregon, Montana, and Idaho (for example: the Northern Cascades, Northern Glaciated Mountains, Columbia Plateau, Blue Mountains, and portions of the Southern Cascades, Northern Great Basin, and Upper Klamath ERUs in Oregon and Washington; the Upper Clark Fork ERU and several adjacent subbasins within the Lower Clark Fork and Northern Glaciated Mountains ERUs in Montana; and the Central Idaho Mountains ERU in Idaho). However, the Upper Klamath ERU, and the Idaho and northwestern Montana portions of the Northern Glaciated Mountains and Lower Clark Fork ERUs were dominated by subbasins classified as Class 1 departures. Nine patches of 13 subbasins (10% of the subbasins) contained the mid-seral lower montane forest community group within its median historical range (table 3.168). Most of these patches were clustered in the western half of the Central Idaho Mountains ERU, and a few adjacent subbasins of the Blue Mountains and Owyhee Uplands ERUs. The patches contained one to three subbasins (median = 1.0 subbasin) each.

Map 3.47—Broad-scale habitat departure of the early-seral lower montane forest terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

Map 3.48—Broad-scale habitat departure of the mid-seral lower montane forest terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

Table 3.168—Fragmentation indices of terrestrial community groups occurring within subbasins at a level within their median historical ranges; summation of Departure Class 3.

	Frequency of Subbasins[1] (%)	Number of Patches	Median Patch Size[2]	Maximum Patch Size
Early-seral Lower Montane Forest	4	5	1.0	1
Late-seral Lower Montane Forest	7	3	2.0	6
Mid-seral Lower Montane Forest	10	9	1.0	3
Early-seral Montane Forest	18	17	1.0	5
Late-seral Montane Forest	9	7	2.0	3
Mid-seral Montane Forest	19	14	1.0	7
Early-seral Subalpine Forest	20	6	1.5	5
Late-seral Subalpine Forest	12	4	1.5	7
Mid-seral Subalpine Forest	20	10	1.5	5
Upland Herbland	12	13	1.0	4
Upland Shrubland	22	9	2.0	11
Upland Woodland	13	9	1.0	4

[1]Frequency of Subbasins = the percentage of those subbasins having at least a 1 percent historical or current period composition of a terrestrial community group and in which that community group occurred within its median historical range.
[2]Patch Size = count of subbasins within a patch.

There were 2 patches of 77 subbasins (71% of the subbasins) in which the mid-seral lower montane forest community occurred within or above its median historical range (table 3.169; map 3.48). One patch was relatively small (2 subbasins) and isolated in the southern portion of the Upper Klamath ERU. The second patch was large (75 subbasins), and although it contained some gaps, the subbasins were well distributed throughout the rest of the Basin. Consequently, species whose fitness is closely correlated with the areal extent of the mid-seral lower montane forest community group are likely doing well across most of the Basin. However, as stated previously, there could be areas within the Basin where the persistence of these species might be in serious jeopardy (for example, the northern Upper Klamath ERU, the western portion of the Northern Great Basin ERU, much of the eastern portion of the Northern Glaciated Mountains ERU, the Lower Clark Fork ERU, and the western portion of the Central Idaho Mountains ERU).

Late-seral Lower Montane Forest

The Basin was dominated by subbasins (78%) in which the late-seral lower montane forest community group existed below its median historical range (table 3.167, map 3.49). Notable exceptions included the Upper Klamath ERU and adjacent portions of the Northern Great Basin ERU. The Upper Klamath ERU and two adjacent subbasins within the Northern Great Basin ERU formed a relatively large contiguous patch of subbasins that contained this community group above its historical range. Three isolated and relatively small (patch size range = 1 to 6 subbasins, median patch size = 2 subbasins; table 3.168) patches of subbasins that had this community group within their median historical range occurred in central Oregon, central Idaho, and southeastern Idaho.

The persistence of those species that rely heavily upon the areal extent of the late-seral lower montane forest community group are likely at risk across most of the Basin. There were only 3

relatively isolated patches of 17 subbasins in which this community group existed within or above its median historical range, and consequently, where these species might be doing relatively well (table 3.169; map 3.49). The largest of these patches (14 subbasins) was located within the Upper Klamath ERU, southern portions of the Southern Cascades and Columbia Plateau ERUs, and southwestern portions of the Northern Great Basin ERU. The two other patches were relatively small (one to two subbasins), and were isolated within the center of the Central Idaho Mountains ERU, and the Upper Snake and Snake Headwaters ERUs.

Early-seral Montane Forest

Although the Basin was dominated by subbasins (51%) in which the early-seral montane forest community group occurred below its median 75 percent historical range (table 3.167, map 3.50), large portions of the Northern Cascades, Southern Cascades, Blue Mountains, and Central Idaho Mountains ERUs were dominated by subbasins in which this community group occurred within or above its median historical range. Seventeen relatively small and isolated patches of 23 subbasins that contained this community group within its median historical range were distributed throughout the Basin (table 3.168; range of patch size = 1 to 5 subbasins; median patch size = 1.0 subbasin).

There were 12 patches of 69 subbasins widely distributed within most of the Basin in which the early-seral montane forest community group existed within or above its median historical range (table 3.169; map 3.50). Patch size of these areas ranged from 1 to 34 subbasins (median = 3.5 subbasins). The most extensive, contiguous patch spanned a large proportion of the Blue Mountains and Central Idaho Mountains ERUs. Relatively extensive patches (that is, at least four contiguous subbasins) also existed within the Northern Cascades, Southern Cascades, Northern Glaciated Mountains, Lower Clark Fork, and Snake Headwaters ERUs.

Mid-seral Montane Forest

Fifty-nine percent of the subbasins that had at least 1 percent of their area in mid-seral montane forest community group, contained that community above its 75 percent median historical range (table 3.167, map 3.51). However, large portions of the Southern Cascades, Upper Klamath, and Central Idaho Mountains ERUs were dominated by subbasins in which this community group existed below its median historical range. Twenty-five (19%) subbasins had this community group within its median historical range, and were distributed across the Basin in 14 patches ranging in size from 1 to 7 subbasins (table 3.168; median patch size = 1.0 subbasin). The largest of these patches occurred in the Columbia Plateau, Snake Headwaters, and Upper Snake ERUs.

Most (78%) of the subbasins that had substantial areas of the mid-seral montane forest community group contained areas of that community group at levels within or exceeding the median historical range (table 3.169; map 3.51). Six patches that comprised 103 subbasins, ranging in size from 1 to 95 subbasins (median = 1.5 subbasins), were widely distributed throughout all but the southwest portion of the Basin. With the exception of the Upper Klamath ERU, the most extensive patches occurred within portions of all ERUs. Species whose fitness is strongly correlated with the areal extent of the mid-seral montane forest community group should be doing well in all areas of the Basin, except within large areas of the Southern Cascades, Upper Klamath, Northern Great Basin, and Central Idaho Mountains ERUs.

Late-seral Montane Forest

The Basin was dominated by subbasins (63%) in which the late-seral montane forest community group occurred below its 75 percent median historical range (table 3.167, map 3.52). However, most of the subbasins in Oregon and many of those within the Central Idaho Mountains ERU contained areas of the late-seral montane forest

Table 3.169—Fragmentation indices of terrestrial community groups occurring within subbasins at a level within or above their median historical ranges; summation of Departure Classes 3, 4, and 5.

	Frequency of Subbasins[1] (%)	Number of Patches	Median Patch Size[2]	Maximum Patch Size
Early-seral Lower Montane Forest	7	5	1.0	3
Late-seral Lower Montane Forest	13	3	2.0	14
Mid-seral Lower Montane Forest	71	2	38.5	75
Early-seral Montane Forest	50	12	3.5	34
Late-seral Montane Forest	37	3	3.0	43
Mid-seral Montane Forest	78	6	1.5	95
Early-seral Subalpine Forest	76	4	6.5	43
Late-seral Subalpine Forest	28	2	13.5	21
Mid-seral Subalpine Forest	53	5	3.0	39
Upland Herbland	19	11	1.0	11
Upland Shrubland	39	8	1.0	39
Upland Woodland	59	4	2.5	58

[1]Frequency of Subbasins = the percentage of those subbasins having at least a 1 percent historical or current composition of a terrestrial community group and in which that community group occurs within or above its median historical range.
[2]Patch Size = count of subbasins within a patch.

community group that exceeded their median historical ranges. Seven patches of subbasins (9%) that contained the late-seral montane forest community group within its median historical range were widely distributed across the Basin (table 3.168). The median patch size of these areas was two subbasins (range = 1 to 3 subbasins).

The distribution of subbasins in which the late-seral montane forest community group existed within or above its median historical range overlapped negligibly with that of the mid-seral montane forest community group (maps 3.51 and 3.52). There were 3 patches of 47 subbasins that contained areas of this community group within or above its median historical range (table 3.169). The largest patch (43 subbasins) spanned large areas of the Southern Cascades, Columbia Plateau, Upper Klamath, Blue Mountains, and Central Idaho Mountains ERUs (map 3.52). The other two patches were isolated within the Northern Cascades (three subbasins) and Snake Headwaters (one subbasin) ERUs. Consequently, we would expect productive populations of those species whose fitness is strongly correlated to the abundance of the late-seral montane forest community group to exist across most of the Oregon and central Idaho portions of the Basin. Conversely, we would anticipate a high risk of extirpation of these species across much of eastern Washington, northern and southeastern Idaho, and those portions of Montana and Wyoming within the Basin; these areas had poor late-seral montane forest community group representation.

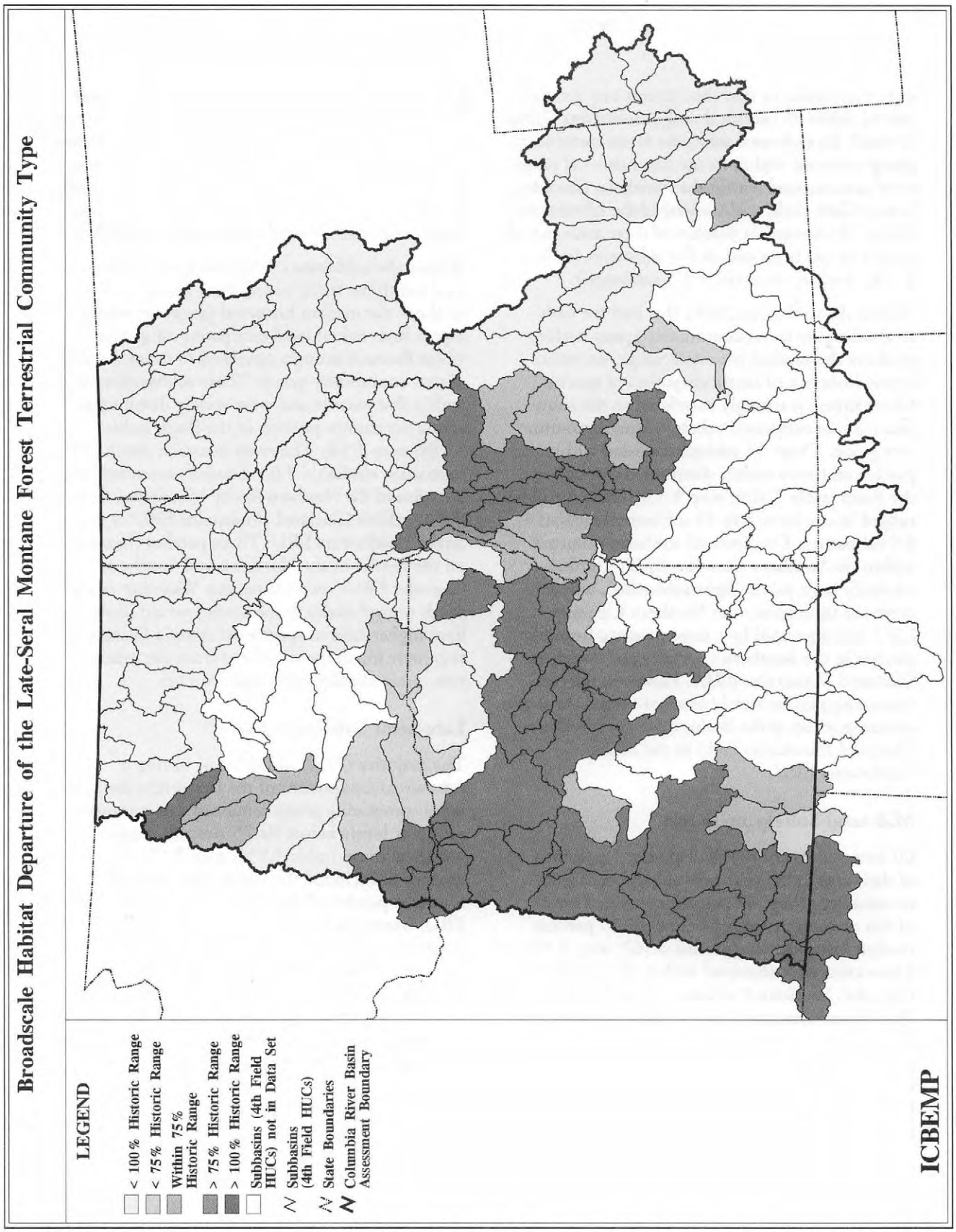
Early-seral Subalpine Forest

Most (56%) subbasins that had at least 1 percent of the area in the early-seral subalpine forest community group contained areas of this community group exceeding the historical ranges (table 3.167, map 3.53). However, a large portion of the Northern Glaciated Mountains and Upper Clark Fork ERUs

Map 3.49—Broad-scale habitat departure of the late-seral lower montane forest terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

Map 3.50—Broad-scale habitat departure of the early-seral montane forest terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

Map 3.51—Broad-scale habitat departure of the mid-seral montane forest terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.



Map 3.52—Broad-scale habitat departure of the late-seral montane forest terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

were exceptions, in that this community group existed below its historical range. Subbasins (20%) in which the early-seral subalpine forest community group occurred within its median historical range were concentrated within the Northern Cascades, Lower Clark Fork, and Central Idaho Mountains ERUs. There were six patches of these areas, which ranged in size from one to five subbasins (table 3.168; median patch size = 1.5 subbasins).

Within the subbasins (76%) that had the early-seral subalpine forest community group within or above the median historical range, we would expect little risk of local extirpation of species whose fitness is strongly correlated to the abundance of the early-seral subalpine forest community group. These 57 subbasins existed within 4 patches and were widely distributed throughout the Basin (table 3.169; map 3.53). These 4 patches ranged in size from 1 to 43 subbasins (median = 6.5 subbasins). One isolated subbasin occurred within the Southern Cascades ERU. Another relatively large patch (eight subbasins), which extended throughout the Northern Cascades ERU, was separated by a large distance from like patches in the Southern Cascades and Northern Glaciated Mountains ERUs. However, the two remaining patches nearly interconnected the entire eastern portion of the Basin, from the Northern Glaciated Mountains ERU to the Snake Headwaters ERU.

Mid-seral Subalpine Forest

Of those subbasins that had at least 1 percent of their area in the mid-seral subalpine forest community group, 47 percent contained areas of this community group below the 75 percent median historical range (table 3.167; map 3.54). These areas were clustered within the Northern Cascades, Southern Cascades, Upper Klamath, Blue Mountains, and Central Idaho Mountains ERUs. However, several relatively extensive areas of the Northern Glaciated Mountains, Lower Clark Fork, Upper Clark Fork, and Snake Headwaters ERUs were dominated by subbasins in which the mid-seral subalpine forest community group existed within or above its historical range. Ten patches of 18 subbasins existed that contained this community group within its median historical range (table 3.168). These patches ranged in size from one to five subbasins (median = 1.5 subbasins), the most extensive of which straddled the Northern Glaciated Mountains and Lower Clark Fork ERUs.

Within the subbasins (53%) that had the mid-seral subalpine forest community group within or above the median historical range, we would expect little risk of local extirpation of species whose fitness is strongly correlated to the availability of that community group. These subbasins existed within five patches and were widely distributed across the eastern portion of the Basin (table 3.169; map 3.54). The most extensive patch (39 subbasins; median = 3.0 subbasins) extended down the spine of the Northern Rocky Mountains, from the Northern Glaciated Mountains ERU to the Snake Headwaters ERU. Three patches (located on the border of the Northern and Southern Cascades ERUs, in northeastern Washington and south central Idaho, respectively) would likely have higher risks of species extirpation because they were much more isolated from the other two (more closely-connected) patches.

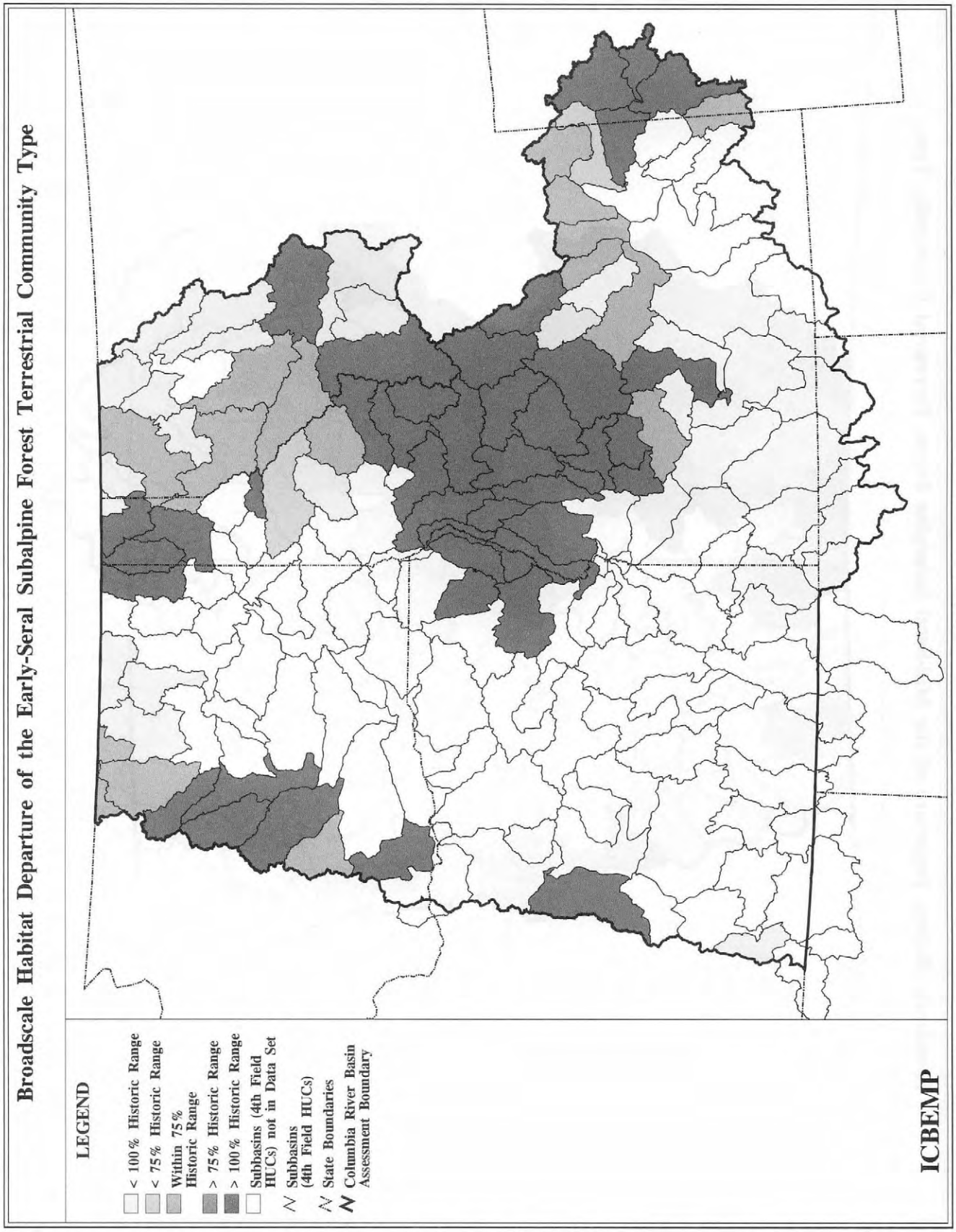
Late-seral Subalpine Forest

The majority (72%) of subbasins having a substantial component of the late-seral subalpine forest community group contained that community group at levels below its 75 percent median historical range (table 3.154; map 3.55). Notable exceptions included the Upper Klamath ERU and southern portion of the Central Idaho Mountains ERU, where the late-seral subalpine forest community group in most subbasins was within or exceeded its median historical range. Only 11 subbasins (12%) contained this community group at a level within its median historical range, and all but one of these were located within or immediately adjacent to the Central Idaho Mountains ERU.

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Map 3.53—Broad-scale habitat departure of the early-seral subalpine forest terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

Map 3.54—Broad-scale habitat departure of the mid-seral subalpine forest terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

The most extensive, contiguous patch of subbasins that contained the late-seral subalpine forest community group within its median historical range was composed of seven subbasins (table 3.168; range = 1 to 7 subbasins; median patch size = 1.5 subbasins).

Species whose fitness is strongly correlated to the abundance of the late-seral subalpine forest group would have a high risk of local extirpation across most (72%) of the subbasins in which this community is a substantial component (table 3.169). However, two relatively large patches (6 and 21 subbasins, respectively) existed in which this community group occurred within or exceeded its median historical range (map 3.55). Although relatively extensive, these two patches were widely separated. The majority of one patch occurred in the Upper Klamath ERU, whereas the majority of the second patch occurred in the Central Idaho Mountains ERU.

Upland Herbland

The upland herbland community group occurred at a level below its 75 percent median historical range (table 3.167; map 3.56) in approximately 81 percent of the subbasins that had it as a substantial component. With the exception of a few subbasins, subbasins within the Oregon and Washington portions of the Basin had areas of the upland herbland community group below the median historical range. Although the Idaho and Montana areas were also dominated by subbasins in which the upland herbland community group existed below its median historical range, there were more extensive areas within the Central Idaho Mountains, Upper Snake, and Snake Headwaters ERUs, where this group existed within or above its median historical range. The 20 subbasins (12%) that had this community group within its median historical range were distributed within numerous (13) patches that were isolated and small in extent (table 3.168; patch size range = 1 to 4 subbasins; median patch size = 1.0 subbasin).

Within the subbasins (81%) that had the upland herbland community group below the median historical range, we would expect high risk of local extirpation for those species dependent on the abundance of the upland herbland community group. However, for the 11 patches of 30 subbasins in which the upland herbland community group existed within or above its historical range, we would expect a lower risk of local extirpation (table 3.169; map 3.56). Eight of the 11 patches were concentrated within the Central Idaho Mountains, Owyhee Uplands, Upper Snake, and Snake Headwaters ERUs. The most extensive patch (11 subbasins) occurred within the Central Idaho Mountains ERU. The Oregon and Washington portions of the Basin contained five small patches, each within a single subbasin that was isolated by expansive distances from the others.

Upland Shrubland

The Basin was dominated by subbasins (61%) in which the upland shrubland community group existed below its 75 percent median historical range (table 3.167, map 3.57). The 31 subbasins in which this community group occurred within its median historical range were distributed across 9 patches that ranged in size from 1 to 11 subbasins (table 3.168; median patch size = 2.0 subbasins). Most of these 31 subbasins were concentrated within the Northern Great Basin and Owyhee Uplands ERUs. Similarly, many of the 52 subbasins in which the upland shrubland community group existed within or above the median historical range were found in the Northern Great Basin and Owyhee Uplands ERUs. Some of these 52 subbasins were also concentrated in the Central Idaho Mountains ERUs. These 52 subbasins existed within 8 patches (table 3.169). The most extensive patch (39 subbasins) was continuous throughout the Northern Great Basin, Owyhee Uplands, and Central Idaho Mountains ERUs. In this extensive area, we would expect a low risk to persistence of species that are dependent on the availability of the upland shrubland community group. The seven remaining patches ranged in size

Map 3.55—Broad-scale habitat departure of the late-seral subalpine forest terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

Map 3.56—Broad-scale habitat departure of the upland herbland terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

Map 3.57—Broad-scale habitat departure of the upland shrubland terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

from one to six subbasins, and were widely distributed across the Northern Cascades, Columbia Plateau, Blue Mountains, Northern Glaciated Mountains, and Upper Clark Fork ERUs. In these seven remaining patches, and also in the subbasins (61%) that had less than 75 percent median historical range extent of the upland shrubland community group, we would expect a greater risk to persistence of the species dependent on upland shrubland availability.

Upland Woodland

Subbasins that had a substantial component of the upland woodland community group were nearly evenly distributed between those which contained this group below its 75 percent median historical range (41%), and those in which this community group occurred above that range (46%; table 3.167; map 3.58). The 14 subbasins (13%) in which the upland woodland community group occurred within its median historical range were widely distributed across the Basin in 9 patches that ranged in size from 1 to 4 subbasins (table 3.168; median patch size = 1.0 subbasin).

Within the subbasins (59%) that had the upland woodland community group within or above the median historical range, we would expect a relatively low risk to persistence of those species dependent upon the availability of the upland woodland community group (table 3.169). Four patches of 63 subbasins in which the upland woodland community group existed within or above its historical range were widely distributed across all but the northern Idaho and Montana portions of the Basin. The most extensive patch (58 subbasins) extended from the western portion of the Northern Glaciated Mountains ERU through the Northern Cascades, Columbia Plateau, Southern Cascades, Blue Mountains, Northern Great Basin, and Owyhee Uplands ERUs. The three remaining patches, which ranged in size from one to four subbasins, were located in the Central Idaho Mountains and Snake Headwaters ERUs.

Terrestrial Community Group Departure Discussion

Of the 12 terrestrial community groups for which we determined departure indices, the early- and late-seral lower montane forest communities departed the most from their historical ranges. Within forested settings, the extents of the montane and subalpine forest communities were more similar to the historical period conditions compared with the lower montane forest communities. The average subbasin frequency within Class 3 departures across early-, mid-, and late-seral structures was approximately 7, 15, and 17 percent for lower montane, montane, and subalpine communities, respectively. No more than 10 percent of the subbasins that comprised substantial components of lower montane forest communities contained those communities within their 75 percent median historical range. However, two community groups in each of the montane and subalpine forest settings approached nearly 20 percent frequency of subbasins falling within their respective median historical ranges (table 3.167).

Since the lower montane forest settings tended to have shorter fire-return intervals, occur on more accessible landforms (for example, level topography), and be closer to human settlements, they typically have been affected by past fire suppression and timber harvest activities to a much higher degree than either montane or subalpine forest settings. Conversely, subalpine forest settings probably more closely approximate their historical conditions because (1) successional change occurs at a slower rate in colder environments, (2) a higher relative proportion of area has been allocated to wilderness and wilderness-like management prescriptions, and (3) subalpine forests have typically been much less accessible to efficient fire suppression and timber harvest activities.

Our departure indices indicated that homogenization of forest structures occurred in the lower montane and montane forest settings. The frequency of subbasins in which early- and late-seral lower montane and montane forest community groups were below their median historical ranges was relatively high (51-94%), as was the

Map 3.58—Broad-scale habitat departure of the upland woodland terrestrial community group. The term "terrestrial community type" used in this map title is actually "terrestrial community group"; terrestrial community types were aggregated into groups for analysis of broadscale habitat departures.

frequency of subbasins in which mid-seral lower montane and montane forest community groups occurred above their historical ranges (approximately 58%). Thus, across most of the Basin in which lower montane and montane forest settings constituted a substantial component of the subbasins, early- and late-seral structures declined, whereas mid-seral structures increased.

The above-mentioned pattern of forest structure homogenization was not apparent within subalpine forest settings. The frequencies of subbasins were dominated by those in which early-seral structures exceeded their historical ranges, whereas mid- and late-seral structures occurred below their respective historical ranges. The observed decline of mid- and late-seral structures within subalpine forest settings was likely attributable to timber harvest activities and the relatively recent occurrence of large wildfires.

The significant declines we observed with the upland herbland community group within most (81%) of the subbasins across the Basin were primarily attributable to agricultural development, and to a lesser degree, the encroachment of upland shrublands, coniferous forests, woodlands, and exotics. However, there were 10 subbasins in which the upland herbland community group exceeded its historical range. Most (80%) of these subbasins were generally wild to semi-wild, minimally to moderately roaded, and had cold to moist forest settings. Nine of 10 of these subbasins were also in areas where we observed the early-seral subalpine forest community group to be above its historical range. Consequently, the observed increase in upland herbland community groups within these subbasins was likely attributable to timber harvest activities and some relatively recent, large-scale wildfires. These activities probably converted some areas into grass/forb communities, which were misclassified as an upland herbland group instead of an early-seral forest group.

Of the subbasins that had a substantial composition of the upland shrubland community group, 61 percent had areas of this community below its median historical range. Conversions to agriculture, and to a lesser degree, the upland herbland, upland woodland, exotic herbland, and lower montane forest community groups, were responsible for these declines. Conversely, 22 subbasins had areas of the upland shrubland community group that exceeded its median historical range. Most (57%) of the subbasins in which we observed substantial increases in upland shrublands were also classified as having moderate to high rangeland integrity (Quigley and others 1996). However, nearly 30 percent of the subbasins in which upland shrublands increased were classified as having low rangeland integrity.

Of the subbasins that had a substantial component of the upland woodland community group, 41 percent had areas of this community group below its median historical range. Most of the upland woodland community group within these subbasins (located predominantly in the Blue Mountains, Central Idaho Mountains, Upper Clark Fork, and Snake Headwaters ERUs) was converted into the upland herbland community group (Jones and Hann 1996c). Conversely, conifer and juniper expansion into shrubland habitats was predominantly responsible for the occurrence of the upland woodland community group above its median historical range within 46 percent of the subbasins. More specifically, the expansion of western juniper was primarily responsible for the substantial increase of the upland woodland community group within many of the subbasins in the Oregon and southwest Idaho portions of the Basin. Expansion of mixed-conifer and limber pine (*Pinus flexilis*) woodlands was largely responsible for all other subbasins in which the upland woodland community group exceeded its historical range.

We recognize that the individual fitness and the population persistence of few species are closely correlated to the areal extent of only one community group. Instead, many species rely upon the availability and spatial juxtaposition of several community groups. Consequently, a multi-community departure approach (that is, similarity index) of indexing vegetation change may be a more powerful tool for predicting the population response of those species having more general habitat requirements.

We are undoubtedly faced with a deficiency of information pertaining to the broad-scale habitat relationships and population responses to habitat change for most species residing in the Basin. Furthermore, there is little likelihood that the information void will ever be satisfactorily filled for the majority of flora and fauna any time soon. We believe that our coarse-filter approach for quantifying broad-scale habitat change and providing some spacial context for those changes, has created a useful data set for predicting the population responses of inadequately investigated species.

Ecological Reporting Unit Broad-Scale Landscape Mosaics

The broad-scale mosaic patterns of physiognomic groups were summarized for the 13 ERUs of the Basin. For a brief review of the specific methods used in the following discussion see the "Physiognomic group patterns" subsection in the "Overview of Methods" section of this chapter, or see table 3.8 for a description of the physiognomic groups.

Blue Mountains ERU

Mosaic patterns changed across 89 percent of the Blue Mountains ERU between the historical and current periods (table 3.170). We detected a net increase of fragmented landscapes within the ERU during this period, which seemed to have been the result of transitions within the forest/woodland physiognomic groups. The shrubland physiognomic groups changed the least. The dominant transition that occurred within the Blue Mountains ERU was the reduction of landscapes characterized by mixed mid-seral and late-seral single-layer forest/woodland physiognomic groups, which changed mostly into landscapes that had either a more uniform pattern and/or which had lost their late-seral single-layer forest/woodland physiognomic group. The next most dominant transitions occurred in rangeland habitats where landscapes characterized by a uniform herbland physiognomic group were converted into landscapes characterized by herbland and agriculture mixed physiognomic groups (that is, herbaceous landscapes were fragmented by agricultural types).

Central Idaho Mountains ERU

Mosaic patterns of physiognomic groups changed throughout most (82%) of the Central Idaho Mountains ERU between the historical and current periods (table 3.170). We detected a marginal net increase (6%) of uniform landscapes throughout the ERU. A single transition dominated the landscapes of this ERU—a decrease in areal extent of mixed mid-seral and early-seral forest/woodland physiognomic groups. The transitions within this group suggested that it became more uniform and older.

Columbia Plateau ERU

Mosaic patterns changed throughout 87 percent of the Columbia Plateau ERU (table 3.170). The ERU appeared to have been substantially fragmented—a trend of more fragmented patterns occurred across 47 percent of the ERU. The ERU was dominated by areal declines of the uniform herbland and uniform low shrub physiognomic groups, which were extensively converted to the agriculture physiognomic group across nearly 94 and 68 percent of their areas, respectively. Conversely, the extent of mixed herbland and agriculture physiognomic groups measurably increased between the historical and current periods.

Lower Clark Fork ERU

Mosaic patterns across virtually the entire Lower Clark Fork ERU changed between historical and current periods (table 3.170). Nearly 85 percent of the ERU had been transformed into more uniform pattern classes. In fact, the uniform pattern class did not occur in the historical period, yet composed nearly 54 percent of the ERU in the current period. Transitions were dominated by changes of two patterns. The most dominant landscape change detected was the decrease in the areal extent of mixed mid-seral and early-seral forest/woodland physiognomic groups, and the subsequent increase in the uniform mid-seral forest/woodland physiognomic group.

Northern Cascades ERU

Mosaic patterns throughout nearly the entire Northern Cascades ERU changed between the historical and current periods (table 3.170). The major trend in pattern was toward more homogeneous landscapes, which increased across 27 percent of the ERU. The increased landscape uniformity was mostly attributable to a reduction of mixed mid-seral and late-seral forest/woodland physiognomic groups, and the subsequent increase of the uniform mid-seral forest/woodland physiognomic group.

Northern Glaciated Mountains ERU

We detected changes of mosaic patterns throughout nearly all of the Northern Glaciated Mountains ERU (table 3.170). Landscapes across 59 percent of the ERU became more homogeneous between the historical and current periods. The most dominant transitions that occurred involved an increase in the uniform mid-seral forest/woodland physiognomic group, at the expense of both early- and late-seral forest/woodland physiognomic groups.

Northern Great Basin ERU

Mosaic patterns remained relatively stable throughout most (69%) of the Northern Great Basin ERU, although we detected a marginal net increase (2%) of more fragmented subwatersheds (table 3.170). Most of the fragmentation was attributable to a reduction of mosaic low shrub and mid shrub physiognomic groups, and the subsequent increase in areal extent of mosaic low shrub and herbland, and mixed low shrub and herbland physiognomic groups.

Owyhee Uplands ERU

Although we detected a net increase of 25 percent in the proportion of more fragmented landscapes in the Owyhee Uplands ERU, the mosaic patterns of most (58%) subwatersheds within the ERU did not change between the historical and current periods (table 3.170). Most of the fragmentation occurred in the uniform low shrub physiognomic group, which decreased by approximately 37 percent (the dominant transition within the ERU). The majority of this decrease was accounted for by increases in mosaic low shrub and herbland, mixed low shrub and herbland, and mixed herbland and agriculture physiognomic groups.

Snake Headwaters ERU

We detected changes of mosaic patterns across 92 percent of the Snake Headwaters ERU (table 3.170). A substantial (46%) trend toward more uniform patterns was evident across nearly 23 percent of the ERU. The increase in uniformity seemed to be attributable to an increase in area of the mid-seral forest/woodland physiognomic group, and subsequent declines of the late-seral forest/woodland and early-seral forest/woodland physiognomic groups. The dominant landscape transition that occurred within the Snake Headwaters ERU was an increase in the uniform mid-seral forest/woodland physiognomic group at the expense of the mixed mid-seral and late-seral multi-layer forest/woodland, and mosaic mid-seral and late-seral multi-layer physiognomic groups. Other less dominant changes included a decline of mixed mid shrub and mid-seral forest/woodland physiognomic groups, which changed mostly to mixed mid shrub and early-seral forest/woodland physiognomic groups.

Table 3.170—Summary of broad-scale mosaic pattern changes within Ecological Reporting Units (ERUs).

Ecological Reporting Unit	Fragmentation Trend[1]	Stability Index[2] (%)	Departure of Landscape Pattern[3]
Blue Mountains	(++)	11	High
Central Idaho Mountains	(--)	18	Moderate
Columbia Plateau	(+++)	13	High
Lower Clark Fork	(---)	3	High
Northern Cascades	(--)	6	High
Northern Glaciated Mountains	(---)	5	High
Northern Great Basin	(+)	69	Low
Owyhee Uplands	(++)	58	Low
Snake Headwaters	(---)	8	High
Southern Cascades	(++)	14	Moderate
Upper Clark Fork	(---)	15	High
Upper Klamath	(--)	4	High
Upper Snake	(++)	22	Moderate

[1]Fragmentation trend assessment of coarse mosaic patterns, that is uniform, mosaic, and mixed: (+) = Slightly fragmented (≤ 5% trend); (++) = Moderately fragmented (6-30% trend); (+++) = Substantially fragmented (≥31% trend); (-) = Slightly more uniform (≤ 5% trend); (--) = Moderately more uniform (6-30% trend); (---) = Substantially more uniform (≥31% trend).

[2]Stability Index = proportion of mosaic patterns that remained stable between historical and current periods.

[3]Landscape departure indices were relativized among ERUs. Low departures had PD <33.3; Moderate departures had PD = 33.3 to 66.6; High departures had PD >66.6. See the "Methods" section of this chapter for derivation of PD (Departure Index).

Southern Cascades ERU

We detected broad-scale pattern changes across 86 percent of the Southern Cascades ERU (table 3.170). Fragmented patterns increased across approximately 6 percent of the ERU. The dominant landscape transitions involved a decrease in mixed mid-seral and late-seral single-layer forest/woodland physiognomic groups, which were replaced by mixed late-seral single-layer and late-seral multi-layer forest/woodland physiognomic groups. The increase of fragmented landscapes occurred primarily in the forest/woodland physiognomic groups. Secondarily, fragmentation increased in rangeland physiognomic groups due to agricultural development.

Upper Clark Fork ERU

Mosaic patterns varied between the historical and current periods on approximately 85 percent of the Upper Clark Fork ERU (table 3.170). We detected a substantial increase of more uniform landscapes across 44 percent of the ERU. The dominant landscape transitions that occurred were the result of the development of the early-seral forest/woodland physiognomic groups, and to a lesser degree, the areal decline of the late-seral forest/woodland physiognomic groups. For example, the uniform mid-seral forest/woodland physiognomic group increased at the expense of the mosaic mid-seral and early-seral physiognomic groups, and mixed mid-seral and late-seral multi-layer forest/woodland physiognomic groups.

Upper Klamath ERU

We detected a change of mosaic patterns across nearly all (96%) of the Upper Klamath ERU (table 3.170). Landscape patterns became more uniform across 22 percent of the area. The most dominant transitions suggested that landscapes composed by the forest/woodland physiognomic groups became older and more homogeneous. For example, the mixed mid-seral and late-seral forest/woodland physiognomic groups transformed into the mosaic or uniform late-seral forest/woodland physiognomic groups. These types of transitions occurred across 34 percent of the ERU.

Upper Snake ERU

Most (78%) of the mosaic patterns of subwatersheds within the Upper Snake ERU changed between the historical and current periods (table 3.170). A net increase of more fragmented landscapes occurred throughout 16 percent of the ERU. The transition matrices indicated that the increase of fragmented patterns occurred primarily within the uniform low shrub physiognomic group, which was converted to mixed and mosaic patterns that included the herbland physiognomic group. We also detected an increase in the uniform herbland physiognomic group, nearly all of which originated from the uniform low shrub physiognomic group.

Summary of Regional Broad-Scale Landscape Trends

Not surprisingly, three anthropogenic terrestrial community groups (that is, agricultural, urban, and exotic herbland) did not occur historically (table 3.171). Although the agricultural community group composed approximately 14 percent of the LCA during the current period, the exotic herbland and urban community groups did not compose substantial proportions of the area. As mentioned previously, we suspect that current period estimates of exotic vegetation prevalence in the Basin were too low. The barren/rock, alpine, and water community groups did not vary substantially between the historical and current periods.

In forested settings, an increasing fragmentation trend was observed between the historical and current periods for the lower montane community group and, to a lesser extent, the subalpine forest community group (table 3.171). However, the pattern indices of the montane forest community group indicated a trend toward increasing uniformity during this time interval. The lower montane forest community group exhibited significant declines in areal extent and mean patch size, while the number of patches increased. Although the areal extent of the subalpine forest community group did not decline substantially, the mean patch size index decreased significantly, while the patch number index increased significantly.

The most substantial changes in the areal extent of a community group across the LCA were the increase of the agricultural group, and the subsequent decrease of the upland herbland and upland shrubland community groups (table 3.171). In rangeland settings the upland shrubland and upland herbland community groups became much more fragmented, while the upland woodland group had a trend of increasing uniformity. We observed significant declines of areal extent, largest patch, and mean patch size indices for both the upland shrubland and upland herbland groups. Conversely, the number of patches of both groups increased significantly between the historical and current periods. On the other hand, the upland woodland community group had ecologically significant increasing trends for areal extent, largest patch, and mean patch size indices.

As a whole, the current period LCA appeared to be substantially more fragmented than the historical landscape (table 3.172). The largest patch and mean patch size indices decreased significantly, while the patch number index increased. As expected, patch richness increased due to the addition of three anthropogenic community groups (urban, agricultural, and exotic herbland) in the current period landscape. Although both diversity and evenness indices increased, and the contagion index decreased, the changes were not ecologically significant.

Table 3.171—Broad-scale trends of regional vegetation patterns within the Landscape Characterization Area (LCA).

Terrestrial Community Group	Period / Change	Class Metric[1]				
		% Land	LPI	NP	MPS	ED
Agricultural	Historical	0	0	0	0	0
	Current	14.4	6.50	1549	7637	0.77
	% Change[2]	NA[3]	NA	NA	NA	NA
Alpine	Historical	0.5	0.09	208	1790	0.05
	Current	0.5	0.09	208	1788	0.05
	% Change	0	0	0	-0.1	0
Barren/Rock	Historical	0.3	0.04	136	1612	0.03
	Current	0.3	0.04	136	1612	0.03
	% Change	0	0	0	0	0
Exotic Herbland	Historical	0	0	0	0	0
	Current	1.4	0.06	870	1323	0.18
	% Change	NA	NA	NA	NA	NA
Lower Montane Forest	Historical	12.3	1.87	1029	9790	0.65
	Current	9.6	2.08	1865	4231	0.76
	% Change	-21.7	11.2	81.2	-56.8	16.9
Montane Forest	Historical	23.1	10.32	1488	12741	1.29
	Current	27.4	10.59	1419	15829	1.38
	% Change	18.5	2.6	-4.6	24.2	7.0
Subalpine Forest	Historical	5.9	0.7	792	6133	0.45
	Current	5.8	0.59	1294	3684	0.54
	% Change	-1.9	-15.7	63.4	-39.9	20.0
Upland Shrubland	Historical	38.0	29.85	827	37706	0.56
	Current	28.8	24.03	1141	20755	0.68
	% Change	-24.1	-19.5	38.0	-45.0	21.4
Upland Herbland	Historical	15.0	6.24	1215	10129	0.65
	Current	5.6	0.49	2005	2292	0.56
	% Change	-62.6	-92.1	65.0	-77.4	-13.8
Upland Woodland	Historical	2.2	0.29	1320	1364	0.27
	Current	2.6	0.53	1113	1939	0.27
	% Change	20.1	82.8	-15.7	42.2	0
Urban	Historical	0	0	0	0	0
	Current	0.1	0.02	128	881	0.02
	% Change	NA	NA	NA	NA	NA
Water	Historical	0.9	0.07	370	2018	0.08
	Current	0.9	0.07	370	2014	0.08
	% Change	0	0	0	-0.2	0

[1]Metric: a means of measuring or specifying values of variablity; see McGarigal and Marks (1994); % LAND=percent of the landscape (%), LPI=largest patch index (%), NP=number of patches, MPS=mean patch size (ha), ED=edge density (m/ha).

[2]% Change = Proportional change between historical and current periods.

[3]NA = Not applicable as the community group did not occur historically.

Table 3.172—Historical and current landscape metrics of regional vegetation patterns within the Landscape Characterization Area (LCA).

Metric[1]	Historical	Current	Percent Change[2]
LPI	29.85	24.02	-19.50
NP	8222.00	13154.00	59.98
MPS	9990.00	6244.00	-37.49
ED	2.11	2.78	31.79
SHDI	1.67	1.90	13.51
SIDI	0.76	0.80	5.65
PR	11.00	14.00	27.27
SHEI	0.70	0.72	3.15
SIEI	0.84	0.87	3.46
CONTAG	48.72	44.50	-8.63

[1]Metric: a means of measuring or specifying values of variablity; see McGarigal and Marks (1994); LPI=largest patch index (%), NP=number of patches, MPS=mean patch size (ha), ED=edge density (m/ha), SHDI=Shannon's Diversity Index, SIDI=Simpson's Diversity Index, PR=patch richness, SHEI=Shannon's Evenness Index, SIEI=Simpson's Evenness Index, CONTAG=contagion index.

[2]Percent Change = Proportional change between historical and current periods.

Broad-Scale vegetation patterns discussion

Our comparison of the historical and current period landscape patterns had inherent limitations as a consequence of differing methodologies and resolutions used in developing each broad-scale vegetation layer. We tried to lessen these inherent limitations by (1) resampling at a much broader resolution (that is, 4-km^2), (2) by comparing relatively coarse vegetation types (that is, terrestrial community groups), and (3) by considering only relatively large magnitudes of change (that is, $\geq$ 20%) as ecologically significant. However, at best our findings, which resulted from the comparison of values derived from different methods and different time periods, should be regarded as working hypotheses. In addition, many, if not most of landscape pattern changes occur at a much finer scale than we used in our analysis. Consequently, our analysis captured broad-scale changes but likely overlooked the more subtle changes that had occurred.

Taken in its entirety, the landscapes of the Interior Columbia Basin and portions of the Klamath and Great Basins became substantially more fragmented between the historical and current periods. However, the coarse-grained fragmentation that occurred within the area as a whole was not consistently apparent among the broad-scale vegetation types (that is, among the broad-scale terrestrial community groups or physiognomic groups) that we assessed, or among the ERUs. For example, landscape patterns throughout roughly one-half of the ERUs became more fragmented, while patterns became more homogenous throughout other ERUs. In addition, we detected increasing fragmentation trends within four terrestrial community groups (lower montane forest, subalpine forest, upland herbland, and upland shrubland), but a trend of increasing homogeneity within two community groups (montane forest and upland woodland). The two opposing trends were not at all independent. The montane forest community group seems to have expanded throughout the LCA, at the expense of the lower

montane forest, and to a lesser extent, the subalpine forest community. Similarly, in the rangeland settings, the upland woodland community group expanded into the upland shrubland community, and to a lesser extent, into the upland herbland community. However, the substantial fragmentation of the upland herbland and upland shrubland community groups was predominantly a consequence of the agricultural conversion of 14 percent of the LCA.

Four primary agents of change were largely responsible for the coarse landscape pattern changes we detected. In forest environments, the primary agents of change included successional processes, fire suppression, and timber harvest activities. As a consequence, a large proportion of the lower montane forest community group converted to the montane forest community group. Fire suppression and successional processes had permitted many of the shade-tolerant and fire-intolerant species (for example, Douglas-fir and grand fir), more commonly associated with the montane forest community, to invade and prosper on sites that would be expected to support the lower montane forest community group (dominated by ponderosa pine). Timber extraction activities commonly exacerbated this situation by targeting the removal of ponderosa pine and promoting stand development of Douglas-fir and grand fir. Fire suppression, in rangeland environments, also contributed to the expansion of the upland woodland community group into the upland shrubland community group. However, as stated previously, agricultural development within the upland herbland and upland shrubland community groups was the dominant agent of change within rangeland environments.

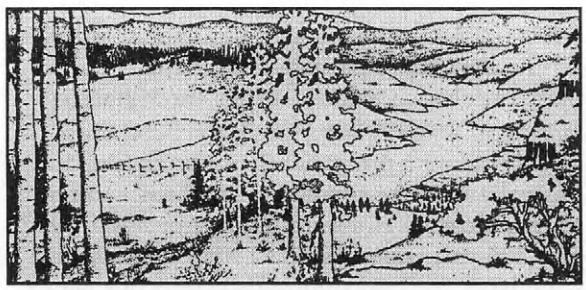
Our analysis suggests that a species whose fitness is positively correlated to an increasing area and larger, more contiguous patches of the agricultural, exotic herbland, montane forest, and upland woodland community groups would likely have a higher probability of long-term persistence during the current period, than they had historically. On the other hand, species whose fitness is negatively correlated to the extensive fragmentation of the lower montane forest, upland herbland, and upland shrubland community groups were likely most at risk.

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RANGELAND ECOLOGY AND GRAZING MANAGEMENT



Causal Agents in Landscape Conditions and Trends On Rangelands and Riparian Areas

This section summarizes the detailed reports written by the project staff on causal agents in landscape trends on rangelands and riparian areas. Causal agents, including herbivory by large herbivores, livestock grazing in riparian areas, western juniper expansion, exotic plants-noxious weeds, and cheatgrass, are each discussed within this section. We propose that much of the literature and findings presented in this section could be applied in rangeland and riparian ecosystems throughout the western United States and therefore should be of use to rangeland managers both within and outside the Basin.

We continue in this section, as in previous sections, to refer to species using their common names and to provide scientific names for each species when first cited in the text. Common and scientific names of all plant species discussed in this section are provided in appendix 3-I.

Herbivory by Large Herbivores

The following subsection originates primarily from Grayson (1993), which is a text that focuses on the Pleistocene and Holocene natural history of the Great Basin, and a report written by ICBEMP staff (Leonard and Karl 1995a).

Large herbivores and herbivory in the Pleistocene and Holocene—Vegetation throughout the Basin was in a continued state of flux during the late Pleistocene (roughly 132,000 to 10,000 years ago; Grayson 1993) and the Holocene (the last 10,000 years; Grayson 1993, Miller and others 1994). Changes in climate and frequency of fire were probably the primary disturbances influencing vegetation change before Euro-American settlement. Herbivory by native grazers played a less dominant role in the late Pleistocene and Holocene (Aikens 1986, in Miller and others 1994; Grayson 1993; Martin 1967, in Miller and others 1994; Miller and others 1994).

Large herbivores present during the late Pleistocene in the Basin included horses (*Equus* spp.), flat-headed peccaries (*Platygonus compressus*), camels (*Camelops hesternus*), mammoths (*Mammuthus columbi* and *M. primigenius*), Harlan's ground sloth (*Glossotherium harlani*), large-headed llama (*Hemiauchenia macrocephala*), and possibly Harlan's muskox (*Bootherium bombifrons*) (Allison 1966, in Grayson 1993; Howe and Martin 1967, in Grayson 1993; Grayson 1993). Of these, horses, camels, and mammoths were the most common on the landscape. Mammoths probably were gregarious and were grazers. Open grasslands have produced the most abundant quantities of mammoth remains. Flat-headed peccaries were believed to be gregarious, and probably preferred open environments. Harlan's muskox apparently preferred open environments as well. These large herbivores, and various other mammals, became extinct in the late Pleistocene. The above-mentioned herbivores were undoubtedly encountered by the earliest human occupants of the Great Basin (Grayson 1993).

Large herbivore abundance and diversity, at least in the Great Basin portion of the Basin, were apparently much reduced during the Holocene compared with the late Pleistocene (Grayson 1993). Elk were present in the Great Basin portion of the Basin at the end of the late Pleistocene and during the early Holocene (approximately 11,000 to 7,200 years ago; Grayson 1993). However, elk abundance declined substantially after this period. Studies have indicated that large herbivore abundance and diversity declined in the Great Basin portion of the Basin from the early Holocene (about 10,000 to 7,500 years ago) to the mid (about 7,500 to 4,500 years ago) and late Holocene (last 4,500 years). Grayson (1993) maintained that the Great Basin, like so many other parts of North America, supported a far richer large mammal fauna toward the end of the Pleistocene than it does today. Apparently, chief among those mammals were horses, camels, and mammoths.

In the late Holocene, prior to Euro-American settlement, environmental conditions and hunting pressure by Native Americans appeared to keep large herbivore populations low. Grazing impacts by large herbivores were probably light, except in localized areas. Grazing by large and small mammals, birds, and insects was likely characterized by heavy and light cyclic extremes that were somewhat attributable to cyclic extremes in herbivore populations (Miller and others 1994). Grazing was likely seasonal, with animals migrating between upper-elevation summer range and lower-elevation winter range (Burkhardt 1996, Miller and others 1994). Consequently, the effects of selective grazing by native herbivores was probably minimal and did not substantially affect interspecific competition and vegetation composition, even during periods of high population densities (Miller and others 1994).

Since the historical period, plant composition of rangelands (the dry grassland, dry shrubland, cool shrubland, woodland, and riparian PVGs) within the Basin changed at unprecedented rates, due to disturbances associated with Euro-American settlement. Agricultural development, introduced livestock (horses, cattle, sheep) and exotic plant species, elevated CO_2 levels, altered fire regimes and hydrologic cycles, recreation, and mining, interacted with a gradual change in climate to substantially change the landscape composition and structure of rangelands within the Basin (Miller and others 1994).

Grazing pressure increased substantially during the Holocene as Euro-American introduced their horses, sheep, and cattle. In the early-1900s, Griffiths (1902, 1903) reported declines in native vegetation abundance and condition in the Great Basin portion of the Basin and in eastern Oregon and Washington. He attributed this decline to the introduction of domestic livestock (particularly cattle and sheep) and wild horses to the region, and excessive livestock grazing pressure. Grass (for example, bluebunch wheatgrass) abundance was declining over most of the rangeland on his reconnaissance route, and he was beginning to observe excessive browsing of shrubs, particularly shrubs of the salt desert shrub PVT such as winterfat. The excessive livestock grazing pressure and its deleterious effects to native vegetation were particularly apparent to Griffiths on Steens Mountain in southeast Oregon. Grassy areas (characterized by prevalence of sheep fescue, and thus what we would refer to as the fescue-grassland PVT), riparian areas (characterized by willow), and areas with aspen, were particularly overused by livestock. Griffiths estimated that in 1901, 182,500 sheep, or 175 sheep per square kilometer, were present on Steens Mountain. In addition, ranchers on the few cattle ranches that were in the lowlands surrounding Steens Mountain placed their cattle on the mountain in the summer.

Grazing pressure exerted on native vegetation of the Basin by large herbivores has thus fluctuated over time. Large herbivores were more abundant and diverse during the Pleistocene compared with the Holocene, and grazing pressure probably declined in the Holocene. Grazing pressure increased substantially as Euro-Americans settled the Basin and introduced sheep, cattle, and horses, perhaps even greater than during the Pleistocene. Deleterious effects on the native vegetation,

particularly during the late-1800s and early-1900s, were clearly evident. We concur with Grayson (1993) that "The native grasses of the floristic Great Basin are not adapted to *heavy* [italics added] grazing by large mammals."

Livestock grazing and vegetation dynamics (historical to current period)—Platou and Tueller (1985) proposed that livestock grazing, and livestock grazing systems, that emulate native grazing regimes of the vegetation communities in the late Holocene (pre-Euro-American settlement) would be more compatible with the evolutionary history of vegetation in the Great Basin. However, pre-Euro-American settlement conditions no longer exist in the Basin. Agricultural and urban development, livestock herbivory (as described by Miller and others 1994), the introduction of exotic plants, and changes in disturbance regimes have resulted in unprecedented changes. Given that landscape conditions have changed in the Basin, we addressed two pertinent questions in our analysis.

1) Can ecosystem functions that have been altered by improper livestock management since the historical period be restored by removing livestock?

Laycock (1994) provided a review of literature comparing the implications of livestock grazing versus no grazing on current period rangelands, and concepts of "state-and-transition" models versus traditional "climax" models to explain vegetation succession and retrogression. Vegetation change on the more mesic rangeland potential vegetation types seems to correspond most closely with the traditional climax model. In this model, the removal of grazing pressure results in improvement through secondary succession (fig. 3.15). The PVTs in the Basin that best fit this model include the riparian types (for example, cottonwood riverine and mountain riparian low shrub), aspen, the grassland types (for example, wheatgrass grassland and fescue-grassland), and open ponderosa pine-grassland types (for example, fescue-grassland with conifer and interior ponderosa pine). We propose that there are exceptions within these types where successional advancement might not be realized, especially in cases of excessive livestock grazing pressure and/or exotic plant invasion.

In contrast, most current period arid and semi-arid rangeland PVTs remain stable at one or more lower (less advanced) successional states for long periods of time after removal of livestock, unless humans intervene in the form of rangeland modifications (for example, seedings). Nearly all sagebrush grassland PVTs (with or without juniper) and the salt desert shrub PVT are included in this category and best fit the state-and-transition model. This model defines vegetation states as:

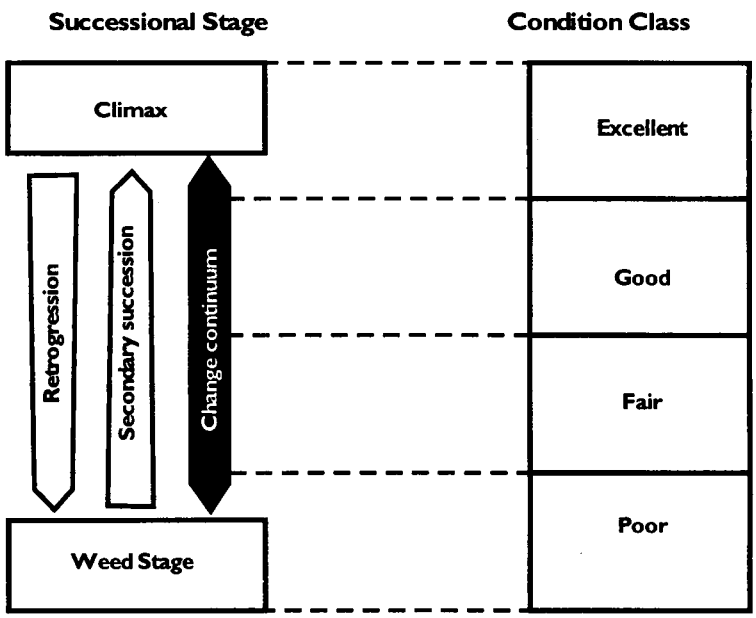


Figure 3.15—Climax model for vegetation succession—The climax model of vegetation succession and the approximate relationships between rangeland condition and degree of retrogression from climax conditions (adapted from Vavra and others 1994).

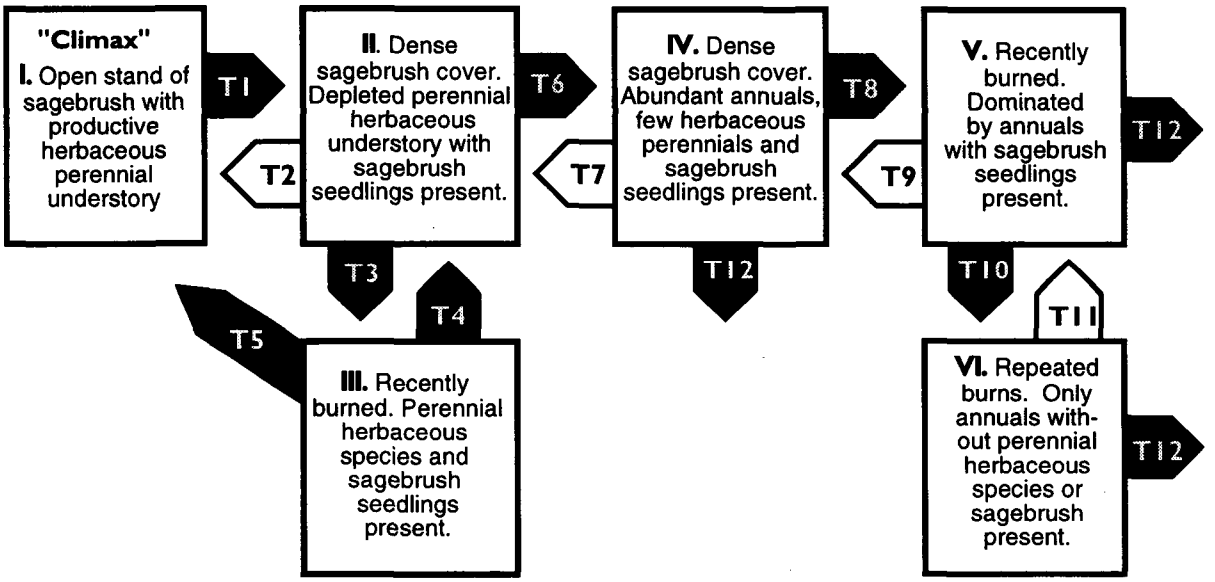


Figure 3.16—State-and-Transition Model for sagebrush grass ecosystem. States I, II, and III exist in areas without exotic annual species (for example, cheatgrass or medusahead). State I is the "climax" or condition undisturbed by livestock grazing. Transition arrow T1 represents excessive livestock grazing pressure which causes deterioration of the understory and increased density and vigor of sagebrush. State II is dominated by sagebrush and will remain stable for long periods of time. Transition T3 is fire or some other force (for example, insects, disease, or a herbivore that consumes sagebrush) that reduces the sagebrush, which permits the understory to improve (State III). With proper livestock grazing management (Transition T5), State III can transition back to a state resembling State I. With excessive livestock grazing pressure (Transition T4), State III will transition to State II, and sagebrush will again dominate the stand. State IV represents areas subjected to excessive livestock grazing pressure where a well-adapted, annual like cheatgrass exists. Continuous excessive livestock grazing pressure (Transition T6) in State II results in State IV, where perennials in the understory have been replaced by annuals. The transitions of State IV to State V (T8), and State V to State VI (T10), represent the role of fires in the conversion to a stable cheatgrass-dominated plant community. Transition T12 represents intervention by humans, for example the seeding of exotic perennial grasses, such as crested wheatgrass. The BLM, for example, plants strips of vegetative fuel breaks (greenstrips) consisting of crested wheatgrass, other grasses, forbs, and shrubs to slow the spread of fires (adapted from Vavra and others 1994).

recognizable, relatively stable assemblages of species occupying a site. Forces such as grazing disturbance or altered fire regimes can cause vegetation to cross a threshold, or transition (fig. 3.16). Once a threshold is crossed, removal of the disturbance will not necessarily result in a transition to a higher successional state without substantial inputs of energy or nutrients. Some functional improvement (for example, improved nutrient status and reduced erosion associated with microbiotic crust redevelopment) within a state might be accomplished with livestock removal in many situations, but we speculate that this improvement is probably not detectible with mid- or broad-scale assessments.

An example of an apparently stable vegetation state is the cheatgrass and/or medusahead dominated areas within some sagebrush grassland PVTs [particularly Wyoming big sagebrush (*Artemisia tridentata wyomingensis*)-warm]. Frequent fires result from the establishment of these highly flammable exotic annual grasses. Current period fire-return frequencies as low as five years largely prevent perennial grass or shrub establishment. Removal of livestock will not reduce fire frequencies and can exacerbate fire susceptibility through the subsequent accumulation of flammable litter.

2) Can livestock be managed in a manner that would be compatible with native plant communities in the Basin?

Archer and Smeins (1991) proposed that some traditional livestock grazing management practices were not compatible with native plant communities. The authors identified several examples of poor compatibility: (1) Traditionally, livestock are concentrated at artificially high levels. In contrast, densities of native herbivores varied seasonally and annually; (2) Fences prevent livestock from moving to new areas when the abundance of desired forages decreases. Consequently, traditional grazing practices result in higher frequencies and intensities of defoliation than would have occurred with pre-Euro-American settlement grazing regimes; (3) Mortality of native herbivores was a feedback loop that reduced grazing pressure, permitting recovery of native vegetation after periods of forage overuse. Supplemental feeding precludes mortality of livestock and thus maintains grazing pressure over a greater portion of the year and over a higher frequency of years, compared with grazing pressure that was exerted by native herbivores; and (4) Prolonged grazing in grasslands or savannas that existed in areas climatically and edaphically capable of supporting trees or shrubs has decreased the capacity of grasses to competitively exclude woody plants. It also concurrently reduced fire frequency, and usually, fire intensity, by preventing the accumulation of fine fuels.

Grazing systems have been promoted to mitigate or prevent the detrimental effects to native plant communities. Rest-rotation grazing has been suggested as a grazing system that approximates the manner in which native ungulates grazed the Great Basin shrub-grassland (Platou and Tueller 1985). Seasonal grazing (Vallentine 1990), characterized by livestock moving higher in elevation with increase of temperature and changes in plant phenology, might also approximate past grazing by native ungulates if constraints of land ownership, tenure, or administration do not prove to be problematic.

Under specific circumstances, rest-rotation, deferred, deferred rotational, and seasonal grazing systems have all been demonstrated to sustain rangeland vascular plant communities within the sagebrush grassland and pine-bunchgrass zones in the Basin (Vallentine 1990). However, none of these grazing systems have been conclusively more effective than light to moderate stocking levels under continuous seasonal use (Hart and Norton 1988, Heady 1975, Stoddart and others 1975, Vallentine 1990). Thus, despite the array of grazing systems conceived and promoted during the last 40 years in the United States, there has been considerable debate over their compatibility with native plant communities.

Grazing systems, and no grazing, are unlikely to elevate many plant communities in a low successional steady state to a higher successional state (Archer and Smeins 1991). Sustainable grazing management then, relies on knowledge of critical thresholds and manipulation of livestock so these critical thresholds are not exceeded. Continued stocking at near-normal levels during periods of moderate to severe drought is probably the greatest cause of range deterioration (Vallentine 1990). Reduced grazing intensities during drought, and for some time after drought, are necessary to minimize damage and hasten recovery of perennial vegetation. Frequency of drought in the Basin and frequency of years that are proposed as favorable for vegetation recruitment have been discussed in various portions of the "Results and Discussion" and are discussed in detail in the "Susceptibility of Rangeland Health to Management-Induced Disturbance Stresses" subsection.

Livestock Grazing in Riparian Areas

This subsection is a summarization of Leonard and Karl (1995b), which is an ICBEMP report based primarily on Kindschy (1994).

Riparian areas (U.S. Department of Interior 1992) are

> a form of wetland transition between permanently saturated wetlands and upland areas. These areas exhibit vegetation or physical

characteristics reflective of permanent surface or subsurface water influence. Lands along, adjacent to, or contiguous with perennially and intermittently flowing rivers and streams, glacial potholes, and the shores of lakes and reservoirs with stable water levels are typical riparian areas. Excluded are such sites as ephemeral streams or washes that do not exhibit the presence of vegetation dependent upon free water in the soil.

Riparian-wetland areas are grouped into two major categories: (1) lentic, which is standing water habitat such as lakes, ponds, seeps, bogs, and meadows, and (2) lotic, which is running water habitat such as rivers, streams, and springs. A preponderance of literature on livestock grazing in riparian areas is associated with lotic systems because of their much greater areal extent in the arid west, and the potentially greater negative affects associated with increased energies of running water.

Historical to current context—Historical evidence indicates that most riparian areas in the Basin have changed dramatically in the last 100 years. A major causal factor has been improper livestock grazing, defined by Chaney and others (1990) as, concentrations of livestock at the wrong time (that is, season), in too great a number (that is, intensity), for too long (that is, duration), or any combination of these factors that results in riparian area degradation. Other major factors have been changes in hydrologic regimes caused by dams, diversions, and irrigation, and to a lesser extent, disturbances associated with logging, roads, and recreational facilities.

Effects attributable to improper livestock grazing—Livestock grazing has occurred across most of the Basin (map 3.25). Riparian sites constitute only a small percentage (2-3%) of the Basin (table 3.18), yet livestock (especially cattle) activity has been disproportionately concentrated within riparian areas (Kovalchik and Elmore 1992, Marlow and Pogacnik 1986) compared with upland areas. Concentrated livestock activity has resulted in excessive herbage removal and physical damage by trampling. Some ramifications of excessive herbage removal and physical damage have included (1) reduced dissipation of stream energy, (2) an increased extent of bare soil and accelerated erosion, and (3) stream channel degradation, which has resulted in reduced floodplain recharge, lowered water tables, and reduced areal extent of riparian plant communities. Erosion and stream channel degradation have affected water quality by increasing suspended sediments. Water temperatures have increased due to the decline in shade provided by vegetation. Simplification of vegetation structural diversity and the presence of early-successional stages has resulted in less diverse and often less productive floral and faunal assemblages. Direct influences of livestock concentrations in riparian areas on water quality include bacterial and protozoal parasite contamination, and nutrient enrichment from fecal material in and near surface waters (Larsen 1996).

Proper functioning condition of riparian-wetland areas—Riparian-wetland capability and potential is defined by the interaction of three components: (1) vegetation, (2) landform and soils, and 3) hydrology. When the interaction of these three components is functioning properly, the negative physical ramifications described above are not apparent and the capability to produce desired biological attributes is maintained. Riparian-wetland areas are functioning properly when adequate vegetation, or large woody debris are present and able to (1) dissipate stream energy associated with high water flows, thereby reducing erosion and improving water quality, (2) filter sediment, capture bedload, and aid floodplain development, (3) improve flood water retention and groundwater recharge, (4) develop root masses that stabilize streambanks, (5) develop diverse ponding and channel characteristics to provide habitat, water depth, duration of water presence, and temperature necessary for fish production, waterfowl breeding, and other uses, and (6) support greater biodiversity (Barrett and others 1993).

Proper functioning condition can exist anywhere along the seral continuum, from early-seral to potential natural community, depending on the particular characteristics of the riparian-wetland area. Although proper functioning condition is viewed by the BLM as the minimum acceptable condition for any goal, management objectives might require vegetation composition, cover, or structure that are representative of advanced seral stages, beyond proper functioning condition. Riparian-wetland areas can be classified as proper functioning condition before they have achieved an advanced ecological status, but achievement of advanced ecological status, [defined in Barrett and others (1993) as "a community with a high coefficient of similarity to a defined or perceived potential natural community for an ecological site, usually late seral or potential natural community ecological status"], is the ultimate goal on Federal rangeland riparian-wetland areas (Barrett and others 1993, U.S. Department of Interior 1990). Advanced ecological status is the ultimate goal because successional advancement and/or increased cover, density, or structure of riparian vegetation is necessary for improvement of degraded systems. Livestock grazing can be implicated in the impedance of desired vegetation changes in many instances. Improvement of riparian areas also hinges on concomitant improvement of degraded uplands or maintenance of healthy upland vegetation. Proper livestock use can improve upland vegetation and result in increased infiltration rates, reduced overland flows, and increased water storage by stream systems (Elmore 1992).

An inventory and assessment of approximately 15,300 stream and shoreline kilometers of riparian areas in Oregon, Washington, Idaho, and Montana by the BLM shows that 31 percent are in proper functioning condition, 53 percent are functional at risk, and 16 percent are nonfunctional (U.S. Department of Interior 1994). Riparian-wetland areas are considered functional-at risk when they function, but are susceptible to degradation attributable to soil, water, or vegetation characteristics. Functional-at risk also indicates riparian areas that can respond rapidly to improved management.

Nonfunctional areas are believed to require stream channel evolution or mitigation of major alterations prior to achievement of proper functioning status. We speculate that the above-stated, percent categorization of functionality can be extrapolated to, and is indicative of, riparian systems within the Basin as a whole.

Livestock grazing strategies, grazing systems, and their effects—Although total exclusion of livestock is shown to improve conditions (Claire and Storch 1977, Duff 1977, Gunderson 1968, Winegar 1977), total exclusion is not always necessary to reduce negative impacts (Krueger and Anderson 1985). Land managers can accomplish riparian area improvement concomitantly with livestock grazing (Chaney and others 1990, Elmore 1992, Elmore and Kauffman 1994) through an increased emphasis on compliance to suitable grazing strategies and practices. There are limitations, however, associated with livestock grazing, because "In essence, livestock are NOT a 'tool' to improve riparian ecosystems. Rather, they are a cost that may often be accommodated and still enable successional advancement of riparian vegetation and attendant functional values [Kruger (sic) and Anderson 1985, Kindschy 1987]" (Kindschy 1994).

There are numerous prescribed grazing strategies for livestock that can be successful in riparian areas (Chaney and others 1990). Many options can be considered for inclusion in successful prescribed grazing strategies. These options can permit successional advancement of vegetation, while satisfying management requirements of the livestock enterprise. Pertinent options include:

1) Livestock type: The adverse effects on riparian vegetation from sheep can be substantially less than from other livestock types, particularly when sheep are herded. Herding keeps the animals out of riparian areas, except for short watering periods.

2) Livestock class: There are behavioral differences between young and mature animals (Swanson 1985). Yearling cattle are less apt to linger within riparian areas compared with cows, especially cows with calves, or bulls.

3) Season of use: The most harmful impacts to riparian vegetation from herbivory are incurred during summer months. Livestock tend to linger near water during the summer season. Willows, and likely other woody plant species, are susceptible to excessive herbivory during this season because the impact coincides with their maximum growth period. Conversely, livestock grazing during spring, autumn, and winter appears to be relatively less deleterious to riparian vegetation.

   a) Spring grazing—Compared with grazing during other seasons, spring grazing is possibly the least deleterious to the majority of riparian plant species (Platts and Nelson 1985, Shaw 1991), partly because of regrowth potential, and partly because livestock tend to avoid riparian areas in the spring. Removal of livestock before the hot summer months permits regrowth and physiological maintenance of plants. This regrowth functions as a filter for instream and flood flows, reduces water velocity, and promotes sediment deposition. Livestock tend to avoid riparian areas that are characterized by wet soil, cold temperatures, and immature forage in the spring (Kovalchik and Elmore 1992, Platts and Nelson 1985).

      Cattle concentrate their foraging effort in uplands rather than riparian areas in spring because forage palatability and climate are more favorable in uplands compared with riparian areas (Platts and Nelson 1985). Soil water availability often limits plant growth earlier in the growing season on upland areas compared with riparian areas; thus, regrowth of upland vegetation and replenishment of their root reserves is curtailed compared with riparian vegetation. Periodic year-long rest from grazing should be incorporated for upland vegetation in this instance.

   b) Summer grazing—Summer grazing, as previously mentioned, can be deleterious to woody species in riparian areas. Woody riparian species, such as willow, experience rapid tissue elongation during summer months. Removal of current year tissue growth for willow results in reduced regrowth potential (Kindschy 1989) in comparison with unbrowsed willow or willow browsed during the dormant periods of the year. Herbaceous species, such as sedges and rushes, can tolerate summer grazing, if periodic rest or deferment is provided for vigor and reproduction recovery. The attraction of livestock to streamside areas during summer often means that 90 to 95 percent of the adjacent upland areas receive little or no grazing pressure (Krueger and Bonham 1986).

   c) Autumn grazing—Autumn grazing has mixed effects on soil and vegetation. Removal of herbaceous material in autumn is not necessarily detrimental because physiologically, herbaceous species in upland and riparian areas have completed (or nearly completed) their current-year growth and have replenished their root reserves by this time. If the autumn herbaceous component is coarse and mature (Roath and Krueger 1982) or heavily used and unavailable for further consumption (Kauffman and others 1983, Kovalchik and Elmore 1992), use of woody species by livestock could increase. Recruitment of willow and black cottonwood can be jeopardized by autumn grazing (Kauffman and others 1983). Sedgwick and Knopf (1991) also noted that willows responded negatively to autumn grazing.

      Depending on the severity of herbage removal and trampling incurred during autumn grazing, stream banks can remain in a disturbed condition through the winter season. Without autumn vegetative

regrowth, riparian areas would be comparatively devoid of vegetative cover during late winter and early spring snowmelt, thus reducing bank protection and energy dissipation during high volume flows.

d) Winter grazing—Winter grazing or dormant-season grazing generally promotes riparian area recovery and maintenance (table 3.173). Herbaceous species have completed current-year growth and have replenished root reserves. To some extent, consumption of woody species does occur (Elmore 1992), and if the herbaceous component is snow covered, livestock can consume undesirable levels of woody tissue. However, Kindschy (1989) reported that willow, which was cut during the time of dormancy to simulate use by beaver, maintained vigor and growth characteristics similar to trees with no history of beaver use. This suggests that dormant-season herbivory might be less deleterious compared with growing-season herbivory, or that other factors related to livestock grazing require further investigation and evaluation. Additional research would aid in clarifying our understanding of herbivory on dormant woody riparian vegetation.

Winter grazing can be more prevalent on upland areas compared with riparian areas, especially in areas where cold air drains into the riparian zone. In these instances, riparian vegetation might benefit because of the shift of grazing to upland areas (Elmore 1992). Livestock trampling effects on soils attributable to winter grazing are less detrimental when soils are frozen (Sedgwick and Knopf 1987).

4) Duration of use: Short-duration grazing, characterized by high-intensity, low-frequency use (long rest period relative to the use period) can permit limited successional advancement of the herbaceous component, but is less beneficial to the woody component. Growth of the woody component during the rest period can be nullified by consumption by livestock during the high-intensity use period.

5) Livestock numbers: A reduction in livestock numbers does not translate into a proportional reduction in grazing pressure in riparian areas. Consequently, a reduction in livestock numbers within pastures where riparian plant communities are of concern will typically have little positive effect on the riparian system (Harlow and others 1989, Marlow 1988). Riparian areas will typically continue to experience a greater proportion of the grazing pressure compared with the uplands. Reduction of livestock numbers in a magnitude sufficient to reduce grazing pressure in riparian areas does not address the more likely causal problems of the riparian area degradation, which include inappropriate livestock distribution, season of use, or duration of use.

6) Livestock exclusion: The exclusion of livestock permits initiation of recovery mechanisms in degraded riparian systems (see "No Grazing" in table 3.173). Livestock exclusion can result in a rapid rate of improvement of highly-sensitive riparian areas, such as critical spawning areas for sensitive fish species. Livestock exclusion from riparian areas apparently does not always, however, result in enhancement of spawning for salmon, compared with riparian areas where livestock are present (Johnson and others 1995). Livestock exclusion will result in immediate improvement of nonfunctional riparian systems only if channel development is at a stage where improvement is possible. Downcut systems that have only recently attained a new base level will not immediately benefit from any option, until the channel system has widened enough to permit vegetation establishment that is sufficient to resist higher flows (Barrett and others 1993).

7) Livestock selection: Swanson (1985) and Roath (1979) indicated that within breeds, or even herds, certain individuals tend to loiter in riparian areas more than others. Culling has been suggested to rid herds of individuals that spend disproportionate amounts of time in riparian areas (George 1996). Additional research is needed in this topic area.

(8) Attraction of livestock out of riparian areas: George (1996) provides a review of practices that tend to reduce the time livestock spend in riparian areas. Seeding of upland areas (Durbin 1977, Storch 1978), seeding and fertilization of the upland areas, and recently burned areas (Swanson 1985) all can result in reduced grazing pressure in riparian areas. Supplemental feeding of livestock, away from water, can also improve livestock distribution (McDougald and others 1989) in winter pastures. Water developments apparently have had mixed results. Stockwater development can significantly reduce use of stream and spring areas (Clawson 1993), although Gillen and others (1985) reported that cattle preferred the quality of free-flowing water. Miner and others (1992) observed that watering tanks resulted in less livestock use near streams, presumably because of warmer water temperatures in the tank compared with free flowing sources of water.

9) Herding: Herding (that is, controlling animal movement typically using horses or vehicles) has been used successfully to direct livestock activity away from riparian areas (Chaney and others 1990, Claire and Storch 1977, Storch 1978). Herding in the Trout Creek Mountains area of southeastern Oregon in the Northern Great Basin ERU has resulted in mitigation of livestock impacts in riparian systems that contain the Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*), a federally listed threatened species.

10) Barriers: Various types of barriers can be used to discourage livestock activity in particularly sensitive areas (George 1996). Prototype electronic (fenceless) control has been tested with positive results (Quigley and others 1990) in discouraging or excluding livestock; however, further research is needed on equipment development and testing.

As previously mentioned, these options can be integrated into prescribed grazing strategies for riparian areas. Our discussion will now focus on several grazing systems and their effects in riparian areas. Grazing systems are defined in Society for Range Management (1989) as specialized grazing management that defines the periods of grazing and non-grazing.

1) Three-pasture, rest rotation—The typical grazing timing for a pasture in this system is for grazing in spring of year 1, summer of year 2, and rest in year 3. Shrub consumption is light in year 1 because upland herbaceous material is green and palatable in the spring. Grazing in year 2 is timed to begin after upland grasses have produced ripe seed (usually in mid July). The desired usage for upland grasses in year 2 is 60 percent or less, but because the upland vegetation has dried and has lost palatability, concurrent usage of riparian herbaceous vegetation might be 80 to 90 percent, or more. Shrub usage escalates concurrently with riparian herbaceous usage levels exceeding 45 percent. The benefit of this system is that it promotes plant vigor, seed production, seedling establishment, root production, and litter accumulation of the herbaceous component (compared with season-long grazing). A limitation of this system is that shrub usage in the second year of the cycle can exceed the growth accruing from year 1 and year 3 of the cycle.

   In summary, this grazing system was designed to satisfy the physiological needs of herbaceous species and does not satisfy the needs of woody species to the same extent (see table 3.173). Woody species in riparian

areas generally decline with this grazing system (Elmore and Kauffman 1994). Excessive shrub utilization however, can be prevented by restricting utilization of riparian herbaceous vegetation to 50 percent or less in the second year (seed-ripe year) of the cycle (Clary and Webster 1989). Additional favorable practices include managing the riparian area as a separate pasture (managed according to the physiological needs of the riparian plant species), or adding more pastures to achieve additional rest from grazing pressure (Elmore 1992).

2) Three-pasture, deferred rotation—As described in Elmore (1992), deferment of grazing in this system is rotated among pastures and years. A pasture on a 3-year cycle would be grazed in early spring in year 1, late spring in year 2, and summer in year 3. Other deferred rotation systems have been described, for example the four-pasture system in Heitschmidt and Taylor (1991). The three-pasture, deferred rotation system does not promote growth of woody species, because of summer usage. The herbaceous component benefits from the periodic growing season rest. Thus, with respect to the response of the herbaceous and woody components, this system is similar to the three-pasture/rest rotation system (table 3.173).

3) Early rotation—As described in Elmore (1992), a pasture in the early rotation system is rested for a portion of the growing season. A pasture might be grazed in early spring in year 1, and late spring in year 2. Effects on the herbaceous and woody vegetation are generally positive (table 3.173). Benefits to herbaceous vegetation accrue from the regrowth after livestock are removed. However, seed and root production are not always enhanced. Woody species can benefit by escaping summer browsing by livestock.

4) Rotation—As described in Elmore (1992), a pasture in the rotation system is rested for a portion of the growing season, similar to the early rotation grazing system. A pasture might be grazed in spring in year 1, and summer in year 2. Again, herbaceous plants typically benefit, but the woody species decline as a result of the summer utilization (table 3.173). An acceptable use of this system would be on low gradient, wide valley sites dominated by herbaceous grasses.

Other grazing systems listed in table 3.173 include season-long, spring and fall, and spring and summer. In general, these grazing systems do not provide for successional advancement of riparian vegetation on any stream system listed in table 3.173.

Using the above-presented options, strategies, and grazing systems, there are numerous case study examples of riparian area improvement in the Basin (Chaney and others 1990, 1993; Kinch 1989). For many of the successful case studies, exclusion of livestock (two years or more) initiated recovery, thereby enhancing the effects of improved management implemented thereafter.

Western Juniper Expansion

This subsection is a summarization of Karl and Leonard (1995), which was derived primarily from Eddleman and others (1994). Unless otherwise cited, text in this subsection originated from Eddleman and others (1994).

Historical to current trends—Western juniper is a relatively small to medium-stature native tree of the Pacific Northwest region. The areal extent of the historical and current distributions of western juniper in the Basin lies primarily in eastern Oregon (maps 3.45 and 3.46). In the historical period, before settlement of the Basin by Euro-Americans, western juniper existed in relatively open, savannah-like woodlands (Nichol 1937, in Miller and Rose 1995; West 1988, in Miller and Rose 1995) or was confined to rocky surfaces or ridges [(Barney and Frishknecht 1974, Cottam and Stewart 1940, Hopkins 1979, and Johnson and Simon 1987), in Miller and Rose 1995]. The rocky surfaces or ridges were characterized by well-drained, shallow soils that produced relatively little

Table 3.173—Generalized relationships between grazing strategy, stream system characteristics, and riparian area variables (shrubs, herbs, and banks) (adapted with permission from Buckhouse and Elmore 1991).

Grazing Strategy	Riparian Variable	Stream System Characteristics (gradient and level of sediment load[1])					
		Steep, Low	Steep, High	Moderate, Low	Moderate, High	Flat, Low	Flat, High
No Grazing	Shrubs	+[2]	+	+	+	+	+
	Herbs	+	+	+	+	+	+
	Banks	NC	NC→+	NC	+	+	+
Winter	Shrubs	+	+	+	+	+	+
	Herbs	+	+	+	+	+	+
	Banks	NC	NC→+	+	+	+	+
Early Growing Season	Shrubs	+	+	+	+	+	+
	Herbs	+	+	+	+	+	+
	Banks	NC	NC→+	+	+	+	+
Deferred	Shrubs	–	–	–	–	–	–
	Herbs	+	+	+	+	+	+
	Banks	NC→–	NC→–	NC→+	+	+	+
3-Pasture Rest Rotation	Shrubs	–	–	–	–	–	–
	Herbs	+	+	+	+	+	+
	Banks	NC→–	NC→–	NC→+	+	+	+
Deferred Rotation	Shrubs	–	–	–	–	–	–
	Herbs	+	+	+	+	+	+
	Banks	NC→–	NC→–	NC→+	+	+	+
Early Rotation	Shrubs	+	+	+	+	+	+
	Herbs	+	+	+	+	+	+
	Banks	NC→–	NC→+	+→NC	+	+	+
Rotation	Shrubs	–	–	–	–	–	–
	Herbs	+	+	+	+	+	+
	Banks	NC→–	NC→+	NC→+	+	+	+
Season-Long	Shrubs	–	–	–	–	–	–
	Herbs	–	–	–	–	–	–
	Banks	NC→–	NC→–	–	–	–	–
Spring and Fall	Shrubs	–	–	–	–	–	–
	Herbs	–	–	–	–	–	–
	Banks	NC→–	NC→–	–	–	–→NC	NC→+
Spring and Summer	Shrubs	–	–	–	–	–	–
	Herbs	–	–	–	–	–	–
	Banks	NC→–	NC→–	–	–→NC	–→NC	NC→+

[1]Stream Gradient: Steep = >4%, Moderate = 2 to 4%, Flat = NC to 2%; and Level of Sediment Load: Low or High.

[2]+ = Increase; NC = No Change; – = Decrease.

understory herbaceous vegetation and did not burn frequently. The juniper woodland cover type portrayed in maps 3.45 and 3.46 generally represents woodlands found on these rocky surfaces or ridges. In the Basin, historical extent of the juniper woodland cover type was estimated at 0.11 percent, whereas the current period extent was slightly greater, at 0.14 percent (table 3.125). The juniper-sagebrush cover type portrayed in maps 3.45 and 3.46 generally represents western juniper where it existed in savannah-like woodlands maintained by relatively frequent fires. These woodlands typically had an understory that included various sagebrush species. Since the late-1800s, and more specifically the 1880s on Steens Mountain (Miller and Rose 1995) in the Northern Great Basin ERU, western juniper increased in density and distribution. Western juniper has expanded into mountain big sagebrush, low sagebrush, quaking aspen, and riparian communities. This expansion is reflected in the trends of the juniper-sagebrush cover type between historical and current periods. The historical extent of the juniper-sagebrush cover type in the Basin is estimated at less than 1 percent, whereas the current period extent is substantially greater (approximately 2%; table 3.125).

The interaction between climate and fire was likely causal in western juniper expansion and contraction before the historical period. Western juniper tended to expand its distribution during climatically cooler and wetter periods, while its distribution contracted during climatically warmer and drier periods. Fire can kill western juniper, particularly young individuals and those less than 4 meters in height.

After Euro-American settlement, the interaction between climate and fire remained operative in western juniper expansion, but excessive livestock grazing pressure entered as an additional causal factor. Climate from the mid-1800s through the early-1900s was characterized by relatively mild and wet winters and cool, wet springs, which were favorable for western juniper growth. Excessive livestock grazing pressure in the late-1800s and early-1900s contributed to a reduction in fuels that could carry fire, thereby decreasing fire frequency. In addition, fire suppression policies have generally lengthened fire-return interval.

Eddleman and others (1994) propose that the historical, excessive livestock grazing pressure played a larger role in fire frequency reduction compared with active suppression. Excessive livestock grazing pressure, through consumption of herbaceous species, also contributed to an increase in density and canopy cover of shrub species, primarily sagebrush. The microenvironment beneath shrub canopies is favorable for western juniper seedling establishment and growth. Western juniper is becoming established with and without livestock grazing, but evidence implicates excessive livestock grazing pressure in hastening its establishment rate.

Effects of western juniper expansion and control on selected ecosystem attributes— Plant communities that are susceptible to invasion by western juniper can be dominated by any of these species: mountain big sagebrush, Basin big sagebrush (*Artemisia tridentata tridentata*), low sagebrush, aspen, bitterbrush, mountain mahogany, Idaho fescue (*Festuca idahoensis*), ponderosa pine, bluebunch wheatgrass, stiff sagebrush (*Artemisia rigida*), Wyoming big sagebrush, Basin wildrye (*Elymus cinereus*), and threetip sagebrush (*Artemisia tripartita*). The concerns with expansion of western juniper into the above-mentioned plant communities relate to understory productivity, biodiversity, hydrology, and wildlife habitat. As western juniper increases in density in these plant communities, understory vegetation production declines. Conversely, after control (reduction in abundance) of western juniper, productivity of understory species typically increases. The effects of western juniper expansion and excessive livestock grazing pressure on understory productivity are confounded (ascribing the proportion of a decline in understory productivity to western juniper expansion or excessive livestock grazing pressure independently, when both are acting together is difficult). However, excessive livestock grazing pressure in this context is believed to hasten the decline of understory productivity.

Although production of understory vegetation typically increases after western juniper control, the species that respond favorably are not always desirable and the positive recovery response is species-specific. Undesirable species, such as cheatgrass, medusahead, and exotic forbs such as knapweeds, can respond favorably to western juniper removal, depending on the technique used for removal, and whether or not these species were present on-site before removal. Fire, particularly if used to control western juniper, can result in an enhancement of exotic, flammable annual grasses such as cheatgrass and medusahead.

Plant species that exist commonly in western juniper woodlands include 9 annual grasses, 48 annual or biennial forbs, 82 perennial forbs, 20 perennial grasses, 3 sedges, 13 shrubs, and 1 tree (ponderosa pine). In addition to flora, 2 amphibian, 53 bird, 29 mammal, and 13 reptile species can regularly be found in western juniper communities (see appendix 3-J for details). Species lists of non-vascular plants, invertebrates, or microorganisms associated with western juniper have not been compiled to our knowledge. Thus, estimates of species richness of western juniper or woodland communities are incomplete, and have yet to be provided for pre- and post-western juniper presence or expansion (Karl and Leonard 1995). For this reason, speculation (for example, Belsky 1995) that western juniper does not reduce biodiversity cannot be supported or refuted definitively with scientific evidence at this time. There is recent evidence that floral species richness (especially forbs) is significantly greater on sites that have received western juniper control, compared with sites where western juniper remains intact (Bates and others 1994). In addition, Burkhardt and Tisdale (1969), in Oregon Department of Fish Wildlife (1993); and West and Van Pelt (1986), in Oregon Department of Fish Wildlife (1993), report that as juniper species (including western juniper) increase in density and canopy cover, plant species richness and abundance declines.

Biodiversity incorporates several levels of biological organization including genetic, population/species, community/ecosystem, and landscape or regional (Noss and Cooperrider 1994). At the landscape level, the expansion of western juniper woodlands might be adding to, rather than detracting from, landscape diversity because these woodlands contribute to the mosaic and pattern of plant communities on the landscape. However, there presumably is a threshold beyond which the expansion of western juniper woodlands no longer enhances landscape diversity. Whether expansion of western juniper woodlands continues or not, the dilemma from a biodiversity perspective relates to how much acreage of western juniper woodlands, of various densities, composition, and structural stages, we wish to maintain on the landscape. Biodiversity at the population/species level, within western juniper woodlands, would be expected to change, often downward, as these woodlands develop successionally (Karl and Leonard 1995).

The expansion of western juniper into sagebrush-grassland communities and subsequent changes in community structure will undoubtedly alter faunal diversity, because faunal diversity in western juniper woodlands probably is tied more closely to structural diversity than to plant species composition (Oregon Department of Fish and Wildlife 1993). Western juniper communities are highly variable in structure, ranging from open stands with a relatively diverse assemblage of shrubs, grasses, and forbs, to dense woodlands with meager understory vegetation. While the structure provided by western juniper does provide thermal cover for large native herbivores such as mule deer, the expansion of western juniper into sagebrush-grassland communities, and the ensuing alteration of the understory structure, can result in reduced forage availability for mule deer and a decline in the quality of their winter range (Liverman 1993, in Haugen 1993). Alteration of low and big sagebrush structures attributable to the expansion of western juniper has the potential to be deleterious to sage grouse populations, because sage grouse have generally been associated with low and big sagebrush

communities. Additional studies designed to address faunal population responses to western juniper expansion and removal would be helpful. The relationships between fauna and (1) density and canopy cover of western juniper; (2) understory composition; and (3) vegetation structure are poorly defined. The effects of patch cutting, thinning, or commercial harvest of western juniper (Swan 1995) on faunal populations are primarily speculative.

The effects of western juniper on hydrology relate to precipitation interception and infiltration, water runoff, and erosion. The western juniper canopy intercepts precipitation, resulting in restricted precipitation input to the soil surface (more so in low-intensity storm events than in high-intensity events). On sites characterized by western juniper with sparse understory vegetation and particularly in gaps between canopies, western juniper has been implicated in reduced infiltration and increased runoff and erosion. More hydrological research conducted in western juniper woodlands is needed to elucidate the role of western juniper in hydrology. Most hydrological research regarding juniper has been conducted in pinyon-juniper woodlands of the southwest United States.

Sediment yields in pinyon-juniper woodlands are apparently greater on xeric sites (characterized by south aspects and shallow soils) compared with more mesic sites (Wilcox and others 1995, in Wilcox and Davenport 1995) attribute this to less understory cover on the xeric sites. With caution, Wilcox and others (1995, in Wilcox and Davenport 1995) propose that xeric sites in western juniper woodlands also are more susceptible to erosion than are more mesic sites. Their caution arises from extrapolating results from pinyon-juniper woodlands in the southwest United States to western juniper woodlands in the Basin. High-intensity summer storms, which are prevalent in the southwest United States and produce the majority of annual runoff on pinyon-juniper woodlands, are somewhat less prevalent in the Basin. Based on results from studies performed on sagebrush sites in the Basin (southwestern Idaho), Wilcox and Davenport (1995) surmise that most runoff in western juniper woodlands is frozen soil runoff that is generated from snowmelt and rain-on-snow events, in contrast to summer runoff in pinyon-juniper woodlands. However, snowcover in western juniper woodlands typically is not present for long periods.

Wilcox and Davenport (1995) proposed several hypotheses regarding runoff and erosion in western juniper woodlands: (1) Although an increasing density and distribution of western juniper will often increase site erodibility, erosion rates in western juniper woodlands are low and are primarily attributable to winter season, frozen soil runoff, or low energy storms. Little sediment yields should be expected. There is an exception to this hypothesis however. Miller (1995, in Wilcox and Davenport 1995) speculates that erosion rates in western juniper woodlands can be great in portions of central Oregon, particularly on sites characterized by erodible soils and steep, south facing slopes. Intense summer storms can occur in this area. (2) Most runoff and erosion is concentrated in the intercanopy zones as a result of raindrop impact, especially in areas having a preponderance of bare soil. (3) Sediments resulting from erosion are redeposited rapidly, before they are transported great distances. Runoff and erosion is scale dependent and generally diminishes as the scale increases. Although runoff and erosion might be greater locally and on-site as a result of western juniper expansion, the distant, off-site impacts are likely to be minimal. In pinyon-juniper woodlands, sediments and associated nutrients that are produced are likely to be redeposited in riparian areas, which might be an off-site benefit (Gifford 1985, in Wilcox and Davenport 1995). Whether or not this sediment redeposition in riparian areas is a net benefit to the entire ecosystem is arguable and subject to testing. An exception to this scale hypothesis is when gully erosion occurs. In this case, erosion might actually increase with scale and off-site redistribution of sediment might be substantial.

The hydrological effects of livestock grazing are not easily differentiated from the hydrological effects attributed to an increased density of western juniper. However, where livestock grazing has contributed to the decline in understory vegetation, it probably has also contributed to increased runoff and erosion (Evans 1988, in Belsky 1996; Karl and Leonard 1995).

Control of western juniper has been promoted to increase water yield, decrease erosion, and decrease sediment yield. One of the major hypotheses that was an impetus for research on the effects of control of pinyon-juniper woodlands was that water yield would increase (Wilcox and Davenport 1995). However, little if any increase in water yield resulted from pinyon-juniper removal in Arizona. In addition, control treatments that were applied, including herbicides and mechanical removal, had little effect on runoff and erosion (Wilcox and Davenport 1995).

As previously mentioned, most runoff in western juniper woodlands is surmised to be generated in winter and early spring, and characterized by a low sediment yield. Based on this conjecture, the assumption could be made that conversion of western juniper woodlands would result in little mitigation of erosion and sediment yield. There are compelling reasons to reduce juniper in some locations, but Wilcox and Davenport (1995) propose that improvement in water quality is not a compelling reason because eroded sediments apparently are redeposited rapidly. Also mentioned previously, this redeposition of sediments is speculated to most likely occur in riparian areas. Land managers (for example, Swanson 1996[3]) remain skeptical however, about the lack of water quality improvement resulting from juniper reduction. Swanson and other land managers have observed numerous cut and adjacent uncut western juniper stands, where sheet and rill erosion was prevalent on the uncut compared with the cut sites. The dilemma appears to focus on scale. We propose that site-specific, fine scale observations by land managers generate the skepticism toward the lack of water quality improvement; Wilcox and Davenport (1995) propose that the lack of water quality improvement associated with juniper reduction is applicable at the watershed scale. Thus, it appears that at a more localized level, juniper control can reduce sheet and rill erosion (Swanson 1996[3]), while at the watershed scale, the evidence is not definitive.

Control of western juniper expansion—Fire, tree cutting, livestock grazing, and revegetation (post-control of western juniper), are potential techniques for constraining western juniper expansion. The primary mortality factor operating in western juniper stands is fire. As mentioned previously, western juniper trees less than 4 meters in height are particularly susceptible to mortality from fire. As tree height increases however, greater fire intensities are required to cause mortality. Western juniper stands with a high canopy cover (relative to the site) typically burn with less predictability because fuel is lacking between and beneath canopies. Thus, as a control agent, fire is particularly effective on sites which have undergone recent expansion by western juniper. Fire on these sites reverses the succession of herbland and shrubland to western juniper woodland, thereby slowing its expansion. Fire-return intervals of 30 to 40 years have been proposed as adequate to prevent western juniper expansion into sagebrush-grassland communities (Burkhardt and Tisdale 1976).

Although fire can be an effective control agent for western juniper, it can also enhance the abundance and expansion of exotic plant species. Cheatgrass, medusahead, and knapweeds (for example diffuse knapweed) are exotic species that can be found in western juniper woodlands. These exotic species were not a component of herbland, shrubland, and woodland physiognomic types representative of the biophysical template. The use of fire in western juniper woodlands can provide acceptable microsites for establishment, and enhance the abundance, of these exotic species, in comparison with native species. Thus, reintroduction of fire

[3] Personal communication. 1996. John Swanson, Acting District Ranger, U.S. Department of Agriculture, Forest Service, Paulina Ranger District, Ochoco National Forest, 171500 Beaver Creek Road, Paulina, OR 97751.

into western juniper woodlands that have been free from fire for long periods might not result in plant assemblages typically associated with native fire frequencies and the biophysical template.

Research is providing evidence for sizeable storage of nutrients aboveground in western juniper tissue, especially nitrogen, phosphorous, potassium, calcium, and magnesium. On inherently nutrient-deficient sites that support western juniper woodlands, there is speculation that the volatilization of nutrients within the aboveground tissue of western juniper will exacerbate an already marginal situation (Belsky 1995). Fire in this instance could cause the vegetation to cross a threshold into a more degraded, stable state (Laycock 1991, in Belsky 1995). An example of this more degraded, stable state is an exotic annual grass dominated site. The cutting and removal of western juniper trees might also substantially reduce the nutrient capital of a nutrient-limited site. Research has yet to provide estimates of nutrient loss attributable to fire (or tree cutting and removal) in western juniper stands. This research is needed to aid land managers in site-specific decision making regarding control of western juniper with fire or tree cutting, and its effects on nutrient capital.

Western juniper slash left on site after cutting should ameliorate the potential effects on available nutrients. Washington and Eddleman (1995) and Washington (1996) evaluated a western juniper cutting and slash distribution technique in western juniper woodlands in central Oregon that were characterized by a meager understory of perennial plants. The technique was used in conjunction with post treatment understory seedings. Steps involved with the technique included broadcast seeding or transplanting of desirable perennial grasses, cutting of western juniper, and subsequent distribution of the western juniper limbs (slash) across the soil surface. Sometimes the understory was burned before broadcast seeding or transplanting, particularly if the understory was dominated by annual, exotic grass species such as cheatgrass and medusahead. Western juniper slash resulted in enhanced seed production and/or establishment of seeded perennial grasses. The causal mechanism was speculated as amelioration of microsite conditions, especially soil water and temperature, that results in enhanced establishment and growth of perennial species. Burning of the exotic annual grasses before seeding or transplanting can result in increased establishment and seed production of perennial grasses. Hydrologically, the use of a similar technique in the southwest United States reduced runoff and erosion, compared with sites where slash and debris were removed (Gifford 1975, in Wilcox and Davenport 1995; Wood and Javed 1991, in Wilcox and Davenport 1995).

Preliminary results from Washington (1996) and Washington and Eddleman (1995) are promising with regard to understory revegetation efforts after control of western juniper woodlands. The western juniper cutting and slash distribution technique shows promise for use on sites where burning alone cannot be expected to control western juniper. These unpublished research results remain site-specific and preliminary; refinement of the technique through additional experimentation is warranted.

Additional research focusing on livestock grazing and its effects on western juniper demography is needed, particularly within existing western juniper woodlands, woodlands that have received western juniper control, and on sites that are susceptible to western juniper expansion. However, in the interim, biological, physiological, and ecological research that has been conducted in woodlands, combined with research on plant response to herbivory, can provide insight into the effects of livestock grazing on western juniper demography.

Using a combination of research information similar to that proposed above, Eddleman and others (1994) proposed livestock grazing strategies that would be least likely to have deleterious effects on understory vegetation and western juniper expansion. These livestock grazing strategies were proposed for four types of western juniper sites and are summarized below by site type. For each site type, discussion will focus on the objectives, the options involved, and the rationale for the livestock grazing strategy.

The livestock grazing strategies presented by Eddleman and others (1994) are speculative, yet are based on observations and findings from many years of research in western juniper ecosystems. These strategies should be regarded as a foundation for discussion and generation of hypotheses for future research into the effects of livestock grazing on western juniper demography.

Site 1. Young woodlands (dominated by trees < 100 years old) with a canopy cover near or at the site maximum, and on shallow soils.

Livestock Grazing Strategy

Objectives:

1) Vigorous, desirable, forage plants

2) Understory plant canopy cover

3) Well dispersed plants across the site

4) Maximum litter cover and dispersion

Options Involved:

- Light utilization of understory plants (not exceeding 15-25%) by livestock when these plants are near maturity, or after maturity.
- Repeated light utilization during the late growth period, permissible only in years when precipitation received during the typical growth period sustains normal to above-normal production. Caution with regard to repeated light utilization should be exercised because the precipitation timing and interval that sustains normal to above-normal production varies by understory species and there is little species-specific information presently available.

Rationale:

Where dry conditions or shallow soils (generally < 30 cm in depth) exist, there is little soil storage of precipitation and the availability of soil water for understory growth becomes limiting in amount and duration. Characteristics of western juniper that exacerbate the potential for understory growth include: (1) the interception of precipitation by the canopy and litter layer, (2) the use of stored soil water from intercanopy areas before understory species commence growth and during their growth periods, and (3) the use of incident precipitation that falls during summer dormancy of understory species. Grazing of understory species during the growth period under the above-stated conditions is deleterious because plant loss of vigor, density, and ground cover is likely. Effective precipitation for growth is restricted mainly to fall, winter, and spring; thus, the window of water and nutrient availability is optimal only early or late in the growing season, and is of short duration. Grazing during the early portion of the growing season would appear to be damaging to understory plant vigor because the short window of soil water and nutrient availability might close and prevent regrowth. Fall precipitation might stimulate regrowth of understory plants that are nearing maturity, and permit light grazing (10 to 15 % utilization).

The deleterious effects of excessive grazing pressure on understory species will probably not be ameliorated by rest (absence of grazing) of one, two, or even three years because during the grazed periods western juniper could incrementally gain in site dominance and impede future recovery of understory species during ungrazed periods. The importance of rest in permitting recovery will increase if rest is concurrent with wet years.

Grazing of plants after maturity has effects on the insulating qualities of the plants relative to the soil, which in turn has hydrological effects on the site. Understory plants insulate the soil from soil temperature fluctuations and moisture evaporation. Understory plants lose their insulating effectiveness if they sustain excessive grazing pressure and do not regrow before winter. Wet soil surfaces in intercanopy areas of western juniper woodlands, characterized by a lack of plant or snow insulation, can develop concrete frost in the cold portion of winter, and subsequently freeze and thaw diurnally in late winter and early spring. Precipitation can run off of soils with concrete frost because infiltration rates are nearly zero. Freeze-thaw activity pulls water to the soil surface where it can evaporate. Temporary warm winter periods in

western juniper woodlands, when coinciding with unfrozen soil, can result in evaporation of surface soil moisture.

Precipitation is typically not sufficient to fully recharge the soil and counteract the evaporative loss in western juniper woodlands that have sustained grazing in the late growing season. Soil water storage and the amount of water that will be available for plant growth in the subsequent growing season could therefore be reduced on shallow soils with inherent low water storage capacity.

Conversely, some shallow soils, particularly those associated with the low sagebrush PVTs, can become saturated during the winter. Added inputs of precipitation or snowmelt on these saturated shallow soils can result in runoff. Plant cover and dispersion, and litter, can reduce sediment transport in this runoff.

Site 2. Young woodlands (dominated by trees < 100 years old) on deep soils.

Livestock Grazing Strategy

Objectives:

Objectives 1 through 4 from Site 1 are again pertinent, with an additional fifth objective:

5) Sustained growth of desired understory plants during the growing season

Options Involved:

On sites characterized by prevalent understory grasses:

- Same strategy as previously mentioned for Site 1.

On sites characterized by a declining grass base:

- Light utilization of understory plants (not exceeding 15-25%) by livestock, and substantial periods of rest.

On sites characterized by virtually no vascular plant cover:

- Non-use.

On sites characterized by full occupancy by annual grasses such as cheatgrass or medusahead:

- Carefully planned grazing or non-use.

Rationale:

Potentially greater amounts of available soil water can be stored in a deep soil compared with a shallow soil. This translates to greater potential biomass production of understory species and greater potential for regrowth and plant recovery from grazing. Healthy understory plants and their canopy cover promote detention of surface water, absence of concrete frost, and dispersion of plant biomass over the site. Grazing pressure that results in high levels of utilization after plant maturity can diminish canopy cover and thus restrict water storage during the winter.

Water storage during the winter, supplemented with additional precipitation in the spring, can sustain plant growth over relatively long durations. Successive, light removal of herbage by grazing should be possible under these conditions and still not adversely affect either plant vigor or the nutrient pool of the plant. Bitterbrush, other shrubs, and forbs would not likely be utilized excessively, and competition of annual grasses with perennial grasses would not likely be increased. The probability of interference of western juniper with understory species is increased if grazing pressure results in utilization that delays plant regrowth initiation.

Sites that support a declining grass base will probably require light use and extended rest periods to permit plant recovery. Sites that support virtually no vascular plant cover cannot legitimately accommodate any grazing prescription except non-use. There should be little expectation for understory species recovery even in the absence of grazing. Full site occupancy by annual grasses (such as cheatgrass or medusahead) mandates carefully planned grazing or non-use because grazing utilization of these species can result in sediment loss from the site during periods of potentially high runoff.

Site 3. Woodlands subsequent to western juniper control.

Livestock Grazing Strategy

Objectives:

Objectives 1 through 5, previously mentioned, are also pertinent, with an additional sixth objective:

6) Rapid site dominance by desired understory species

Options Involved:

On sites that support prevalent understory vegetation at the time of control:

- Non-use in year 1 (post-treatment); defer grazing until seed set in year 2.
- Repeated light utilization, rest, rotated seasonal utilization, and deferred utilization are options permissible within a grazing strategy.

On sites that support moderate understory vegetation at the time of control:

- Non-use in year 1 and 2 (post-treatment); defer grazing until seed set in year 3.
- Repeated light utilization, rest, rotated seasonal utilization, and deferred utilization are options permissible within a grazing strategy.

On sites that support little if any understory vegetation at the time of control:

- Non-use until year 3 or 4 (post-treatment), when recovery of plant vigor is apparent, including reproduction and seedling establishment.
- Single or repeated light utilization when plants are nearing maturity, or light utilization after maturity, possibly until year 5 or 6 (post-treatment).
- Repeated light utilization, rest, rotated seasonal utilization, and deferred utilization are options permissible within a grazing strategy.

On sites that are seeded:

- Non-use until year 2, 3, or 4 (post-treatment) when seedling establishment is attained and a competitive population is present.
- Single or repeated light utilization when plants are nearing maturity, or light utilization after maturity, possibly not until year 4, 5 or 6 (post-treatment).
- Repeated light utilization, rest, rotated seasonal utilization, and deferred utilization are options permissible within a grazing strategy.

Adjustments in this livestock grazing strategy might be necessary because control of western juniper could be accomplished by several different techniques, each of which affect site responses to grazing management somewhat differently. Adjustment in the grazing strategy might be necessary to foster certain species compositions over others. For example, there is potential for this grazing strategy to accelerate invasion of exotic plant species, such as cheatgrass, medusahead, or noxious weeds.

Control of western juniper does not equate to eradication. Western juniper seedlings will undoubtedly be present in uneven-aged stands that sustain juniper control. A sizeable seed bank of western juniper will undoubtedly exist in even-aged or uneven-aged stands that sustain juniper control. These mechanisms ensure future site dominance by western juniper. Subsequent periodic control with burning, tree cutting, or commercial harvest (not yet practiced on Federal land) will maintain non-woodland or open (minor canopy cover) woodland conditions.

Rationale:

Understory species typically respond positively in production after control of western juniper. Herbaceous production on a species-specific level typically peaks at year 2 or 3 (post-control of western juniper). Subsequent herbaceous production typically declines to a level somewhat greater than the pre-control level. Recovery time might be delayed on sites that support moderate to low quantities or no understory vegetation because

species would need to establish new populations from newly formed seed banks or other propagules.

The probability and amount of understory regrowth are increased on these sites because of enhanced soil water availability attributable to the control of western juniper (that is, reduction in photosynthetic tissue and transpirational leaf area). Enhanced soil water availability extends the length of the growing period: observations indicate continuous spring, summer, and fall understory growth in year 1 and 2 (post-control of western juniper). Grazing pressure resulting in light utilization will ensure that some photosynthetic tissue remains after grazing from which regrowth can initiate, rather than total denudation of plants and regrowth being initiated through new tiller and leaf material.

Site 4. Sites susceptible to western juniper encroachment and dominance.

Livestock Grazing Strategy

Objectives:

Objectives 1 through 5, previously mentioned, are pertinent here, with three additional objectives:

7) Maintain site dominance by desired understory species

8) Prevent rapid dispersal of western juniper seed originating from upslope

9) Limit big sagebrush density

Options Involved:

Numerous options within grazing strategies previously mentioned are applicable here. The strategy selected will depend on soil depth of the sites, and visual trend and composition (for example, stable trend, declining trend, dominance by annual grasses, virtually no herbaceous biomass) of the herbaceous understory vegetation.

Rationale:

The rate of western juniper encroachment and dominance will be constrained if a vigorous grass understory is maintained. A vigorous grass understory will restrict surface flow of water during the late fall, winter, and early spring periods, which are typical seed dispersal periods for western juniper. A decline in western juniper recruitment will result.

As previously mentioned, big sagebrush provides a safe site for establishment of western juniper seedlings. Sagebrush control measures might be necessary on some sites to reduce sagebrush densities to a reasonable level. The maintenance of a vigorous understory will restrict establishment of sagebrush and western juniper seedlings.

Exotic Plants-Noxious Weeds

This subsection is primarily a summarization of Karl and others (1995), an ICBEMP report which focused on exotic plants that have proven to be problematic on Basin rangelands and riparian areas. Additional information regarding exotic plants on forested lands is incorporated into this subsection, primarily from the Invaders database (ICBEMP Invaders database 1995[4]).

Historical trends—The Basin has experienced numerous exotic plant invasions in the last 100 years [(Franklin and Dyrness 1973, Yensen 1981, and Young and others 1972), in Mack 1986]. Presently, there are approximately 862 species of exotic plants existing within the Pacific Northwest (Washington, Oregon, Idaho, Montana, and Wyoming; Rice 1994). Nearly all of these 862 species inhabit the Basin. These 862 exotic plant species represent 43 percent of the estimated 2,000 exotic plant species present in the entire United States (U.S. Congress, Office of Technology Assessment 1993, in Vitousek and others 1996).

[4] ICBEMP Invaders database. 1995. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management, Interior Columbia Basin Ecosystem Management Project, Walla Walla, WA 99362.

Many of the exotic plants existing within the Basin originated in the Mediterranean region. The climate of the Mediterranean region (wet, cool autumns and winters; and dry, hot summers) is similar to the climate of the Basin, particularly the portion of the Basin that lies west of the Rocky Mountains. Thus, many exotic plants are adapted to the Basin climate (Trewartha 1981, in Mack 1986; Young and others 1972, in Mack 1986).

Euro-American settlement of the Basin in the late-1800s facilitated the invasion and expansion of exotic plants. Agricultural practices were the major avenue by which exotic plants initially entered the Basin. The seed of many exotic plants was a contaminant of crop seed, and some exotic plants were deliberately introduced to provide livestock forage. The severe depletion of native bunchgrasses on Basin rangelands, caused by livestock overgrazing and trampling, was often the impetus for deliberate introductions of forage species (Mack 1981, in Mack 1986). Thus, the land-use change from wildlands to agriculture—a transition that was the most prevalent change between the historical and the current periods—has promoted invasions of numerous exotic plants in the Basin. Not surprisingly, this change in land use has promoted invasions of exotic plants on a global scale as well (Vitousek and others 1996).

Noxious weeds: a subset of exotic plants—Of the 862 exotic plants existing within the 5-state region (Washington, Oregon, Idaho, Montana, and Wyoming) of the Pacific Northwest, 115 species have been legally declared as "noxious weeds" by at least one of the five states. "Noxious" is a legal classification and not an ecological term. Plants that can exert substantial negative environmental or economic impact can be designated as "noxious" by various governmental agencies. Of the 25 exotic plant species listed in table 3.13, 24 are legally declared noxious in at least one of five Basin states. These 24 noxious weeds represent a subset of the 115 noxious weeds.

Success of exotic plants-noxious weeds—Present distributions of many exotic plants within the Basin, including the noxious weeds, are increasing rapidly and in some cases exponentially (Asher 1994, Rice 1994, Rice and Rider 1995). This rapid rate of expansion is partly attributable to the life history of exotic plants. Exotic plants are often opportunists, and many are pioneer, colonizing species. They are frequently one of the first species to arrive and colonize areas that have experienced soil-surface disturbance or areas that lack plant cover. Their establishment and spread is aided by disturbance to the soil surface (Baker 1986, Bazzaz 1986). Exotic plants that are characterized as having an opportunistic, colonizing life history—referred to as "colonizers" by Bazzaz (1986)—are typically prolific producers of disseminules and often are adapted to long-distance dispersal by means of vehicles, wind, wildlife, livestock, water, or machinery. They usually germinate under a wide variety of conditions, establish quickly, exhibit fast seedling growth, and out-compete native species for water and nutrients.

Other exotic plants, such as the noxious weeds spotted knapweed, yellow starthistle, and leafy spurge, can be categorized as "invaders" (Bazzaz 1986). Invaders can establish within relatively intact vegetation cover, and displace the native species without the aid of soil-surface disturbance. While noxious weeds can be colonizers or invaders or both, depending on the plant community, it is noteworthy and perhaps indicative of their noxious weed status that many of them act as invaders. For example, spotted knapweed, yellow starthistle, and leafy spurge have exhibited the ability to invade relatively undisturbed sites, including wilderness areas and National Parks (Asher 1994, Tyser and Key 1988).

Reasons why exotic plants-noxious weeds are problematic—Exotic plants, including noxious weeds, represent biological invasions. As agents of global change, exotic plants were rated as highly as climate change by Vitousek and others (1996). The invasive potential of exotic plants can alter the biophysical template by altering ecosystem processes. Vitousek and others (1996) listed examples of potentially altered ecosystem processes including: (1) primary productivity, (2) decompo-

sition, (3) hydrology, (4) nutrient cycling, and (5) natural disturbance regimes. Alteration of these processes by exotic species can lead to displacement of native biota.

The invasion of exotic plants can change the structure, composition, and successional pathways of ecosystems at various scales (from the landscape element to subregional scale). An example of the subregional scale is the invasion and dominance of cheatgrass and/or medusahead in the Snake River Plains of the Owyhee Uplands ERU. The establishment of potential vegetation that is representative of the biophysical template can be prevented by exotic plant invasion. In effect, potential vegetation can be changed from a native plant type to an exotics type. The reduction in biodiversity at all scales is a possible response of this change in potential vegetation. Indeed, Billings (1994) warns that in the cheatgrass-dominated areas of the Intermountain region, including the Snake River Plains of the Owyhee Uplands ERU, some native biota are in danger of extirpation at the local or regional scale.

Although studies concerning the effects of exotic plants on hydrologic systems are generally lacking, accumulating evidence is revealing that invasions of exotic plants into native plant communities can result in increased surface runoff and sediment yield, particularly at the plot scale (Lacey and others 1989). Watershed-scale studies of the hydrological effects of exotic plant invasion would be helpful in clarifying the effects to aquatic ecosystems.

The fact that exotic plants can function as agents of change of native succession/disturbance regimes has frequently been addressed in this chapter. Exotic annual grasses, for example cheatgrass, medusahead, and ventenata, can produce relatively greater amounts of flammable, fine fuels compared with native herbaceous species. Susceptibility to wildfire tends to increase in the effected cover types as fine-fuel loads become greater, thus shortening the fire-return interval. Native plants that are not adapted to the shortened fire-return interval cannot sustain their populations. As native plant populations decline, exotic annual grasses incrementally gain in dominance, further perpetuating the shortened fire-return interval.

Conversely, the presence of some exotic forbs might lengthen fire-return intervals. Bushey (1995) reports that plant communities dominated by diffuse knapweed or spotted knapweed are difficult to burn because of a lack of fine fuels. Bushey (1995) speculates that the lack of fine fuels is attributable to allelopathy by these forbs. Another causal mechanism might be the aboveground morphology of these forbs, which in comparison to graminoids is skewed toward greater stem material production rather than leaf production. Allelopathy and prevalence of stem material would reduce the likelihood of fire spread between plants. Experimental studies would aid in clarifying the relation of exotic forbs to fire and disturbance regimes.

Susceptibility of broad-scale cover types to invasion, and broad-scale distribution of 25 selected exotic plants—Dewey and others (1991) propose that "The precision and usefulness of federal weed control Environmental Assessment (EA) and Environmental Impact Statement (EIS) documents would be significantly improved by knowing the exact location and extent of lands vulnerable to specific noxious weeds." We endeavored to do just that by developing a Susceptibility to Invasion Index for 38 broad-scale Basin cover types and characterizing their susceptibility to invasion by the 25 focal exotic plants (table 3.174).

Of the 25 exotic plant species assessed in Karl and others (1995), 11 exhibit a somewhat restricted county distribution in the Basin; and 14 exhibit a widespread county distribution in the Basin (table 3.13). County distributions for widespread species ranged from 48 counties for oxeye daisy (*Chrysanthemum leucanthemum*) to all 97 counties located within the five Basin states (Washington, Oregon, Idaho, Montana, and Wyoming) for Canada thistle and cheatgrass. County distributions for the somewhat restricted species ranged from four counties for squarrose knapweed (*Centaurea virgata*) to 55 counties for yellow starthistle.

County-distribution maps for these 25 species can be found in Karl and others (1995) and Rice and Rider (1995).

The susceptibility of Basin cover types to invasion, and distributional patterns of the 25 focal exotic plants are described in detail as follows:

(A) Exotic plants with somewhat restricted distributions:

Common crupina (*Crupina vulgaris*)

The distribution of common crupina is disjunct with populations existing in Washington, Oregon, and Idaho. Common crupina is particularly prevalent in north-central Idaho, where the Columbia Plateau, Blue Mountains, and Central Idaho Mountains ERUs meet. Sites that are particularly susceptible to invasion in the aforementioned ERU convergence area and presently support populations of common crupina are southern slopes in steep canyon grasslands (for example, the wheatgrass bunchgrass and fescue-bunchgrass cover types; rated of moderate susceptibility to invasion; table 3.174) and areas at elevations of approximately 300 to 1,000 meters and within a 38 to 76 centimeters annual precipitation zone.[5]

Dyers woad (*Isatis tinctoria*)

Populations of Dyers woad exist throughout the Basin, but distribution by county is scattered. The area of greatest prevalence is in southeast Idaho, in the Snake Headwaters and Upper Snake ERUs. At present, the Northern Cascades, Columbia Plateau, and Northern Glaciated Mountains ERUs are primarily outside the distribution of Dyers woad. Numerous cover types are of high susceptibility to invasion by Dyers woad, including grasslands (fescue-bunchgrass and wheatgrass bunchgrass), shrublands (big sagebrush, low sagebrush, mountain big sagebrush), and agricultural lands (cropland/hay/pasture)(table 3.174).

Halogeton (*Halogeton glomeratus*)

The distribution of halogeton is restricted primarily to southeast Oregon and southern Idaho, in the Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs. Halogeton populations in these ERUs are restricted primarily to (1) elevations of 700 to 2,200 meters, (2) saline soils, (3) annual precipitation zones of approximately 12.5 to 33.0 centimeters, and (4) the salt desert shrub cover type, which is of high susceptibility to invasion by halogeton (table 3.174).

Mediterranean sage (*Salvia aethiopis*)

The distribution of Mediterranean sage lies primarily in Oregon and north-central Idaho. An area of great prevalence is in southeast Oregon, particularly in the Northern Great Basin ERU. At present, the Northern Cascades, Southern Cascades, Northern Glaciated Mountains, Lower Clark Fork, Upper Clark Fork, Upper Snake, and Snake Headwaters ERUs are primarily outside the distribution of this species. The grassland cover types (fescue-bunchgrass and wheatgrass bunchgrass) and the big sagebrush cover type are of high susceptibility to invasion by Mediterranean sage (table 3.174) and support populations of this species.

Medusahead (*Taeniatherum caput-medusae*)

The present distribution of medusahead is in the western portion of the Basin, but medusahead is spreading eastward. Areas of great prevalence are in the Columbia Plateau, Northern Great Basin, Blue Mountains, and Owyhee Uplands ERUs in Oregon and Idaho. Currently, the Lower Clark Fork, Upper Clark Fork, Central Idaho Mountains, Upper Snake, and Snake Headwaters ERUs are primarily outside the distribution of medusahead. Sites that are susceptible to medusahead establishment and support populations are characterized by (1) the presence of vertic soils (soils with a substantial clay component that shrink and

[5] Personal communication. 1995. Peter M. Rice, Research Associate, Division of Biological Sciences, University of Montana, Missoula, MT 59812-1002.

swell from drying or wetting); (2) an annual precipitation zone of 25 to 100 centimeters; (3) an elevation of less than 1,400 meters; and (4) numerous cover types, particularly grassland (wheatgrass bunchgrass and fescue-bunchgrass), shrubland (low sagebrush and big sagebrush), and juniper cover types (juniper/sagebrush and juniper woodland), all of which are of moderate susceptibility to invasion (table 3.174).

Orange and yellow hawkweeds (*Hieracium aurantiacum, H. pratense*)

The distributions of these two species are similar. Both have distributions centered in the Idaho panhandle, northwest Montana, and northeast Washington, in the Northern Glaciated Mountains and Lower Clark Fork ERUs. Sites that are susceptible to invasion by the hawkweeds in the aforementioned locations include elevations exceeding 600 meters and mountain meadows. The herbaceous wetlands and cottonwood/willow cover types are of high susceptibility to invasion by orange and yellow hawkweed, respectively (table 3.174).

Rush skeletonweed (*Chondrilla juncea*)

The distribution of rush skeletonweed primarily lies within the Columbia Plateau, Blue Mountains, Central Idaho Mountains, and Owyhee Uplands ERUs. Areas of great prevalence are in southwest Idaho in the Owyhee Uplands ERU, and in eastern Washington in the Columbia Plateau ERU. Cover types that are of high susceptibility to invasion and support populations of rush skeletonweed are cropland/hay/pasture and exotic forbs/annual grass (table 3.174). Other cover types, rated of moderate susceptibility in table 3.174, that also are of particular susceptibility to invasion are big sagebrush, wheatgrass bunchgrass, and bitterbrush/bluebunch wheatgrass.[6]

[6] Personal communication. 1995. Peter M. Rice, Research Associate, Division of Biological Sciences, University of Montana, Missoula, MT 59812-1002.

Squarrose knapweed (*Centaurea virgata*)

The distribution of this species lies primarily in the Blue Mountains and Owyhee Uplands ERUs in Oregon. Its areal extent in the aforementioned ERUs is minor (< 350 ha in 1990) and is primarily in the Blue Mountains ERU. Cover types that are susceptible to squarrose knapweed establishment and support populations include juniper/sagebrush, juniper woodland, and big sagebrush (Roche and Burrill 1992), all of which are of moderate susceptibility to invasion (table 3.174).

Sulfur cinquefoil (*Potentilla recta*)

The distribution of sulfur cinquefoil primarily lies within the Northern Glaciated Mountains, Upper Clark Fork, Lower Clark Fork, Central Idaho Mountains, and Blue Mountains ERUs. Its distribution is expanding to the west and south, within the Basin. Areas of great prevalence are in the Upper Clark Fork, Lower Clark Fork, and Northern Glaciated Mountains ERUs in the Idaho panhandle and western Montana. Cover types that are of high susceptibility to invasion and support populations of this species in the aforementioned ERUs include grasslands (fescue-bunchgrass, wheatgrass bunchgrass, and herbaceous wetlands), the drier forests (interior ponderosa pine and interior Douglas-fir), and the exotic forbs/annual grass type (table 3.174).

Yellow starthistle (*Centaurea solstitialis*)

The distribution of yellow starthistle includes portions of all ERUs except the Snake Headwaters, and possibly the Upper Snake. The areas of greatest prevalence are in the Columbia Plateau and Blue Mountains ERUs in extreme southeast Washington and the Idaho panhandle, and the Owyhee Uplands ERU in southwest Idaho. Cover types that are of high susceptibility to invasion and support populations of this species in the aforementioned ERUs include grasslands

Table 3.174—Cover type Susceptibility to Invasion Index by 25 exotic plant species (24 legally-declared noxious, plus cheatgrass).

	Exotic Plant Species Code[1]																									Total			
Cover Type	Brte	Canu	Caspp	Cedi	Cema	Cere	Ceso	Cevi	Chju	Chle	Ciar	Civu	Crvu	Eues	Hagl	Hiau	Hipr	Isti	Lida	Livu	Lysa	Onac	Pore	Saae	Taas	H	M	L	U
Alpine Tundra	L[2]	L	L	L	L	L	L	L	L	L	M	M	L	L	L	M	L	L	M	L	L	L	L	U	L	0	4	20	1
Aspen	M	M	M	M	M	M	M	M	M	M	H	M	M	M	M	M	M	M	M	M	L	U	M	U	M	1	21	1	2
Big Sagebrush	H	U	M	M	M	M	M	M	M	U	M	M	L	M	M	L	L	H	M	M	L	M	U	H	M	3	15	4	3
Bitterbrush / Bluebunch Wheatgrass	H	M	M	H	M	U	M	M	U	U	M	M	M	M	M	L	L	M	M	M	L	U	M	U	M	2	15	3	5
Chokecherry / Serviceberry/Rose	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	H	M	M	M	M	M	U	M	1	23	0	1
Cottonwood / Willow	M	M	M	M	H	M	M	M	M	H	H	M	L	H	L	M	H	M	M	M	M	M	M	U	M	5	17	2	1
Cropland / Hay / Pasture	M	M	H	M	H	M	H	M	H	M	M	M	M	H	M	M	M	H	M	M	L	M	M	U	M	6	17	1	1
Engelmann Spruce / Subalpine Fir	H	H	M	M	M	M	M	M	M	H	H	H	L	M	L	M	M	L	M	M	M	U	M	U	M	5	15	3	2
Exotic Forbs / Annual Grass	H	M	H	M	M	M	H	H	H	M	M	M	M	M	M	M	M	H	H	H	M	M	H	M	M	9	16	0	0
Fescue-Bunchgrass	H	H	M	H	H	M	H	M	M	M	H	H	M	H	M	L	L	H	H	H	L	M	H	H	M	13	9	3	0
Grand Fir / White Fir	M	M	M	M	M	M	M	M	M	M	M	M	L	M	L	M	U	L	M	M	M	U	M	U	M	0	19	3	3
Herbaceous Wetlands	M	M	M	M	H	M	H	M	L	H	H	M	L	M	L	H	M	M	M	H	H	M	H	U	M	8	13	3	1
Interior Douglas-fir	H	H	M	M	H	M	M	M	M	M	H	H	M	M	M	M	M	M	M	M	L	M	H	U	M	6	17	1	1
Interior Ponderosa Pine	H	M	M	H	H	M	M	M	M	M	M	M	M	M	M	L	L	M	M	M	L	M	H	U	M	4	17	3	1
Juniper / Sagebrush	M	M	M	M	M	U	M	M	M	U	M	M	L	M	M	L	L	H	M	M	L	U	U	U	M	1	15	4	5
Juniper Woodlands	M	M	M	M	M	U	M	M	M	U	M	M	L	M	M	L	L	M	M	M	L	U	M	U	M	0	17	4	4
Limber Pine	M	M	M	M	M	M	M	M	M	M	M	M	M	L	M	M	L	M	M	M	L	L	M	U	M	0	20	4	1
Lodgepole Pine	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	L	M	M	M	L	M	M	U	M	0	22	2	1
Low Sagebrush	M	U	M	M	U	U	M	M	U	U	M	M	L	M	M	L	L	H	M	U	L	U	U	U	M	1	11	4	9
Mixed-Conifer Woodlands	H	M	M	M	H	M	M	M	M	U	H	M	L	M	M	L	L	M	M	M	L	U	H	U	M	4	14	4	3
Mountain Big Sagebrush	H	M	M	M	M	M	M	M	M	U	M	M	L	M	M	L	L	H	M	M	L	M	M	U	M	2	17	4	2
Mountain Hemlock	M	M	M	M	M	M	M	M	M	M	M	M	L	L	L	M	M	L	M	M	M	L	M	U	M	0	19	5	1
Mountain Mahogany	M	M	M	M	M	M	H	M	U	U	M	M	M	M	M	L	L	M	H	M	L	U	M	H	M	3	16	3	3
Native Forb	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	L	L	M	M	M	M	M	H	U	M	1	21	2	1

Table 3.174 (continued).

Cover Type	Exotic Plant Species Code[1]																									Total			
	Brte	Canu	Caspp	Cedi	Cema	Cere	Ceso	Cevi	Chju	Chle	Ciar	Civu	Crvu	Eues	Hagl	Hiau	Hipr	Isti	Lida	Livu	Lysa	Onac	Pore	Saae	Taas	H	M	L	U
Oregon White Oak	M	U	M	M	M	M	M	M	M	M	M	M	M	M	M	L	L	M	U	M	L	M	M	U	M	0	19	3	3
Pacific Ponderosa Pine	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	L	L	M	M	M	L	M	M	U	M	0	21	3	1
Pacific Silver Fir / Mountain Hemlock	M	M	M	M	M	M	M	M	M	M	M	M	L	L	L	M	M	L	M	M	M	L	M	U	M	0	19	5	1
Red Fir	M	M	M	M	M	M	M	M	M	M	M	M	L	L	L	M	M	L	M	M	M	L	M	U	M	0	19	5	1
Salt Desert Shrub	M	M	M	L	L	M	L	M	L	L	M	M	L	M	H	L	L	L	L	L	L	L	L	U	L	1	8	15	1
Shrub or Herb / Tree Regen	M	M	M	M	M	M	M	M	H	M	M	M	M	M	M	M	L	M	M	M	L	M	H	U	M	2	20	2	1
Shrub Wetlands	M	H	M	M	H	M	M	M	L	M	H	H	L	M	L	M	M	M	M	M	H	M	M	U	M	5	16	3	1
Sierra Nevada Mixed-Conifer	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	L	L	M	M	M	L	M	M	U	M	0	21	3	1
Western Larch	M	M	M	M	M	M	M	M	M	M	H	M	M	M	M	M	M	M	M	M	L	M	M	U	M	1	22	1	1
Western Redcedar / Western Hemlock	M	H	M	M	M	M	M	M	M	H	H	H	L	M	L	M	M	L	M	M	M	U	M	U	M	4	16	3	2
Western White Pine	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	L	U	M	U	M	0	22	1	2
Wheatgrass Bunchgrass	H	M	M	H	H	M	H	M	M	M	H	M	M	M	M	L	L	H	H	M	L	M	H	H	M	9	13	3	0
Whitebark Pine	L	L	L	L	L	L	L	M	L	L	M	M	L	L	L	M	L	L	M	L	L	L	L	U	M	0	6	18	1
Whitebark Pine / Subalpine Larch	L	L	L	L	L	L	L	L	L	L	M	M	L	L	L	M	L	L	M	L	L	L	L	U	L	0	4	20	1
Total H	10	5	2	4	9	0	6	1	3	4	11	5	0	3	1	1	1	9	4	3	2	0	9	4	0				
Total M	25	27	33	30	24	31	28	35	26	22	27	33	19	28	25	21	14	19	32	30	10	19	22	1	35				
Total L	3	3	3	4	4	3	4	2	6	4	0	0	19	7	12	16	22	10	1	4	26	8	4	0	3				
Total U	0	3	0	0	1	4	0	0	3	8	0	0	0	0	0	0	1	0	1	1	0	11	3	33	0				

[1] Species codes for exotic plants: Brte = cheatgrass; Canu = musk thistle; Caspp = whitetop; Cedi = diffuse knapweed; Cema = spotted knapweed; Cere = Russian knapweed; Ceso = yellow starthistle; Cevi = squarrose knapweed; Chju = rush skeletonweed; Chle = oxeye daisy; Ciar = Canada thistle; Civu = bull thistle; Crvu = common crupina; Eues = leafy spurge; Hagl = halogeton; Hiau = orange hawkweed; Hipr = yellow hawkweed; Isti = Dyers woad; Lida = dalmatian toadflax; Livu = yellow toadflax; Lysa = purple loosestrife; Onac = Scotch thistle; Pore = sulfur cinquefoil; Saae = Mediterranean sage; Taas = medusahead.

[2]Susceptibility classes: H = High susceptibility to invasion — Exotic plant species is an "invader" and invades the cover type successfully and becomes dominant or codominant even in the absence of intense or frequent disturbance; M = Moderate susceptibility to invasion — Exotic plant species is a "colonizer" and invades the cover type successfully because high intensity or frequency of disturbance impacts the soil surface or removes the normal canopy cover; L = Low susceptibility to invasion — Exotic plant species typically does not establish because the cover type does not provide suitable habitat; and U = Unknown susceptibility to invasion — Herbarium records did not indicate any association between the exotic plant and the cover type, and/or ecological requirements of the exotic plant are not available in the literature, and/or there was a lack of distribution records (for example, herbaria mounts) for the exotic plant, and/or the extent of the cover type in the Basin might be so minor as to prevent or restrict the probability of obtaining distribution records for the exotic plant within that cover type.

(fescue-bunchgrass and wheatgrass bunchgrass), agricultural lands (cropland/hay/pasture), and exotic forbs/annual grass (table 3.174). The areal extent of these highly susceptible cover types within the 30.0-to-63.5-centimeters precipitation zone of yellow starthistle is portrayed spatially in map 3.27. In descending order of extent (percent of ERU), ERUs with greater than or equal to 10 percent extent of lands of high susceptibility to invasion by yellow starthistle are: Upper Snake (29%), Columbia Plateau (27%), Blue Mountains (22%), Snake Headwaters and Upper Clark Fork (14% each), and Central Idaho Mountains and Northern Glaciated Mountains (10% each) (map 3.27). The extent of lands that are of high susceptibility to invasion in the Upper Snake and Snake Headwaters ERUs is notable because the distribution of yellow starthistle has not yet expanded into those ERUs.

(B) Exotic plants with widespread distributions:

Bull thistle (*Cirsium vulgare*)

The distribution of bull thistle includes portions of every ERU. About three-quarters of the Basin counties have confirmed the presence of bull thistle, with unconfirmed counties lying primarily in southern Idaho in the Owyhee Uplands and Upper Snake ERUs. Presence of bull thistle is suspected in these unconfirmed counties, however.[7] Cover types of high susceptibility to invasion by bull thistle include some forest types (Engelmann spruce/subalpine fir, interior Douglas-fir, and western redcedar/western hemlock), grasslands (fescue-bunchgrass), and riparian types (shrub wetlands) (table 3.174).

Canada thistle (*Cirsium arvense*)

At the ERU and county scales, the distribution of Canada thistle is ubiquitous in the Basin. Populations are typically located within a 38- to 76-centimeters precipitation zone. Numerous cover types are of high susceptibility to invasion, including grasslands (fescue-bunchgrass and wheatgrass bunchgrass), riparian types (cottonwood/willow, herbaceous wetlands, and shrub wetlands), and some forest types (aspen, Engelmann spruce/subalpine fir, interior Douglas-fir, and western redcedar/western hemlock) (table 3.174).

Cheatgrass (*Bromus tectorum*)

At the ERU and county scales, the distribution of cheatgrass is ubiquitous in the Basin. Areas of great prevalence include the Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs. Cover types that are of high susceptibility to invasion and support cheatgrass populations in the aforementioned ERUs include grasslands (fescue-bunchgrass and wheatgrass bunchgrass), shrublands (big sagebrush), shrubland-grassland (bitterbrush/bluebunch wheatgrass), the drier forest types (interior ponderosa pine and interior Douglas-fir), and exotic forbs/annual grass (table 3.174). The areal extent of these highly susceptible cover types within the 15-to-56-centimeters precipitation zone of cheatgrass is portrayed spatially in map 3.26. In descending order of extent (percent of ERU), ERUs with greater than or equal to 25 percent extent of lands of high susceptibility to invasion by cheatgrass are: Owyhee Uplands (67%), Northern Great Basin (64%), Upper Snake (46%), Blue Mountains and Columbia Plateau (34% each), Upper Klamath (28%), and Upper Clark Fork (26%) (map 3.26).

Dalmatian toadflax (*Linaria dalmatica*)

The distribution of dalmatian toadflax includes portions of every ERU. Counties with unconfirmed dalmatian toadflax presence primarily lie in southeast Idaho in the Owyhee Uplands and Upper Snake ERUs. Cover types that are of high susceptibility to

[7] Personal communication. 1995. Loal Vance, Idaho Department of Agriculture, 120 Klotz Lane, Boise, ID 83712.

invasion by this species include grasslands (fescue-bunchgrass and wheatgrass bunchgrass), mountain mahogany, and exotic forbs/annual grass (table 3.174).

Yellow toadflax (*Linaria vulgaris*)

The distribution of yellow toadflax includes portions of every ERU, but its distribution at the county scale is less extensive than dalmatian toadflax. Counties with unconfirmed presence lie primarily in the Columbia Plateau, Blue Mountains, and Owyhee Uplands ERUs. Cover types that are of high susceptibility to invasion include grasslands (fescue-bunchgrass and herbaceous wetlands) and exotic forbs/annual grass (table 3.174).

Diffuse knapweed (*Centaurea diffusa*)

The distribution of diffuse knapweed includes portions of every ERU. Counties with unconfirmed presence lie primarily in the Central Idaho Mountains, Upper Snake, and Snake Headwaters ERUs in Idaho. Areas of great prevalence lie within the Northern Glaciated Mountains, Northern Cascades, Southern Cascades, and Columbia Plateau ERUs in Washington and Oregon. Cover types that are of high susceptibility to invasion and support populations of diffuse knapweed in the aforementioned ERUs include grasslands (fescue-bunchgrass and wheatgrass bunchgrass), shrubland-grassland (bitterbrush/bluebunch wheatgrass), and dry forest (interior ponderosa pine) (table 3.174). The areal extent of these highly susceptible cover types within the 15-to-89-centimeters precipitation zone of diffuse knapweed is portrayed spatially in map 3.37. In descending order of extent (percent of ERU), ERUs with greater than or equal to 10 percent extent of lands of high susceptibility to invasion by diffuse knapweed are: Upper Klamath (37%), Blue Mountains (24%), Southern Cascades (23%), Upper Clark Fork (22%), Central Idaho Mountains and Northern Cascades (18% each), Northern Glaciated Mountains (15%), and Columbia Plateau (13%) (map 3.37). The extent of lands that are of high susceptibility to invasion in the Upper Klamath and Blue Mountains ERUs is notable because diffuse knapweed is not reported to be prevalent in these ERUs at present; it is present, however, and spreading in the Blue Mountains ERU (Harrod and others 1996).

Whitetop (*Cardaria draba, C. chalapensis, C. pubescens*)

The distribution of the whitetop species complex includes portions of every ERU. Counties with unconfirmed presence are few and scattered across the Basin. Whitetop is particularly prevalent in northeast Oregon in the Blue Mountains ERU. Cover types that are of high susceptibility to invasion include agricultural lands (cropland/hay/pasture) and exotic forbs/annual grass (table 3.174). Whitetop commonly migrates from the cropland/hay/pasture cover type to the big sagebrush cover type, particularly with disturbance to the soil surface (Miller and others 1994, Smergut 1991).

Leafy spurge (*Euphorbia esula*)

There is confirmed presence of leafy spurge in about three-quarters of the counties in the Basin, and its distribution includes portions of every ERU. Counties with unconfirmed presence lie primarily in eastern Washington and eastern Oregon in the Northern Cascades, Columbia Plateau, Southern Cascades, and Northern Great Basin ERUs. The distribution of leafy spurge is expanding westward within the Basin. Areas of prevalence include the Northern Glaciated Mountains, Lower Clark Fork, and Upper Clark Fork ERUs in Montana, and the Upper Snake ERU. Cover types that are of high susceptibility to invasion and support populations of this species in the aforementioned ERUs include grasslands (fescue-bunchgrass), riparian

types (cottonwood/willow), and agricultural types (cropland/hay/pasture) (table 3.174). The areal extent of these highly susceptible cover types is portrayed spatially in map 3.36. In descending order of extent (percent of ERU), ERUs with greater than or equal to 10 percent extent of lands of high susceptibility to invasion by leafy spurge are: Columbia Plateau (49%), Upper Snake (39%), Blue Mountains (24%), Central Idaho Mountains, Owyhee Uplands and Snake Headwaters (14% each), and Northern Glaciated Mountains and Upper Clark Fork (13% each) (map 3.36). These percentages represent the extent of the cover types only, without regard for the precipitation range of leafy spurge; thus, the percentages are inflated and require adjustment downward as further information is collected.

Musk thistle (*Carduus nutans*)

The distribution of musk thistle includes portions of every ERU. Counties with unconfirmed presence are scattered across the Basin. Musk thistle is primarily restricted to mesic sites with moist, alluvial soils that receive greater than 25 centimeters of annual precipitation. Cover types of high susceptibility to invasion include grasslands (fescue-bunchgrass), riparian types (shrub wetlands), and some forest types (Engelmann spruce/subalpine fir, interior Douglas-fir, and western redcedar/western hemlock) (table 3.174).

Oxeye daisy (*Chrysanthemum leucanthemum*)

The distribution of oxeye daisy includes portions of all ERUs except the Owyhee Uplands and Upper Snake. County distribution for oxeye daisy is centered in the northern and eastern portions of the Basin. Cover types of high susceptibility to invasion include riparian types (cottonwood/willow and herbaceous wetlands) and some forest types (Engelmann spruce/subalpine fir and western redcedar/western hemlock) (table 3.174).

Purple loosestrife (*Lythrum salicaria*)

The distribution of purple loosestrife is ubiquitous at the ERU scale, and widespread but scattered at the county scale. Purple loosestrife is restricted to wetland habitats. Areas of greatest prevalence include the Northern Glaciated Mountains, Columbia Plateau, and Owyhee Uplands ERUs in these river valleys: Okanogan, Yakima, Columbia, Snake, Owyhee, and Boise. Cover types of high susceptibility to invasion include the riparian types (herbaceous wetlands and shrub wetlands) (table 3.174).

Russian knapweed (*Centaurea repens*)

The distribution of Russian knapweed is ubiquitous at the ERU scale. Counties with unconfirmed presence lie primarily in Idaho. Areas of prevalence include the Owyhee Uplands and Upper Snake ERUs in Idaho,and the Columbia Plateau ERU in Washington. Sites that are particularly susceptible to invasion include floodplains, seasonally-wet habitats, and portions of the wheatgrass bunchgrass cover type that are mesic enough to permit growth of Basin wildrye.

Scotch thistle (*Onopordum acanthium*)

The distribution of Scotch thistle includes portions of all ERUs except the Upper Clark Fork. Areas of great prevalence are in the Blue Mountains and Owyhee Uplands ERUs, particularly within the Snake River System and its tributaries (for example, Grande Ronde, Powder, Burnt, and Malheur Rivers). Scotch thistle appears to be expanding its distribution northward, from Oregon into southeast Washington. Cover types that are of particular susceptibility to invasion include riparian types (cottonwood/willow, herbaceous wetlands, and shrub wetlands) and agricultural (cropland/hay/pasture). These cover types are rated of moderate susceptibility to invasion in table 3.174.

Continue

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Spotted knapweed (*Centaurea maculosa*)

The distribution of spotted knapweed is ubiquitous at the ERU scale, and nearly ubiquitous at the county scale. Areas of great prevalence lie within the Northern Glaciated Mountains, Lower Clark Fork, Upper Clark Fork, and Central Idaho Mountains ERUs in western Montana and northern Idaho. Cover types that are of high susceptibility to invasion and support spotted knapweed populations in the aforementioned ERUs include grasslands (fescue-bunchgrass and wheatgrass bunchgrass), riparian types (cottonwood/willow, herbaceous wetlands, and shrub wetlands) and dry forest types (interior ponderosa pine and interior Douglas-fir) (table 3.174). The areal extent of these highly susceptible cover types within the 30-to-76-centimeters precipitation zone of spotted knapweed is portrayed spatially in map 3.35. In descending order of extent (percent of ERU), ERUs with greater than or equal to 20 percent extent of lands of high susceptibility to invasion by spotted knapweed are: Upper Klamath (56%), Blue Mountains (48%), Upper Clark Fork (39%), Columbia Plateau (35%), Northern Glaciated Mountains and Southern Cascades (33% each), Snake Headwaters (31%), Northern Cascades (27%), Upper Snake (25%), and Central Idaho Mountains (22%) (map 3.35).

Susceptibility of broad-scale cover types: salient findings—Broad-scale cover types in the Basin vary considerably in their susceptibility to invasion by the 25 focal exotic plant species. Some salient findings are discussed below:

1) Based on the number of species that show an affinity for specific cover types (that is, the plant is labeled "invader" or "colonizer" in table 3.174), the exotic forbs/annual grass cover type is the most susceptible to invasion by exotic plants; all 25 exotic plant species show some affinity for this cover type.

2) Except for the exotic forbs/annual grass cover type, the grassland cover types (particularly fescue-bunchgrass, herbaceous wetlands, and wheatgrass bunchgrass) are the most susceptible to invasion by exotic plants. We base this finding on the large number of exotic plants labeled "invaders" in the grassland cover types (table 3.174).

3) High-elevation cover types, particularly alpine tundra, whitebark pine/subalpine larch, and whitebark pine, are the least susceptible to invasion by exotic plants. We base this finding on the small number (between 4 and 6) of exotic plants labeled "colonizers" or "invaders" in these high-elevation cover types.

4) Moist and shady forested cover types with meager light intensity in the understory (for example, grand fir/white fir, limber pine, lodgepole pine, mountain hemlock, Pacific ponderosa pine, Pacific silver fir/mountain hemlock, red fir, and western white pine) appear to be less susceptible to invasion by exotic plants than are drier, open-canopied forested cover types with greater light intensities in the understory, (for example, interior Douglas-fir and interior ponderosa pine). We base this finding on the lower number (zero) of exotic plants labeled "invaders" in the moist and shady forested cover types compared with the drier, open-canopied forested cover types (number of invaders equaled 4 to 6). Engelmann spruce/subalpine fir and western redcedar/western hemlock cover types are exceptions to this finding, as the number of invaders for these moist forest cover types equaled the drier, open-canopied forested cover types (table 3.174).

5) Extremely arid cover types are less susceptible to invasion by exotic plants. For example, of all the rangeland cover types, salt desert shrub is the most arid and is also one of the least susceptible to exotic plant invasion. We base this finding on the low number (nine) of exotic plants labeled "invaders" or "colonizers" in salt desert shrub cover type (table 3.174).

The five previously-mentioned findings are in agreement with Baker (1986) and Forcella and Harvey (1983). Grasslands, riparian areas, and some relatively open forests are more susceptible to invasion by exotic plants than are dense forests, high montane ecosystems, and deserts. The former have frequent gaps in the natural plant cover, which provide favorable microsites for exotic plant establishment; whereas, the latter are characterized by relatively closed vegetation or climatic stresses, which are tolerated by only a few exotic plant species.

While there are relatively few exotic plants categorized as invaders in forested cover types within the Basin, there are numerous exotic plants categorized as colonizers. Basin-wide, invasion by these colonizers into forested cover types appears to be dependent on harvest or road-building activities, which create gaps in forest vegetation and thereby provide microsites for establishment, and ample sunlight. The colonizers are restricted primarily to the gaps. Successional processes within the gaps that result in forest canopy cover eventually shade out the exotic plants and reduce their extent. The lack of exotic plants categorized as invaders in forested cover types within the Basin is probably attributable to this same shade-intolerance effect.

6) Some exotic plants show no affinity to many cover types in the Basin. These include riparian-obligate species (such as purple loosestrife), and other species (such as orange and yellow hawkweed) that show affinity to montane forest and herbaceous cover types at high elevation. We base this finding on the high number of cover types labeled low susceptibility to invasion by these species (table 3.174).

7) Some exotic plants (particularly Mediterranean sage, Scotch thistle, and oxeye daisy) have not been investigated extensively, so rating susceptibility to invasion by those species was not possible for many cover types. There are numerous reasons for this lack of information, including (1) exotic plant herbarium mount labels generally do not include associated species found at the collection site, therefore cover type cannot be determined for that site; (2) ecological requirements of the exotic plant are not available in the literature; (3) lack of distribution records; and (4) the probability of obtaining distribution records for the exotic plant within a cover type is prevented or restricted because the areal extent of that cover type within the Basin is very small.

Use and limitations of the Susceptibility to Invasion Index—The Susceptibility to Invasion Index is a first approximation of the susceptibility of broad-scale cover types in the Basin to invasion by exotic plants. The accuracy of the susceptibility to invasion ratings will be improved by additional observation and research. There is, in our estimation, a preponderance of "moderate" ratings in the Index (that is, a high quantity of species labeled colonizers). We propose that additional observation and research will change many "moderate" ratings to "high" or "low" ratings. The preponderance of "moderate" ratings is a consequence of the liberal manner in which susceptibility to invasion was rated (see the "Rangeland Ecology and Grazing Management" subsection of the "Overview of Methods" section of this chapter).

A specific example of the liberal manner in which susceptibility to invasion was rated is halogeton. Halogeton is restricted primarily to xeric rangeland cover types that receive less than 30 centimeters of annual precipitation. According to the Index, halogeton shows some affinity (is categorized as either an invader or colonizer) for 68 percent of the cover types. We speculate that a more realistic appraisal would decrease halogeton affinity to the big sagebrush, cropland/hay/pasture, exotic forbs/annual grass, low sagebrush, and salt desert shrub cover types, which represent about 13 percent of the cover types.

The susceptibility to invasion ratings should be interpreted to be "generally adequate" as a broad-scale characterization of the invasive potential of exotic plants to Basin cover types. Fine-scale observations will generate many exceptions to the broad-scale ratings in the Susceptibility to Invasion Index. Fine-scale observation and

research that can be extrapolated to the broad-scale would be informative and useful to improve the Index. We can surmise many exceptions: for example, an exotic plant species might act as an invader in a cover type in one or several ERUs in the Basin, yet that plant might act as a colonizer in the same cover type in other ERU(s) within the Basin. Thus, the susceptibility to invasion rating of the cover type to that exotic plant would be high in some ERUs and moderate in other ERUs. Exotic plants adapt and changes are inevitable.

We did not locate exotic plant inventories that were compiled at the Basin scale. Finer-scale exotic plant inventories (for example, BLM Districts, National Forests, and counties) could be compiled and summarized at the Basin scale, however. These finer-scale inventories would provide some exotic plant information for the Basin, but would be incomplete in their coverage of the landscape; not every unit of land has been searched for exotic plant presence. A great effort was expended in Karl and others (1995) to portray "reasonably" accurate distributions of 25 exotic plants, widely accepted by exotic plant experts as problematic, at the county scale within the Basin. Therefore, the actual extent and distribution of most exotic plants found within the Basin, even at the broadscale, is poorly known.

The Susceptibility to Invasion Index permits land managers to assess which cover types are most at risk of invasion by exotic plant species. The Index can be spatially portrayed to provide a regional visualization of risk of invasion. A link of the Index with other broad-scale attributes, for example precipitation (as shown for four exotic plants in maps 3.26, 3.27, 3.35, and 3.37) can provide more accurate regional visualizations of risk to invasion. The extent of the susceptible cover types (or lands characterized by many variables associated with exotic plant presence) to a specific exotic plant can be compiled for various land units. The Susceptibility to Invasion Index will continue to improve if locality records for exotic plants include information on associated plant species, which would provide a link between the exotic plant and a cover type. Improvement in the Index will enhance our ability to predict risk of invasion, assess where loss of biodiversity is at greatest risk, and assess where risk to succession/ disturbance regime alterations is greatest.

New invaders: problematic exotic plants of the future in the Basin—Several exotic plants in the Basin are localized in distribution at present. Because similar and suitable habitat can be found within the Basin, exotic plant experts suspect that exotic plants that presently exist outside of the Basin will soon establish within it. These exotic plants represent new, or potentially new, invaders to the Basin. We discuss the distribution and other characteristics of nine of these exotic plants. These nine species are regarded as potentially problematic, invasive species in the Basin (see Karl and others 1995 for literature sources pertaining to these species), but do not represent an all-inclusive list of potential problematic invaders in the Basin.

Syrian bean-caper (*Zygophyllum fabago*)

This perennial, bush-like species has been legally declared noxious in Washington and Idaho. In Washington, Syrian bean-caper exists in Adams, Grant, Okanogan, and Whitman Counties. In Idaho, Syrian bean-caper exists near the town of Aberdeen in Bingham County. Oregon has not yet reported the presence of this species, and little is known about its potential to establish or be problematic in Oregon.[8] All infestations in California have been eradicated. It appears that Syrian bean-caper shows potential for spread into waste places, PVTs in the dry grass PVG, and desert areas (probably equivalent to our PVTs in the dry shrub PVG); these are its native habitats in southwest Asia. Rice and Rider (1995) collected 13 distribution records for this species and proposed that Syrian bean-caper is a colonizer of the fescue-bunchgrass cover type.

[8] Personal communication. 1995. Dennis Isaacson, Field Operations Manager, Oregon Department of Agriculture, 635 Capital Street NE, Salem, OR 97310-0110.

African rue (*Peganum harmala*)

This perennial, succulent forb has been legally declared noxious in Washington. During the current period, African rue existed in the Columbia Plateau ERU in Grant County, Washington; at present (1995), it also exists in the Columbia Plateau ERU in Crook County, Oregon. African rue is native to the desert shrublands of northern Africa and the Middle East, as far east as Tibet. Its potential to spread within the Basin is unknown. African rue has been known to displace native rangeland plant species in the southwest United States, and can establish in areas receiving less than 25 centimeters of annual precipitation.

Iberian starthistle and purple starthistle *(Centaurea iberica, C. calcitrapa)*

These two biennial forbs are nearly indistinguishable and have been legally declared noxious in Oregon (both) and Washington (purple starthistle only). In Oregon, this species complex has been reported within the Columbia Plateau ERU from Sherman and Wasco Counties. In Washington, it has been reported within the Columbia Plateau (Walla Walla County) and Blue Mountains (Asotin County) ERUs. Both species are problematic in California. Purple starthistle also exists in Utah and Wyoming.

Distaff thistle (*Carthamus lanatus*)

This annual forb has been legally declared noxious in Oregon, and during the current period, existed outside the Basin in Douglas County, Oregon. This species has established and is problematic in California and is believed by weed experts to be adapted to the Basin. Its potential for spread into the Basin appears to be greatest in areas that receive between 40 and 61 centimeters of annual precipitation.

Camelthorn (*Alhagi pseudalhagi*)

This perennial shrub species has been legally-declared noxious in Oregon and Washington. At present, camelthorn is not believed to exist in Oregon, but does exist in Washington. Camelthorn is problematic in California, where it is subjected to intensive control.

Saltcedar (*Tamarix ramosissima*)

This shrub or small tree species is legally declared noxious in Washington, where at present, populations are known to exist on approximately 140 hectares along the Columbia River in the Columbia Plateau ERU in Grant and Franklin Counties. Small populations also exist scattered along the Bruneau River in the Owyhee Uplands ERU of Idaho.[9] Saltcedar has established on many riparian areas in the western United States, and has the potential to establish in riparian areas across most of the Basin.[10] Saltcedar displaces native riparian plants, including willow and cottonwood, and we speculate that the cottonwood/willow cover type is of high susceptibility to invasion by saltcedar.

Matgrass (*Nardus stricta*)

This perennial grass is legally declared noxious in Oregon and Idaho. In Oregon, matgrass exists in the Upper Klamath ERU in western Klamath County. Matgrass appears problematic in areas that have been subjected to excessive livestock grazing pressure. Its present rate of expansion is slow. Rice and Rider (1995) collected three distribution records for this species and proposed it to be a colonizer of the wheatgrass bunchgrass and fescue-bunchgrass cover types.

[9] Personal communication. 1996. Roger Rosentreter, Botanist, U.S. Department of Interior, Bureau of Land Management, Idaho State Office, 1387 South Vennell Way, Boise, ID 83709.

[10] Personal communication. 1995. Dennis Isaacson, Field Operations Manager, Oregon Department of Agriculture, 635 Capital Street NE, Salem, OR 97310-0110.

Squarrose knapweed (*Centaurea virgata*)

This perennial forb is legally declared noxious in Oregon. In Oregon, squarrose knapweed exists in the Blue Mountains and Owyhee Uplands ERUs in Union, Grant, Wheeler, and Malheur Counties. Its extent in Oregon in 1990 was reported as 320 hectares, none of which existed on BLM- and FS-administered lands. Squarrose knapweed exists in Utah, outside the Basin, on rangeland that receives only 15 to 20 centimeters of annual precipitation. It has yet to be reported from Washington and Idaho, but Roche and Burrill (1992) suspect it is present in southern Idaho.

Ventenata (*Ventenata dubia*)

This annual graminoid is not legally declared noxious in the Basin. It is a relatively recent (the last 40 years) invader to the Basin. Ventenata is now distributed in the western foothills of the Blue Mountains in the Blue Mountains ERU; the canyon grasslands of west-central Idaho in the Blue Mountains, Columbia Plateau, and Central Idaho Mountains ERUs; and in southeast Oregon in the Owyhee Uplands ERU (Hironaka 1994, Karl 1996[11], Larson and Sheley 1994, Northam and Callihan 1994, Tisdale 1986). Based on Karl's (1996)[11] observations ventenata appears to be an invader in the wheatgrass bunchgrass and fescue-bunchgrass cover types, and is displacing cheatgrass in the foothills of the Blue Mountains. Northam and Callihan (1994) report that ventenata appears to be displacing medusahead as well.

[11] Personal observations. 1996. Michael G. "Sherm" Karl, Rangeland Management Specialist-Ecologist, U.S. Department of Agriculture, Forest Service, Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar, Walla Walla, WA 99362.

Cheatgrass

This subsection is a summarization of Pellant (1996). Most of the literature cited in this subsection originates from Pellant (1996).

Ecology—Cheatgrass is an annual grass that was introduced to the Basin region from Europe in the late 1880s probably via contaminated grain (Mack 1981, Mack and Pyke 1983). By 1930, cheatgrass had already attained its current distributional range among the western states of the United States (Mack 1981). In 1995, cheatgrass existed in every county within the Basin (Karl and others 1995).

Cheatgrass has several characteristics that enhance its establishment in native plant communities, particularly those communities that are under stress or have been disturbed. These characteristics include high seed production (Hulbert 1955); ability to germinate in the autumn or spring; greater germinability in comparison with native grasses (Mack and Pyke 1983, Martens and others 1994); tolerance to grazing; and population expansion attributable to frequent fire regimes (Klemmedson and Smith 1964). Standing dead cheatgrass and litter produced by cheatgrass is extremely flammable and results in a shorter fire-return interval compared with the fire-return interval characteristic of the pre-Euro-American settlement period (Billings 1948). Native sagebrush communities had fire-return intervals of 32 to 70 years (Wright and others 1979), while current period sagebrush communities have return-fire intervals of five years or less, particularly on cheatgrass-dominated, southern Idaho rangelands in the Owyhee Uplands ERU (Pellant 1990). This scenario is referred to by Pellant (1996) as the cheatgrass-wildfire cycle. As a result of shorter fire-return intervals, the extent of big game winter range in the Great Basin has declined (Pellant 1990, Updike and others 1990); habitat supporting the densest concentration of nesting raptors in North America has declined (Kochert and Pellant 1986); the persistence of some native plant species is threatened (Rosentreter 1994); non-game bird abundance has declined (Dobler

1994); native plant species richness has been reduced at all landscape scales; and successional recovery periods have been extended (Billings 1994, Whisenant 1990). Cheatgrass plants in post-fire environments are adapted to appropriate nutrients and soil water more efficiently than native plants. The cheatgrass-wildfire cycle presents the greatest risk to the Wyoming big sagebrush component of the big sagebrush cover type, and the more mesic sites within the salt desert shrub cover type (Pellant 1990, Peters and Bunting 1994).

Cheatgrass has adapted to many plant communities, from low-elevation salt-desert shrub communities (Sparks and others 1990, Young and Tipton 1990) to higher elevation ponderosa pine communities (Daubenmire 1952). These communities exist at elevations ranging from approximately 450 to 2,745 meters, where the annual average precipitation ranges between 15.2 and 56.0 centimeters (Bradley 1986). The adaptability of cheatgrass can be attributed in part to the genetic variability of its populations. This genetic variability has contributed to the evolution of ecotypes that are adapted to different environments (Novak 1994).

Cheatgrass completes its life cycle relatively early in the growing season, typically by June. Cheatgrass photosynthesis essentially is completed by this time, whereas in most native plant communities there exists an assemblage of plants that continue to photosynthesize later in the growing season. In cheatgrass-dominated communities then, the duration of photosynthesis, and therefore energy flow, is truncated. In addition, a consequence of the relatively early senescence of cheatgrass is a considerably shorter period of palatability and nutrition for herbivores, compared with many native herbaceous species (Klemmedson and Smith 1964).

Although the growth period for cheatgrass is truncated compared with many native perennial species, cheatgrass can occasionally produce more annual biomass than can native vegetation, or introduced seeded wheatgrass species (Hull and Pechanec 1947). However, cheatgrass production varies greatly from year to year (Klemmedson and Smith 1964, Stewart and Young 1939). This variability in annual production necessitates variable livestock stocking rates.

Cheatgrass typically provides adequate soil surface cover for watershed protection. However, in drought years and after wildfires, cheatgrass production can be inadequate to provide soil surface cover suitable for watershed protection. This is especially evident on sites with soils susceptible to water and wind erosion, and on sites with moderate to steep slopes. Under these circumstances, the potential for erosion is greater.

The ecological relationships between cheatgrass and microbiotic crusts are not understood completely. Where intact, microbiotic crusts apparently can restrict cheatgrass establishment (Kaltenecker and Wicklow-Howard 1994). Microbiotic crust development appears to be restricted within cheatgrass-dominated plant communities, in comparison with native sagebrush communities (Pellant and Kaltenecker 1996[12]). Subsequent to burning, cheatgrass can rapidly dominate sites, and hinder the recovery of microbiotic crust species. The lack of microbiotic crust development and microbiotic crust species richness might have negative implications in nutrient cycling, native plant succession, site stability, and exotic species invasion, such as cheatgrass.

The cheatgrass-wildfire cycle has indirectly resulted in a reduction of native plant species richness because of the common practice of planting introduced wheatgrasses, primarily crested wheatgrass, after wildfires. Post-wildfire seeding with seed mixtures composed primarily of crested wheatgrass was a common practice to prevent cheatgrass dominance after wildfires and to provide livestock forage from the 1950s to the 1970s. This practice has continued to a certain

[12] Mike Pellant and Julie Kaltenecker. 1996. Unpublished research data on cheatgrass and microbiotic crust. Mike Pellant, Rangeland Ecologist, U.S. Department of Interior, Bureau of Land Management, Idaho State Office, 1387 South Vennell Way, Boise, ID 83709.

extent into the current period (Pellant and Monsen 1993). Although seedings have reduced the extent of cheatgrass monocultures on the landscape, seedings of perennial grasses tend to perpetuate reduced levels of native plant species richness. However, seedings of perennial grasses more closely resemble the structure and disturbance regimes of native communities compared with cheatgrass monocultures. Recent trends toward the use of seed mixtures containing native species might ameliorate the reduction of native plant species richness (Pellant and Monsen 1993) and further approximate species compositions and disturbance regimes of native communities.

Cheatgrass thresholds: a potentially useful concept in determining risk to rangeland health—In the subsection "Herbivory by large herbivores", we introduced the concept of thresholds and state-and-transition models for vegetation succession. Cheatgrass-dominated areas were used as an example of an apparently stable vegetation state that had crossed a threshold. Therefore, removal of livestock grazing pressure would not definitively be an impetus for movement of this stable state to a more advanced, higher successional state. In the context of rangeland health, which is defined as "the degree to which the integrity of the soil and the ecological processes of rangeland ecosystems are sustained" (National Research Council 1994), cheatgrass-infested sites that have crossed a threshold represent sites where ecological processes (for example, succession, energy flow, nutrient cycling) have been disrupted, and soil instability is apparent. Therefore, rangeland health is at risk on sites where cheatgrass, measured by density for example, approaches or crosses a threshold.

Unfortunately, science has yet to provide definitive thresholds for cheatgrass. There would not be only one ubiquitous threshold density for cheatgrass; threshold densities could vary depending on ecological site, climatic conditions, management activities, disturbance regimes, and plant composition. In addition, science has yet to provide definitive ratios of cheatgrass to native plants that do not represent a risk to rangeland health (that is, densities of cheatgrass that are not yet impairing ecosystem processes and soil integrity). Speculation at present is that cheatgrass densities below approximately 40 to 50 per square meter might not negatively affect recruitment of native plants. A density of three plants per square meter for crested wheatgrass has been proposed as adequate for maintaining perennial vegetation in low elevation sagebrush communities (Evans and Young 1977), whereas 2.5 plants per square meter for native perennial species has been proposed as adequate to prevent cheatgrass dominance on sites where the shrub structure has been removed (Evans and Young 1978). The determination of threshold densities for cheatgrass and native perennial plants, and associated risk to rangeland health, is more an art than a science at present.

Cheatgrass control—The concept of a cheatgrass threshold can be used as a benchmark for management decisions regarding cheatgrass control (reduction in cheatgrass abundance). For example, if a cheatgrass threshold is crossed, scientific evidence suggests that intervention through artificial reseeding might be the only recourse for establishment of native or introduced perennial plant communities. Prior to artificial reseeding, cheatgrass must be controlled (Evans and Young 1977, Hull and Stewart 1948, Jordan 1983). If a cheatgrass threshold has yet to be crossed, techniques have been tested and are becoming available that control cheatgrass with the objective of releasing resident perennial plants from the competitiveness of cheatgrass.

Techniques including mechanical (disking or plowing), burning, grazing, herbicides, and biological control have been applied to control cheatgrass. These techniques vary in their effectiveness depending on factors including the phenological stage of cheatgrass at the time of application, pre- and post-application climatic conditions, and soil water.

Mechanical techniques, to be effective in cheatgrass control, must bury cheatgrass seed to a minimum depth of 6 centimeters (Hulbert 1955) to prevent the emergence of cheatgrass seedlings. Plowing,

especially using a moldboard plow, has proven to be an effective cheatgrass control technique. Plowing or disking are most effective when applied before cheatgrass seedripe, or after fall germination of cheatgrass seeds. Rocky soils limit the use of this technique.

Burning, particularly in the late spring before cheatgrass seed dissemination, can be an effective control technique (Pellant 1990, Stark and others 1946). Burning can result in substantial reductions in cheatgrass densities the year after the burn (Pechanec and Hull 1945, Stewart and Hull 1949). Although cheatgrass densities are reduced in burned areas the year after the burn, reproductive inflorescence production and seed production per cheatgrass plant in burned areas are greater than for cheatgrass plants in unburned areas. In addition, seeds on the soil surface and in the seed bank can survive burning, which permits recovery of the cheatgrass stand in just a few years after the fire event, unless reseeding with perennial grasses was successful. Thus, burning can control cheatgrass but does not eradicate it.

In general, livestock grazing is not an effective control technique for cheatgrass (Vallentine and Stevens 1994). Although cheatgrass production of seeds and biomass can be reduced with livestock grazing, benefits to remnant native perennial species typically will not accrue. Livestock grazing pressure that results in the control of cheatgrass also typically results in comparatively greater deleterious effects to remaining native plants in the community (Young and Tipton 1990, in Vallentine and Stevens 1994) because they are consumed concomitantly with the cheatgrass. However, excessive livestock grazing pressure that is intentionally applied to cheatgrass can (1) prepare sites for artificial seeding of perennial species, (2) decrease cheatgrass fine-fuel production, and (3) lengthen fire-return intervals.

The use of herbicides is an effective technique for control of cheatgrass, although herbicides are costly to approve and apply. An atrazine-based, chemical fallow weed control technique was developed by Eckert and others (1974) to control cheatgrass preceding the seeding of perennial wheatgrasses for revegetation. Since the 1970s, environmental constraints have limited the use of herbicides for control of cheatgrass on public lands (for example, atrazine is no longer registered for use on rangeland; Ogg 1994). As a consequence of the *Final Environmental Impact Statement for Vegetation Treatment on BLM Lands in Thirteen Western States* (U.S. Department of Interior 1991), 21 herbicides were approved for use in control of various weed species, including cheatgrass. One herbicide in particular, sulfometuron-methyl, has proven to be effective in controlling cheatgrass in southern Idaho, without a concomitant deleterious effect on most perennial native plants. Other herbicides registered for control of cheatgrass are presented in Ogg (1994). Not all of these herbicides have been approved for use on public lands.

Biological control of cheatgrass on extensive acreages of rangeland is not yet practiced. Some bacterial species have proven effective in controlling cheatgrass in an agricultural setting (Kennedy 1994); thus, Kennedy (1994) speculates that there is potential for control of cheatgrass on rangelands with bacteria. The hypothesis stimulating research into bacterial control agents is that plant-suppressive bacteria can be used to suppress the growth of unwanted plant species growing in association with more desirable plant species.

Perennial plant revegetation—The revegetation with perennial plants of communities that were previously infested with cheatgrass was a research and management priority in the Great Basin beginning in the 1930s and the 1940s (Hull and Pechanec 1947, Piemeisel 1932). This and subsequent research conducted in southern Idaho (Hull 1974, Hull and Holmgren 1964, Hull and Stewart 1948) have provided strong evidence that introduced wheatgrasses, especially crested wheatgrass, are superior to native grasses in establishing and persisting in communities previously infested with cheatgrass. The reduction in native plant species richness that tends to be perpetuated with seedings of these introduced grasses has been mentioned previously in this subsection and is the crux of the

controversy surrounding the use of exotic plants to revegetate rangeland communities infested with cheatgrass. Recent seeding practices implemented by the BLM incorporate the use of native species in seeding mixtures; this trend toward the use of native species is becoming more prevalent (Pellant and Monsen 1993).

Greenstripping—A proactive technique to reduce the magnitude of the cheatgrass-wildfire cycle is to seed strips of fire-resistant vegetation (otherwise referred to as a "greenstrip") at strategic locations, in order to slow or stop the spread of wildfires (Pellant 1990). Pellant (1994) describes various criteria to consider when planning a greenstrip project for wildfire reduction. Site preparation and the correct selection of plant materials are essential for the establishment of a functional greenstrip. Herbaceous plant species commonly used in greenstrips include introduced wheatgrasses (for example crested wheatgrass), Russian wildrye (*Elymus junceus*), dryland alfalfa (*Medicago* sp.), Lewis flax (*Linum lewisii*), and small burnet (*Sanguisorba minor*) (Pellant 1994). Greenstripping is not a solution to the cheatgrass-wildfire cycle. However, greenstripping can aid in reducing the size and frequency of wildfires. The ecological benefits to greenstripping include conservation of native plant species richness and shrub cover on fire-prone landscapes, and the eventual enhancement of native plant species richness (West 1979, Whisenant 1990, Young and Evans 1978).

The future—Cheatgrass will remain a component of many PVGs in the Basin. The distribution and dominance of cheatgrass continues to expand, particularly within the dry forest, dry shrub, and dry grass PVGs. Although cheatgrass tends to form a stable vegetation state after establishment, attributable to frequent fire, other exotic plants are invading cheatgrass-dominated communities and potentially degrading rangeland health even further. Examples of these other exotic plants include medusahead, yellow starthistle, and ventenata. Ventenata is a relatively recent (during the last 40 years) exotic annual grass invader that is distributed in the western foothills of the Blue Mountains in the Blue Mountains ERU; the canyon grasslands of west-central Idaho in the Blue Mountains, Columbia Plateau, and Central Idaho Mountains ERUs; and in southeast Oregon in the Owyhee Uplands ERU (Hironaka 1994, Karl 1996[13], Larson and Sheley 1994, Northam and Callihan 1994, Tisdale 1986).

Research focused on integrating weed control techniques for control of cheatgrass and other exotic plant species will become more prevalent in the future. Integrated weed management incorporates combinations of techniques that might act synergistically to permit more effective control of weed species. Two examples of integrated weed control techniques for cheatgrass are (1) biological control agents [for example, rhizobacteria (bacteria active in root tissue)] combined with herbicides (Kennedy 1994), and (2) burning or livestock grazing, combined with herbicides.

Microbiotic Crusts: A Rangeland Landscape Element of Concern

This subsection is a summary of Leonard and others (1995), which is an ICBEMP report focusing on the ecological roles and implications of microbiotic crusts for rangeland management. Leonard and others (1995) is based primarily on two other ICBEMP reports, Kaltenecker and Wicklow-Howard (1994) and Williams (1994), and secondarily on other literature sources.

Microbiotic crusts consist of lichens, bryophytes, algae, microfungi, cyanobacteria, and bacteria growing on or just below the soil surface (Eldridge and Greene 1994). Microbiotic crusts play a role in nutrient cycling, soil stability and soil moisture, and interactions with vascular plants. Microphytic plants provide forage for invertebrates, and some lichens growing on or near the soil surface such as vagrant (non-attached) lichens, provide forage for big game species during critical winter periods

[13] Personal observation. 1996. Michael G. "Sherm" Karl, Rangeland Management Specialist-Ecologist, U.S. Department of Agriculture, Forest Service, Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar, Walla Walla, WA 99362.

(Thomas and Rosentreter 1992). Some microphytes are also potential environmental indicators. The ecological role of microbiotic crusts is probably most substantial in arid ecosystems in which above-ground productivity is inherently low. Potential vegetation types in the Basin that can be associated with substantial microbiotic crust development include salt desert shrub, low sagebrush (includes mesic, mesic with juniper, and xeric), big sagebrush-warm, big sagebrush-cool, and juniper (map 3.59).

Ecological Roles

Nutrient cycling—Soils stabilized by microbiotic crusts tend to have greater concentrations of organic material, nitrogen, exchangeable manganese, calcium, potassium, magnesium, and available phosphorous (Harper and Pendleton 1993). Nitrogen fixation by microbiotic crusts (composed of cyanobacteria, both free-living and in lichen species) has been well documented (Skujins and Klubek 1978a, 1978b; West and Skujins 1977). Evans and Ehleringer (1993) concluded that microbiotic crusts were the source of nitrogen in a juniper-sagebrush woodland ecosystem that apparently contained no other nitrogen-fixing organisms. The availability of the nitrogen that is fixed by microbiotic crusts, and its necessity to vascular plants and community structure and function, continues to be an unresolved issue (Evans and Ehleringer 1994, Harper and Pendleton 1993, Rychert and others 1978, Snyder and Wullstein 1973).

Soil stability—In some areas, microbiotic crusts can compose 70 to 80 percent of the living cover (Belnap 1990). Microbiotic crusts contribute to aggregate structure, and thus to stability, by binding soil particles within the physical structures of the microphytes and trapping soil particles in gelatinous exudate (Belnap and Gardner 1993, Campbell and others 1989, Danin and others 1989, Danin and Yaalon 1980, Graetz and Tongway 1986, Schulten 1985). Microtopography becomes more complex with microbiotic crust development. The resulting surface roughness reduces water velocity and associated erosion and creates ponding that enhances sediment deposition (Alexander and Calvo 1990, Brotherson and others 1983).

Soil moisture—The influence of microbiotic crusts on infiltration and soil moisture is not definitive; it depends on soil type, climate, disturbance history, state of wetness of a particular soil type when it is rewetted, and types of organisms in the crust and their degree of development (Seyfried 1991, Williams 1993). Depending on the study, the influence of microbiotic crusts has been reported as positive (Johnson and Blackburn 1989, Johnson and Gordon 1986, Loope and Gifford 1972, Seyfried 1991), negative (Bond 1964, Brotherson and others 1983, Graetz and Tongway 1986, Rogers 1977, Stanley 1983), or neutral (Fletcher 1960, Williams 1993). While some microbiotic crust researchers propose that microbiotic crusts generally improve infiltration (for example, Eldridge and Greene 1994), others[14] remain skeptical. Microbiotic crusts can be present on, and their development can be enhanced by, soil types that physically cause ponding of water on the surface, or soil types that are composed of clay and fine silt and are characterized by poor soil moisture infiltration (Eldridge and Greene 1994).

Interactions with vascular plants—Microbiotic crusts and vascular plants have complex interrelationships that can be either competitive, mutualistic, or neutral, depending on the phenological stage of the organisms, climate, edaphic resources, plant-animal interactions, and resource management. Documented mutualistic interactions include enhanced floral species richness (Beymer and Klopatek 1992; Graetz and Tongway 1986; Kleiner and Harper 1972, 1977; Meyer 1986; Mucher and others 1988) and increased seedling establishment of vascular plants (Eckert and others 1986; Harper and Marble 1988; St. Clair and

[14] For example, personal communication. 1996. John D. Williams, Agronomist-Hydrologist, U.S. Department of Agriculture, Agricultural Research Service, Columbia Plateau Conservation Center, Pendleton, OR 97801.

Map 3.59—Potential vegetation types (PVTs) that have the greatest potential for microbiotic crust development expected within the Basin.

others 1984; Sylla 1987, in West 1990). Increased seedling establishment and floral species richness is attributed to an increased availability of microsites, nutrients, and water resulting from microbiotic crust structure.

In other instances, microbiotic crusts have been described as inhibiting the establishment of vascular plant seedlings and reducing community structure (Dulieu and others 1977, McIlvanie 1942, Savory and Parsons 1980). While some plants, such as needlegrass (*Stipa* spp.), are better adapted morphologically to establish in well-developed microbiotic crusts (West 1990), establishment of other plants, such as less-adapted weedy exotics, is probably inhibited by intact microbiotic crusts (Rosentreter 1994). Soil properties and the degree of microbiotic crust development (Kaltenecker and Wicklow-Howard 1994) apparently affect establishment success of vascular plants, yet more research is needed to further elucidate the interrelationship of microbiotic crusts and seedling establishment.

Forage—Gerson and Seaward (1977) described lichens as the base (in this context, a forage base) of a food web that includes invertebrates and their predators. The microfloral and autotrophic components of microbiotic crusts probably provide a forage base for invertebrates as well. The relative contribution of microbiotic crusts as forage is unknown compared with the contribution of vascular plants. This is attributable to our limited knowledge concerning the number of invertebrate taxa that might depend on these crusts for forage or habitat.

Environmental indicators—Lichens, including many associated with microbiotic crusts, have been used as bio-indicators of air quality. Rosentreter (1995) identified 120 soil lichens, including 17 associated with shrubland-grassland soil crusts and 9 associated with calcareous shrubland-grassland environments, as potential bio-indicators of air quality in the Basin. All shrubland-grassland and calcareous shrubland-grassland lichens identified in the study were also believed to be indicators of advanced ecological status (indicative of a long period without major disturbance).

Response to Disturbances

Soil surface disturbing activities, including grazing, off-road vehicle use (both recreational and military), recreational hiking, and others can reduce the maximum potential development of microbiotic crusts. Fire can also deplete microbiotic crusts, at least temporarily. A high density of exotic annual plants, such as cheatgrass and medusahead, and the resultant litter accumulation, poses a long-term threat to microbiotic crust development and maintenance. Airborne pollutants and urbanization can also negatively affect the abundance and composition of microbiotic crusts. Except where habitat is completely displaced, for example urban areas, or altered by dominance by exotic annuals, initial recovery of microbiotic crusts is fairly rapid (ranging from a few years to 100 years) after the disturbances abate. Cyanobacteria and algae are the first stage of recovery, with later successional stages of recovery characterized by bryophytes and lichens (Belnap and Gardner 1993, Rosentreter 1986).

Grazing—Continuous season-long grazing is deleterious to microbiotic crusts, as shown by Jeffries and Klopatec (1987) and Brotherson and others (1983). Likewise, short-duration grazing strategies characterized by intense physical impact to the soil surface are deleterious to microbiotic crusts, especially on rangeland characterized by wet winter and dry summer climates in the Great Basin (Johansen 1986) and the Columbia Basin. Platou and Tueller (1985) suggest that the pre-Euro-American settlement period grazing system in the shrubland-grassland was more similar to the rest-rotation system designed by Hormay (1970), rather than the high-intensity, short-duration grazing that was probably operative in the Great Plains.

Grazing impacts on microbiotic crusts, and the thresholds (characterized by timing and intensity of grazing pressure) at which those impacts become limiting to on-site sustainability and productivity of microbiotic crusts, is a topic worthy of considerably more research in various biophysical settings

(Kaltenecker and Wicklow-Howard 1994). Grazing/microbiotic crust studies conducted by Anderson and others (1982) and Marble and Harper (1988) in the eastern Great Basin are particularly noteworthy because their long-duration grazing controls allow comparison of treatment effects. Heavy (probably connotes high levels of grazing pressure), early winter grazing when soils are wet or frozen is not deleterious to microbiotic crust cover. Heavy grazing that persists into late winter and early spring, however, becomes deleterious (Marble and Harper 1988) because it limits the time available for regrowth of microphytes. Growth of microphytes can continue from late winter through early spring because of optimal soil water conditions, but this growth is disrupted if livestock grazing persists. After early to late spring, soil water conditions are no longer optimal for microbiotic crust development. We believe that the results from these studies can be extrapolated to the Basin, particularly in the salt desert shrub and adjacent dry sagebrush (for example, low sagebrush and Wyoming big sagebrush) PVTs.

Fire and exotic annual grasses—Fire and flammable exotic annual grasses are interrelated in their effects on microbiotic crusts. Microbiotic crusts can be temporarily damaged by fire (Harper and Marble 1988, West 1990). Algal and cyanobacterial components of microbiotic crusts can recover to develop substantial cover within 5 to 10 years after a fire event, whereas lichens and mosses might require 10 to 20 years to achieve substantial cover (Johansen and Rayburn 1989). Rosentreter (1996)[15] speculates that recolonization of disturbed sites by a diverse assemblage of lichen species might require 100 years. Average wildfire intervals of 50 years in the shrubland-grassland (Wright and others 1979), to as high as 100 years in the more arid Snake River Plain (Peters and Bunting 1994), are adequate to restore microbiotic crust components. With the invasion of flammable exotic grasses, for example cheatgrass and medusahead, fire frequency has increased. Fire intervals of less than five years which pose a substantial risk to microbiotic crust recovery have been documented on the exotic annual grasslands of the Snake River Plain (Whisenant 1990). The increase in cover of exotic annual grasses and their associated litter (often observed between fires), further reduces or prevents microbiotic crust recovery (Kaltenecker and Wicklow-Howard 1994).

The ecological roles that microbiotic crusts perform are not well understood at the present time. More research needs to be conducted to ascertain their ecological roles, particularly with regard to hydrology, nutrient cycling, energy flow, and biodiversity. There has been a lack of research conducted to ascertain the response of microbiotic crusts to disturbances, particularly anthropogenic disturbances associated with traditional land uses (such as livestock grazing) in the Basin. Microbiotic crusts are not currently inventoried by the BLM or the FS in a manner that permits monitoring of their condition and extent at multiple spatial scales. Consequently, we were unable to assess the broad-scale trends of microbiotic crusts in the Basin.

Susceptibility of Rangeland Health to Management-Induced Disturbance Stresses

This subsection was derived primarily from Leonard and Karl (1995c, 1995d), Pellant (1996b), U.S. Department of Agriculture (1993), and Redmond (1995)[16].

Defining Rangeland Health

The National Research Council (NRC) (1994) proposes that new methods are needed to classify, inventory, and monitor rangeland ecosystems. In particular, the impetus for this proposal is the finding that gross inconsistencies exist among land

[15] Personal observation. 1996. Roger Rosentreter, Botanist, U.S. Department of Interior, Bureau of Land Management, Idaho State Office, 1387 South Vennell Way, Boise, ID 83709.

[16] Unpublished data. 1995. Kelly Redmond, Climatologist, Western Regional Climate Center, Atmospheric Sciences Center, Desert Research Institute, PO Box 60220, Sage Building, 5625 Fox Avenue, Reno, NV 89506.

management agencies and rangeland managers in the methods used to evaluate rangeland conditions and ecological status of rangelands. Therefore, because different methods of evaluation are used, investigators interpret the data in various ways, none of which result in definitive conclusions about rangeland condition and status. Without a definitive assessment of rangeland condition, confusion surfaces amongst the public, legislators, ranchers, and rangeland scientists themselves, concerning whether the capacity of rangelands to satisfy values and produce commodities is being sustained, improved, or degraded.

The concept of rangeland health is proposed by the NRC as a foundation for a consistent approach to assessing rangelands. Their definition of rangeland health is "the degree to which the integrity of the soil and the ecological processes of rangeland ecosystems are sustained" (National Research Council 1994). Rangeland health is proposed by the NRC as the minimum ecological standard for rangeland management, a standard that is applicable to rangelands regardless of how the rangeland is used or managed. A decline in rangeland health reduces the capacity of rangelands to produce commodities and satisfy values, and reduces the options for use and management of rangelands in the future.

An evaluation of rangeland health as recommended by the NRC should incorporate indicators of (1) soil stability and watershed function, (2) distribution of nutrients (that is, nutrient cycling) and energy (that is, energy flow), and (3) change in recovery mechanisms. Of these three categories of indicators, soil stability and watershed function are given the greatest weight in the evaluation of rangeland health. Measurement of indicators in all three categories is recommended because it provides a more complete evaluation and increases the probability that rangeland degradation will be detected early enough for corrective measures to be implemented. Examples of potential indicators in Category 1 include soil surface characteristics; in Category 2, degree of fragmentation of plant distribution, litter, roots, or photosynthetic period; and in Category 3, change in vegetation cover or plant vigor.

The rangeland health publication of the NRC (1994), and other recent publications, including Barrett and others (1993), Task Group on Unity in Concepts and Terminology (1995), and West and others (1994), have served as the impetus and direction for initiation of an interagency workgroup. This interagency workgroup is developing and field testing an assessment procedure for rangeland health that relies entirely on qualitative measurements or judgments. At current, this qualitative assessment of rangeland health includes four categories. These categories are: (1) cover by vegetative lifeform and ground cover for site protection, (2) species abundance relative to dominant plant cover, (3) physical environment status based upon 10 indicators of soil and watershed stability, and (4) biotic environment status based upon eight indicators of the integrity, structure, and function of the flora, fauna, and ecological processes. The physical and biotic indicators are evaluated in the field and an appropriate descriptive category is selected for each indicator. The descriptive categories roughly correspond to functioning (healthy), at risk, or improperly functioning (unhealthy) condition.

Although the rangeland health categories of at risk, or improperly functioning (unhealthy) condition are interpreted to be a result of some historical or recent disturbance(s), the qualitative assessment does not establish the cause of at risk or improperly functioning (unhealthy) rangelands. Rather, the qualitative assessment identifies where a problem exists for rangeland health.

Inventory information is meager for many of the proposed indicators within the rangeland health categories. However, there are soil, vegetation, and climate attributes available for assessment that can be used as indicators of the susceptibility of rangeland health to management-induced disturbance stresses. In particular, some soil and climate attributes are indicative of an inherent "natural" stress and a relatively low tolerance to management-induced disturbance stress. Susceptibility does not indicate that particular areas are functioning (healthy), at risk, or improperly functioning (unhealthy). Rather, the presence of susceptibility

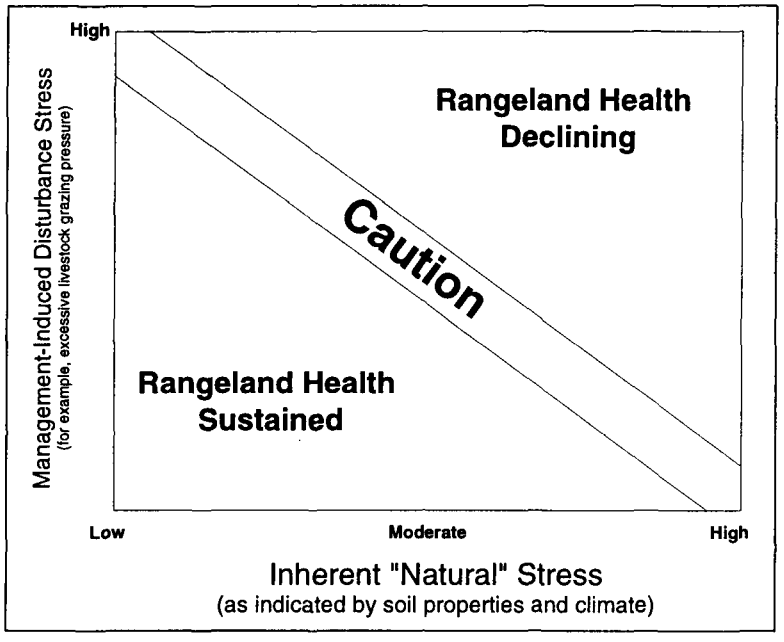


Figure 3.17—This figure is a theoretical conceptualization of rangeland health and its association with biophysical and management-induced stresses. As the level of inherent "natural" stress of a biophysical system increases (attributable to soil properties or climate, for example), the biophysical system is less able to absorb management-induced disturbance stress (attributable to excessive livestock grazing pressure, for example) before rangeland health declines. Management-induced disturbance stress that exceeds a threshold (the "Caution Zone" in this figure) results in decline in rangeland health because the disturbance stress exceeds the capacity of the biophysical system to absorb it.

indicators denotes an inherent "natural" stress on these sites. This inherent "natural" stress confers some susceptibility of rangeland health to management-induced disturbance stresses (fig. 3.17). Theoretically, as the level of inherent "natural" stress of a biophysical system increases (attributable to soil properties or climate, for example), the biophysical system can absorb less management-induced disturbance stress (such as that attributable to excessive livestock grazing pressure) before rangeland health declines. Management-induced disturbance stress that exceeds a threshold (Caution Zone, fig. 3.17) results in decline in rangeland health because the disturbance stress exceeds the capacity of the biophysical system to absorb it.

Soil Property Indicators

Soil properties that are indicative of an inherent natural stress and can enhance the susceptibility of rangeland health to management-induced disturbance stresses include erodibility by water or wind, salinity, sodicity, and shrink-swell potential. These soil properties have been discussed in detail in the "Rangeland Ecology and Grazing Management" subsection of the "Overview of the Methods" section of this chapter.

Climate Indicators

Climate influences rangeland health through its effects on soil formation, vegetation production, and ecological processes such as nutrient cycling and energy flow. Climatic events, for example drought (defined here as a specified period of time in which the precipitation received is less than 75 percent of average) can represent natural stresses that reduce plant vigor and vegetation production, alter plant composition, and expose more soil to erosive agents. In addition, climate can govern the post-disturbance rate of recovery of vegetation and ecological processes. In this regard and as we discussed previously in the "Herbivory by large herbivores" subsection, vegetation in arid and semi-arid regions is inherently slow to recover after disturbance(s) (for example, excessive livestock grazing pressure) subside. The recovery potential apparently diminishes with increase in aridity.

In arid regions of the western United States, emergence and establishment of perennial plants [for example spiny hopsage (*Grayia spinosa*)] in the Basin (Shaw and Haferkamp 1994) and numerous perennial species in the Mojave Desert (Ackerman

1991, in Shaw and Haferkamp 1994; El-Ghonemy and others 1980, in Shaw and Haferkamp 1994) appear to be episodic in and dependent on above-average precipitation periods (Shaw and Haferkamp 1994). The episodic and unpredictable plant recruitment, owing to the unpredictability of the frequency of above-average precipitation periods, limits the recovery potential of vegetation and therefore rangeland health. Drought and a high incidence of drought are known to exacerbate disturbances attributable to grazing (Vallentine 1990). Conversely, we maintain that management-induced disturbance stresses, such as excessive livestock grazing pressure, when coupled with climatic events, such as drought, can exacerbate the effects of climate on rangeland health. We propose that increasing aridity, frequency of drought, and frequency of favorable periods of precipitation for plant emergence and establishment can be indicative of, and/or can heighten, the inherent natural stress of the biophysical system and the susceptibility of rangeland health to management-induced disturbance stresses.

Frequency of drought, and frequency of favorable periods of precipitation for plant emergence and establishment, are portrayed for climate divisions in the Basin in table 3.38. As a general overview of the climate divisions, those divisions located in the Washington, Oregon, and central and northern Idaho portions of the Basin receive their maximum 6-month median precipitation during the fall and winter seasons. The remaining portions of the Basin, in southern and eastern Idaho, western Montana, and western Wyoming, receive their maximum 6-month median precipitation during either the winter and spring seasons, or spring and summer seasons. These trends reflect the continental climatic influence in the eastern portions of the Basin and the coastal climatic influence in the western portions of the Basin. The arid climate divisions are those that include a majority of their area within the less than 30 centimeters annual precipitation zone, and thus are dominated by arid to semi-arid rangeland. In decreasing order of maximum 6-month median precipitation, the arid climate divisions are: Oregon North Central, Idaho Southwest Valleys, Oregon South Central, Washington Okanogan-Big Bend, Idaho Southwest Highlands, Idaho Upper Snake River Plains, Washington Central Basin, Oregon Southeast, Idaho Central Plains, and Idaho Northeast Valleys (table 3.38).

Frequency of drought in the Basin from 1895 to 1994 ranges from 6 to 20 percent, depending on the climate division. The arid climate divisions tend to have a greater frequency of drought (average = 17.0%, standard error = 0.66, sample size = 10) compared with the more mesic climate divisions (average = 12.2%, standard error = 1.11, sample size = 12). Thus, with increasing aridity, frequency of drought tends to increase.

Favorable periods of precipitation for plant emergence and establishment, portrayed in table 3.38 as periods greater than 110 percent for more than 2 years, occur only two to nine times in the 100-year period for the Basin, depending on the climate division. The arid climate divisions tend to have a greater number of favorable periods of precipitation for plant emergence and establishment (average = 6.9, standard error = 0.48, sample size = 10) compared with the more mesic climate divisions (average = 6.2, standard error = 0.65, sample size = 12). The average duration of these favorable periods does not differ however, between the arid climate divisions (average duration of a favorable period = 2.58 years, standard error = 0.089, sample size = 10) and the more mesic climate divisions (average duration of a favorable period = 2.63 years, standard error = 0.093, sample size = 12). Thus, with increasing aridity, the number of favorable periods of precipitation for plant emergence and establishment tends to increase also, although the trend is not as noteworthy compared with frequency of drought.

The result of the combination of increased frequency of drought, and increased incidence of favorable periods of precipitation for plant emergence and establishment is a greater degree of variability about the mean precipitation. This combination tends to characterize the arid climate divisions that have a majority of their area within

the less-than-30-centimeters annual precipitation zone. Thus, there appears to be a greater degree of unpredictability of precipitation as aridity increases. We propose that the operation of recovery mechanisms, of which plant emergence and establishment is an example, is less predictable because of this unpredictability of precipitation. Perennial plant emergence and establishment that is fostered by the frequency of favorable precipitation periods can easily be offset by the increased frequency of drought, which has been detected in the arid climate divisions. The result is less predictability with respect to perennial vegetation recovery, particularly vegetation that has been effected by management-induced disturbance stresses.

Extensive areas of rangeland that receive less than 30 centimeters of annual precipitation within the Basin have been subjected to management-induced disturbance stresses, including excessive livestock grazing pressure, colonization by exotic plants, and alteration of fire regimes. Extensive areas within the 25-to-30-centimeters precipitation zone have already been colonized by the exotic annual grass cheatgrass, and are highly susceptible to further invasion by cheatgrass (maps 3.24 and 3.26). Certain life history characteristics of cheatgrass, especially its annual life cycle and prodigious production of seeds that can survive more than one year, ensures successful recruitment at some level despite the unpredictability of precipitation.

The 25-to-30-centimeters precipitation zone is recognized in most seeding guides as being within the lower range for successful reseeding of perennial grass species, providing that soil factors are not limiting (Miles and Karl 1995). Rangelands within a less-than-25-centimeters annual precipitation zone appear to be somewhat less susceptible to colonization by exotic annual grasses and other exotic plants, compared with rangelands in higher precipitation zones. For example, medusahead is less likely to successfully colonize sites that receive less than 25 centimeters of annual precipitation, compared with more mesic sites. Only a few exotic plants (for example, halogeton and squarrose knapweed) thrive in cover types (for example, salt desert shrub) within this precipitation zone. Once the exotic annual grasses have established, though, there is little likelihood of recovery of these sites by reseeding or natural succession. For example, of several perennial grass species typically used for the reseeding of arid rangelands, most are not able to successfully establish in the less-than-25-centimeters annual precipitation zone. A major exception, however, is the crested wheatgrass complex, as some cultivars (for example "Siberian" crested wheatgrass) can successfully establish in the less-than-25-centimeters annual precipitation zone (Miles and Karl 1995).

These findings suggest that the recovery potential of (1) vegetation, (2) soil integrity, and (3) ecological processes in the less-than-25-centimeters precipitation zone is diminished compared with the 25-to-30-centimeters precipitation zone, which in turn is diminished compared with the less-than-30-centimeters precipitation zone. We propose that the greater-than-30-centimeters precipitation zone (>12 inch zone in map 3.24) confers a moderate-low susceptibility of rangeland health to management-induced disturbance stresses (susceptibility shifts from moderate to low in association with precipitation increase above 30 cm); the 25-to-30-centimeters precipitation zone (10-12 inch zone in map 3.24) confers a moderate susceptibility of rangeland health to management-induced disturbance stresses; and the less-than-25-centimeters precipitation zone (0-6, 6-8, and 8-10 inch zones in map 3.24) confers a high susceptibility of rangeland health to management-induced disturbance stresses.

Spatial Extent of Susceptibility

The landscape extent of moderate and high susceptibility of rangeland health to management-induced disturbance stresses, as indicated by the 25-to-30-centimeters (10-12 inch) and less-than-25-centimeters (<10 inch) precipitation zones in map 3.24, is sickle-shaped and extends from northern Washington south through eastern Oregon, and east through southern Idaho. About 23 percent of the Basin lies within these two precipitation zones.

Rangeland health of high susceptibility— Rangeland health of high susceptibility to management-induced disturbance stresses is of greatest extent in the Columbia Plateau, Owyhee Uplands, Upper Snake, and Northern Great Basin ERUs (map 3.24), where for all land ownerships, it exceeds 10 percent of the land area of each ERU [table 3.46; see climate indicators, percent of ERU, and All lands]. In the Owyhee Uplands and Northern Great Basin ERUs, the high susceptible lands are primarily FS/BLM ownership (table 3.46). Rangeland health of high susceptibility is negligible in extent in the remaining ERUs, never exceeding 3 percent of the land area.

Over 50 percent of the lands of high susceptibility in each of the Columbia Plateau, Owyhee Uplands, Upper Snake, and Northern Great Basin ERUs is also characterized by one or more soil property indicators of susceptibility (table 3.46; see soil property indicators and All lands). In the Columbia Plateau ERU, the high susceptibility land area is particularly susceptible to soil erosion by water (map 3.39) or wind (map 3.18). Soils susceptible to erosion by wind (map 3.18), saline soils (map 3.42), and soils susceptible to the combination of these two indicators (map 3.34), are prevalent in the high susceptibility lands of the Owyhee Uplands and Northern Great Basin ERUs. In the Upper Snake ERU, the land of high susceptibility is particularly susceptible to soil erosion by water, and soil salinity is extensive (map 3.41).

Rangeland health of moderate susceptibility— Rangeland health of moderate susceptibility to management-induced disturbance stresses is also of greatest extent in the Upper Snake, Owyhee Uplands, Northern Great Basin, and Columbia Plateau ERUs (map 3.24), where for all land ownerships, it equals or exceeds 20 percent of the land area in each ERU [table 3.46; see climate indicators, percent of ERU, and All lands]. The moderate susceptibility land in FS/BLM land ownership is roughly 50 percent or greater in these ERUs, except for the Columbia Plateau ERU, where moderate susceptibility land is primarily in Other land ownership (table 3.46). Rangeland health of moderate susceptibility to management-induced disturbance stresses is not prevalent in any of the remaining ERUs, never exceeding 5 percent of the land area.

Over 50 percent of the moderate susceptibility land in each of the Upper Snake, Owyhee Uplands, Northern Great Basin, and Columbia Plateau ERUs is also characterized by one or more soil property indicators of susceptibility (table 3.46; see soil property indicators and All lands). In the Upper Snake ERU, the moderate susceptibility land is particularly susceptible to soil erosion by wind (map 3.18), soil salinity (map 3.42), the combination of soil erosion by wind and soil salinity (map 3.34), and the combination of soil erosion by water and soil salinity (map 3.41). The moderate susceptibility land in the Owyhee Uplands ERU is particularly susceptible to soil erosion by wind (map 3.18), and the combination of soil erosion by wind and soil shrinking or swelling from drying or wetting (map 3.19). In the Northern Great Basin ERU, soil erosion by wind is the most prevalent soil property indicator on the moderate susceptibility land (map 3.18). Both soil erosion by water (map 3.39), and soil erosion by wind (map 3.18), are prevalent soil property indicators on the moderate susceptibility land of the Columbia Plateau ERU.

Rangeland health of moderate-low susceptibility— Rangeland health of moderate-low susceptibility to management-induced disturbance stresses ranges from 45 to 56 percent of the land in the Columbia Plateau, Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs [map 3.24, table 3.46; see climate indicators, percent of ERU, and All lands]. Conversely, in each of the remaining ERUs, rangeland health of moderate-low susceptibility exceeds 90 percent of the land base (map 3.24, table 3.46). Lands in these remaining ERUs contain nearly all of the forested lands in the Basin, thus a more accurate extent of rangeland health of moderate-low susceptibility would be much less within each of these ERUs than is portrayed in table 3.46.

Prevalent soil property indicators on the moderate-low susceptibility lands in the Columbia Plateau, Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs are similar to what was reported for high and moderate susceptibility lands in these ERUs (table 3.46). Moderate-low susceptibility lands in the Columbia Plateau ERU are particularly susceptible to soil erosion by water (map 3.39) and soil erosion by wind (map 3.18). Soil erosion by wind (map 3.18), and the combination of soil erosion by wind and soil shrinking or swelling from drying or wetting (map 3.19), are prevalent soil property indicators on moderate-low susceptibility land in the Northern Great Basin and Owyhee Uplands ERUs. In the Upper Snake ERU, moderate-low susceptibility land is particularly susceptible to (1) soil erosion by wind (map 3.18), (2) soil erosion by water (map 3.39), (3) soil salinity (map 3.42), (4) the combination of soil salinity and soil erosion by water (map 3.41), and (5) the combination of soil salinity and soil erosion by wind (map 3.34).

Generalities for soil property indicators on rangelands—There are some soil property conditions worthy of reiterating and summarizing for the Columbia Plateau, Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs. The majority of the lands (found within the Basin) with rangeland health of high and moderate susceptibility to management-induced disturbance stresses exist in these ERUs. These soil property conditions are as follows:

1. Susceptibility of soils to erosion from rainfall on the lands with high and moderate susceptibility is particularly prevalent in the Columbia Plateau, Owyhee Uplands, and Upper Snake ERUs. This is also true for lands with moderate-low susceptibility in the Columbia Plateau and Upper Snake ERUs (maps 3.38, 3.39, 3.40 and 3.41).
2. Susceptibility of soils to erosion from wind on the high, moderate, and moderate-low susceptibility lands is particularly prevalent in the Columbia Plateau, Northern Great Basin, and Owyhee Uplands ERUs, and on the moderate and moderate-low susceptibility lands in the Upper Snake ERU (maps 3.18, 3.19, 3.34, 3.38, and 3.40).
3. Soils with quantities of soluble salts (saline soils) sufficient to limit plant growth are particularly prevalent on the high susceptibility lands in the Columbia Plateau, Northern Great Basin, and Owyhee Uplands ERUs. This is also the case on the high, moderate, and moderate-low susceptibility lands in the Upper Snake ERU (maps 3.34, 3.40, 3.41, 3.42, 3.43, 3.44, and 3.60).
4. Sodic soils are not particularly prevalent on the high, moderate, or moderate-low susceptibility lands in the Columbia Plateau, Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs. The Owyhee Uplands and Upper Snake ERUs have the greatest extent of sodic soils on these lands; yet even in these ERUs, the extent is nearly negligible at the broad-scale (maps 3.44 and 3.60).
5. Soils that shrink or swell from drying or wetting are particularly prevalent in the Owyhee Uplands and Northern Great Basin ERUs (maps 3.19, 3.20, 3.43, 3.60, and 3.61), and are less prevalent in the Columbia Plateau and Upper Snake ERUs (maps 3.19, 3.20, and 3.43). Shrink-swell soils on high susceptibility lands are most prevalent in the Owyhee Uplands ERU. Shrink-swell soils in the Columbia Plateau ERU are limited to the southern portion of that ERU.

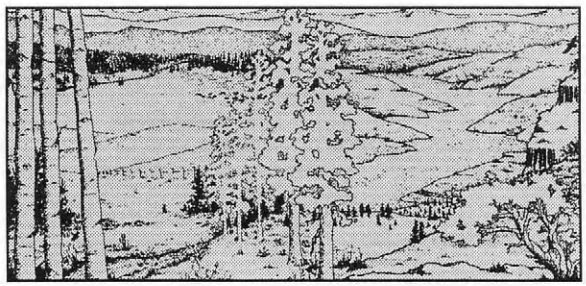
Map 3.60—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil salinity and sodicity, potential for soil to shrink or swell from drying or wetting, and soil erodibility to wind. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having these specific soil-property indicators: salinity of 8 to 16 millimhos per centimeter (mmhos/cm), and a SAR between 5 to 12, and a high shrink-swell potential (SSP), and wind erodibility Groups 1 through 3; the other focal, soil-property indicator was not present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

Map 3.61—Susceptibility of rangeland health to management-induced disturbance stresses in the Basin as indicated by the linking of climate with soil erodibility to water and wind, and potential for soil to shrink or swell from drying or wetting. Shaded areas represent soil map units with a 75 percent or greater areal extent of soils having these specific soil-property indicators: a soil erodibility factor (K factor) exceeding 0.37, and a high shrink-swell potential (SSP), and wind erodibility Groups 1 through 3; neither of the other two, focal, soil-property indicators are present in the soils over 75 percent of their extent. Soil map units existing in the less-than-25-centimeters precipitation zone represent rangeland health of high susceptibility to management-induced disturbance stresses; soil map units existing in the 25-to-30-centimeters precipitation zone represent rangeland health of moderate susceptibility; and soil map units existing in the greater-than-30-centimeters precipitation zone represent rangeland health of moderate-low susceptibility.

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REGIONAL TRENDS IN LANDSCAPE DYNAMICS

General Landscape Patterns

We were able to detect general landscape patterns relative to landforms, types of landscape mosaics, potential vegetation groups, succession and disturbance regimes, and vegetation composition and structure.

At the subbasin scale there are three coarse patterns of landscape mosaics relative to PVGs: (1) subbasins dominated by forest PVGs; (2) subbasins dominated by rangeland or non-forest PVGs; and (3) subbasins dominated by an array of forest and rangeland PVGs (table 3.175). The forest landscape pattern is largely composed of subbasins that receive at least 76 centimeters annual precipitation, whereas the rangeland landscape pattern is composed of subbasins that receive 20 to 36 centimeters average annual precipitation. The forest/rangeland landscape pattern is largely ecotonal in nature (that is, in terms of precipitation), and is composed of subbasins that receive 36 to 76 centimeters average precipitation per year. The forest and rangeland landscape patterns typically have relatively low topographical relief, whereas the forest/rangeland pattern commonly occurs in areas having relatively steep and dissected topography. The forest/rangeland pattern subbasins are generally more dynamic in terms of biophysical conditions, succession/disturbance regimes, and composition of vegetation types. Ecological processes within the forest/rangeland pattern subbasins are more dynamic than the other two landscape patterns. This is because there are steeper energy gradients between upper and lower elevations and between the large variety of biophysical templates within the mosaic. The composition of landscape patterns within the Basin as a whole and within BLM/FS lands occurs in nearly equal proportions (table 3.175).

Our classification of subbasins, which incorporated the landscape pattern and landform, resulted in 13 unique classes (table 3.176). We believe these strata were highly correlated to both environmental and land-management potentials. The forest/rangeland, forest, and rangeland landscape patterns were each composed of seven, four, and two classes, respectively. Although only two rangeland subbasin landscape classes occurred on BLM/FS lands (the dry shrub plains and the dry-cool shrub plains), they accounted for nearly 35 percent of BLM/FS lands. Similarly, approximately 30 percent of BLM/FS lands occurred within the four subbasin landscape classes comprised by the forest landscape patterns. Not surprisingly, the landscape classes were not distributed evenly with respect to the EEIS and UCRB management regions (table 3.176).

Our landscape dynamics assessment of the Basin focused on key ecological relationships of BLM/FS lands. Consequently, our discussion of the patterns of broad-scale succession and disturbance regimes is oriented toward wildland environments, not areas dominated by agricultural and urban land uses. At a coarse scale, the detected patterns of succession/disturbance regimes appear to be stratified by the pattern of landforms and PVGs that dominated subbasin landscapes. We evaluated the patterns of succession/disturbance regimes in relation to traditional practices of forestry, fire, livestock, and reserve management.

Table 3.175—Areal extent of landscape (subbasin level) pattern types by land ownership group.

Landscape Pattern	BLM/FS land Ownerships	BLM/FS Percent of All land Ownerships	Other land Ownerships	All land Ownerships
		Percent		
Rangeland / Forest				
BLM/FS land	35	18	18	36
Forest				
BLM/FS land	30	16	13	29
Rangeland				
BLM/FS land	35	18	17	35
Total				
BLM/FS land	100	52	48	100

Forest landscape patterns

Forest landscape patterns have predictable patterns of succession/disturbance regimes (fig. 3.11a, b, and c; table 3.20). The ridge and terrace landforms usually have a maintenance regime in which the dominant overstory structure is maintained by periodic, non-lethal disturbances. Typically, ridges and terraces support a late-seral single-layer forest that is dominated by coniferous species. Understory trees are commonly killed by disturbances, which can include fire, insects, diseases, grazing, and stress. Periodicity of disturbances in this landscape pattern range from 5 to 50 years; more frequent disturbance intervals generally occur in warmer environments, whereas less frequent intervals occur in colder environments. However, regardless of the frequency, the composition and structure of forests in these areas are maintained over the long term. Slope landforms usually support an accelerated-cycling regime, in which non-lethal and mixed disturbances thin or create gaps within the overstory and understory of susceptible species, thereby promoting the growth of the residual vegetation mosaic. Consequently, slope environments within the forest landscape pattern commonly support a mixture of early- and mid-seral coniferous forests that typically have emergent residual trees as an overstory component. However, a lethal fire disturbance can eventually cycle the overstory, thus creating large patches of early-seral forest, and smaller scattered patches of mid-seral forest composed of large, shade-intolerant, insect-, disease-, and fire-resistant trees. The footslope landform generally has an irregular-maintenance regime in which non-lethal and mixed disturbances occur at irregular intervals. Thus, the irregular-maintenance disturbance regime can typically sustain structurally diverse forest stands composed of multiple cohorts and multiple canopies. Consequently, footslopes commonly support coniferous stands dominated by a late-seral multi-layer structure. Toeslope landforms are adjacent to the channel zone and may incorporate a draw. Toeslopes are usually associated with disturbances (including fires and floods) that occur at moderate intervals, and which are lethal to the overstory. Younger soils with coarser textures typically support a mosaic of shrubs and herbs, whereas older soils containing finer textures often support a mosaic of mid-seral broadleaf- or conifer-dominated forests, and herb-dominated communities. The channel zone/draw landform occurs within the average-annual-wetted

Table 3.176—Subbasin (4th field hydrologic unit codes) landscape patterns and their respective landscape classes on BLM/FS lands.[1]

Subbasin Landscape Pattern	Subbasin Landscape Class Name	Number of Subbasins			Percent of BLM/FS lands
		EEIS	UCRB[2]	Total	
Forest	Moist Forest Foothills and Mountains	11	20	31	15[3]
Forest	Moist-Cold Forest Foothills and Mountains	3	6	9	8
Forest	Cold Forest Mountains	1	9	10	7
Forest	No BLM/FS lands	0	0	1	0
Rangeland	Dry Shrub Plains	22	6	28	18
Rangeland	Dry-Cool Shrub Plains	4	15	19	17
Rangeland / Forest	Dry Shrub / Dry Forest Foothills	6	1	7	3
Rangeland / Forest	Dry Forest Foothills	14	2	16	8
Rangeland / Forest	Dry-Cool Shrub/ Dry-Moist Forest Plains, Foothills, and Mountains	3	1	4	1
Rangeland /	Dry-Moist Forest Foothills and Mountains	7	4	11	4
Rangeland / Forest	Dry-Cool Shrub / Dry-Cold Forest Plains, Foothills, and Mountains	2	6	8	4
Rangeland / Forest	Dry-Cold Forest Foothills and Mountains	1	9	10	7
Rangeland / Forest	Dry-Moist-Cold Forest Foothills and Mountains	4	6	10	8

[1]Subbasin landscape classes are based on grouping subbasins with similar potential vegetation group, climate, and landform composition on BLM/FS lands.

[2]UCRB = UCRB and GYE management regions combined.

[3]Percents were rounded and do not sum to 100.

perimeter of streams and rivers. Consequently, the channel zone/draw landform is subject to a short-cycle disturbance regime that is lethal to the overstory and concomitantly maintains relatively sparse communities of shrubs and herbs.

Management strategies that produced traditional commodity forestry and reserve patterns also produced predictable patterns of succession and disturbance regimes, and subsequently, vegetation patterns. For example, timber harvest activities, as well as the establishment of reserves have been associated with topographic features. As a general rule, harvesting generally occurred in the more accessible areas that supported large trees, whereas the establishment of reserves has often been associated with the least accessible and least productive areas. Traditional forestry management in conjunction with fire suppression has substantially changed the pattern of succession/disturbance regimes.

Harvest treatments on ridges and terraces were commonly clearcuts or selective cuts, which removed the large trees, and concomitantly changed the succession/disturbance regime from a maintenance regime to a cycling regime. Since ridge and terrace landform sites are commonly dry and exposed to the sun, regeneration rates and growth rates of large trees are slow, and regenerating trees are usually unable to reach maturity during the interval between fire events. Artificial regeneration practices (that is, planting), when successful, typically results in dense stands that stagnate and become more susceptible to fire, insects, and disease disturbances. Consequently, the succession/disturbance regime shifts to a very long-cycle regime. Harvest treatments have often resulted in relatively large fuel accumulations compared with the maintenance regime. Without human intervention to restore the native succession/disturbance regime, it is most likely that these sites will cycle several times and mortality risks associated with insect, disease, stress, and fire intensity will increase, before the regime shifts back to the maintenance regime.

In areas with traditional reserve management landscape patterns, the succession/disturbance regime within non-harvested stands and forests, where fires have been excluded, has commonly shifted to a retrogressive regime. This has been particularly true in areas where the disturbances are dominated by insect, disease, and stress mortality agents that occur throughout all size classes of trees. The retrogressive regime does not cycle the overstory back to an earlier succession stage in one, single event. Instead, the conversion of the overstory is the cumulative result of years of disturbance, for example the gradual loss of large, shade-intolerant trees resulting from harvest activities, fire exclusion, and stress. In these areas, succession has shifted the relatively open late-seral single-layer forest to a relatively dense late-seral multi-layer forest that may or may not have large old trees. In areas affected by traditional forestry practices, the large trees have typically been selectively cut, whereas the large trees may still remain in the reserve areas.

Without active restoration activities designed to change the succession/disturbance regime, it is likely that these sites will succumb to a lethal crown fire. Furthermore, in the absence of restoration, two to four lethal-fire cycles will likely occur before traditional commodity (forestry) or reserve landscape pattern areas will eventually return to their native maintenance succession/disturbance regimes.

On slope landforms, traditional forestry and fire management has caused a decline of large, shade-intolerant, residual trees, thereby fostering the development of dense, mid-seral stands. Consequently, slope landforms in traditional commodity patterns commonly comprise a mosaic of late-seral multi-layer and mid-seral communities that have a retrogressive regime. Fire exclusion in reserve areas has also resulted in a similar mosaic, but large residual emergent trees are usually still present. Because of their relatively steep topography and the change from the accelerated to the retrogressive regime, these areas have a high risk of lethal crown fires, which have the potential to kill even the large emergent trees. Without human intervention to restore the native regime, these areas could go through very-long regeneration periods following a fire, due in part to the lack of a seed source. In addition, when regeneration is successful, the new forest could be dominated by a species that is atypical of the biophysical template. After one cycle without human intervention, some of these areas could return to the accelerated-cycle regime, native to the biophysical template. However, in areas of the moist or cold forest PVGs — where western white pine or whitebark pine played a dominant role prior to the introduction of blister rust — no other tree species endemic to the region can grow to maturity and survive insect-, disease-, and stress-attacks, or mixed- and lethal fire events.

Traditional forestry practices within footslope landforms usually involved clearcut or selective harvest prescriptions. Footslope landforms on traditional commodity landscape patterns commonly supported stands composed of large trees and high timber volumes, prior to Euro-American

settlement. The footslope landform is relatively accessible. Consequently, this landform is highly correlated with road locations. The footslope environment often occurs in areas prone to frosts and high soil moisture. The irregular-maintenance regime common to footslope landforms during the historical period, did not cycle the overstory because the tall dense canopy, high humidity, and high duff moisture levels dampened the severity of fire events. This overstory of large trees also protected regenerating trees from frost, produced high rates of transpiration, and maintained the water table below the surface soil horizon during the growing season. Traditional forestry practices typically removed the overstory, thereby exposing the regenerating trees to frost and high water tables. Consequently, the footslope landform succession/disturbance regime within traditional commodity management patterns, has commonly shifted from the native irregular-maintenance regime to the very long-cycle regime.

Restoration of the footslope landform native regime typically occurs with or without human intervention, but humans could shorten the regeneration process by planting tree species that are tolerant of frost and high water tables, or by taking other protective measures such as planting trees in higher, frost-free microsites. Roads in the footslope landform exacerbate the problems associated with high water tables, because they have the potential to raise subsurface water flows closer to the surface. Roads have a short-cycle disturbance regime with high erosion potential. Furthermore, footslope landforms are commonly relatively close to streams, thus the sediment produced from roads has a short delivery distance to stream networks.

In the toeslope and channel zone/draw landforms, traditional forestry management typically excluded fire; lowered the water table through removal of beavers and large logs from the streams, and by channelizing streams; and constructed roads in areas with narrow valley bottoms. Fire exclusion and lowered water tables in toeslopes and channel zone/draw landforms have been more conducive to mid-seral and late-seral multi-layer coniferous forests than the more poorly-drained mosaic of shrubs, herbs, and broadleaf forests. Traditional forestry practices have thus, extended the intervals of the cycling regime native to these landforms. When fires occur in the heavier fuel-laden areas beneath a coniferous overstory or in dryer conditions attributable to lower water tables, they tend to be more severe.

In channel zone/draw landforms, declining subsoil moisture resulting from channelization and higher transpiration rates has caused a concurrent change of vegetation; the density of shrubs and trees has increased. In landscapes having higher precipitation rates and where upland landforms are densely roaded and have been harvested the frequency of runoff events has increased. Although these runoff events typically are of short duration, they tend to be relatively severe. Channel zone/draw landforms in these areas have less resiliency to these more frequent and severe events because of the concurrent decline of riparian vegetation and channel stability. Depending on the stream gradient, above-normal sediment loads are commonly deposited in pools and other slack water areas, further exacerbating the channel instability. Bridges and culverts in these channels further alter the channel dynamics.

Several traditional forestry practices within the forest landscape pattern seem to have resulted in major changes in the succession/disturbance regimes and subsequent vegetation patterns, regardless of landform. Managers of BLM- and FS-administered lands have commonly tried to accelerate the regeneration process of harvested areas, and to a lesser degree, areas burned by lethal fires. These regeneration efforts have shortened the regeneration period that is common to native systems, thereby reducing the areal extent of stand initiation structures. Precommercial thinning, another practice common to traditional commodity landscape pattern areas, was not extensive enough to mimic the maintenance and accelerated-cycle regimes of the native system. Consequently, successional sequences of many thinned areas stagnated until they were cycled by a disturbance event that was lethal to the overstory. In addition,

when we simulated the effects of no harvest and fire exclusion at a landscape level, we found that the resultant vegetation patterns became measurably different from native systems within 50 years in warmer landscapes and within 100 years in colder landscapes.

The response of vegetation patterns to traditional forestry practices varied according to the scale of analysis. At the broadscale, the 1-square-kilometer resolution tended to "blend" patterns together, making them appear more homogeneous and contiguous than they had been historically. However, at the mid-scale, the mosaic patterns of landscapes that had been managed with traditional forestry practices were typically more diverse and fragmented than they had been historically (Hessburg and others 1996a). Harvest patterns on lands administered by the Forest Service have been somewhat constrained since the National Forest Management Act of 1976 (U.S. Laws and Statutes 1976). The restrictions limiting the size of harvest patches to less than 16 hectares, and the more recent trend toward smaller patches, has led to the systematic fragmentation of forest landscapes.

Traditional reserve or wilderness management has generally emphasized a passive approach to management, and thus, involved little direct vegetation management and a very conservative prescribed natural-fire program. The guidelines for prescribed natural fires typically only allow fires to burn that are lightning-ignited and that have a high likelihood of remaining within the reserve. Few lightning-caused fires meet the prescription guidelines. Consequently, the extent of current period fire disturbances was well below that of the historical period. Therefore, traditional reserve landscape patterns have experienced substantial changes in succession/disturbance regimes and the associated vegetation structures and composition. As with traditional commodity landscape patterns, measurable fire disturbances in reserves have been less frequent but more severe, than they were in the native system.

Broad-scale and mid-scale (Hessburg and others 1996a) vegetation patterns within traditional reserve landscape patterns were typically more homogeneous and contiguous than they were in native landscape patterns. Our simulations of successional responses to traditional reserve management patterns suggest that because of productivity differences that cause different rates of succession and mortality, the mosaic pattern that existed historically could merge and become one similar landscape in as little as 50 to 100 years in warmer and colder landscapes, respectively. The retrogressive regime that dominated the traditional reserve landscape pattern, in conjunction with variable successional rates and productivity, tends to result in homogenization of different community structures into one similar structure.

Rangeland Landscape Patterns

The primary disturbance agents of the rangeland landscape pattern include fire, herbivory, and drought. Areas dominated by rangeland PVGs also have repeatable patterns of succession/disturbance regimes associated with landform patterns (fig. 3.12a, b, and c; table 3.21). However, because rangeland environments commonly have lower relief, the landform profile may be more extended and not as obvious as it was within the forest landscape pattern.

The ridges, and terraces or plains usually have a mixed moderate-cycle and maintenance-disturbance regime that supports an herb-dominated grassland having a diverse component of upland grasses, sedges, forbs, and scattered shrubs. Scattered large conifers or junipers, or patches of shrubs are often found in areas (for example, rock outcrops) that have non-lethal fires. The intervals of disturbances in ridge, plains and terrace landforms vary between infrequent events in colder or dry environments, to more frequent events in warmer and moister environments.

Slope landforms usually support a moderate-cycle regime that maintains a shifting mosaic of shrub and herb communities. Shrub-dominated patches

are typically open, relatively young and vigorous, and have a diverse array of understory grasses and forbs. Herb-dominated patches are typically dominated by grasses with a subdominant array of sedges, forbs, and scattered shrubs. Shrub patches are often associated with topographic rises or rocky areas that have a high likelihood of non-lethal disturbances. Herb patches are commonly associated with concave areas that have deep soils and that may have a higher probability of lethal fires.

Footslope landforms have a maintenance regime that has a similar disturbance frequency as the ridge, terrace, and plains landforms. Footslopes are typically dominated by herb communities composed by large, robust grasses and forbs. However, inclusions of small patches of shrubs or broadleaf trees are commonly associated with springs and seeps.

In the toeslope landforms, flood or fire cycles typically occur at moderate intervals. Younger soils with coarser textures typically support a mosaic of shrub- and herb-dominated communities, whereas older soils having finer textures often support a mosaic of shrub and mid-seral broadleaf trees. Channel zone/draw landforms generally have a short-cycle regime and support scattered shrubs and herbs.

The effects of traditional grazing or reserve management practices also have predictable patterns of succession/disturbance regime changes. Traditional livestock grazing, fire exclusion, and the introduction of exotic plants have substantially altered the patterns and areal extent of lands affected by the succession/disturbance regimes. The succession/disturbance regime of the ridge landform changed from a mixed moderate cycle-maintenance regime to a long-cycle regime due to fire exclusion. Consequently, the herb-dominated communities that commonly occurred historically have been replaced by communities dominated by conifers or junipers. In areas that can not support trees, the herb-dominated communities are currently dominated by dense, decadent shrubs. In either case, ignition probabilities have declined substantially due to the lack of fine-grass fuels. These woody communities typically burn only during very dry conditions, rather than at intervals common for the native system. Furthermore, recent fires have generally burned more severely than they did historically, due to the increased amount of woody fuels that is common to the ridge landforms. Higher severity fires commonly kill the sparse understory of perennial grasses and forbs.

The soils of ridge landforms generally develop with a predominance of grasses, have relatively fine textures, and are subject to erosion when vegetation cover is removed. Conifer and juniper species retain nutrients in their canopy, rather than annually cycling nutrients through litter-fall as do shrubs, grasses, and forbs. When high-intensity fires occur in conifer stands, nutrients are often volatilized or transported off-site by runoff and erosion of the ash layer. Without human intervention to restore the native maintenance succession/disturbance regime, it is most likely that ridge landforms will continue to cycle at long intervals and have a concomitant decline of productivity due to the loss of soils and nutrients.

The response of slope landforms to traditional grazing management and fire suppression followed several pathways depending on the presence and composition of exotic plants. The moderate-cycle regime common to native slope landforms changed to a long-cycle regime if exotic species did not comprise a substantial proportion of the ground cover. However, on many sites, exotic plants have been introduced and now dominate. If exotic perennial herbs dominate the site, the native regime will likely change to a retrogressive regime. A retrogressive regime can result if perennial exotic forbs (for example, knapweeds, leafy spurge, and yellow starthistle) dominate a site due to poor fuel flammability (fires do not carry) and increased soil erosion. Lack of fires can prevent the overstory of exotic forbs from cycling back to other species. Furthermore, these sites commonly have reduced soil cover, and consequently soil erosion can be extensive. As soils continue to erode, the productivity of the exotic overstory eventually declines,

thereby causing the community to retrogress back to a site dominated by rock or pavement (gravels). On the other hand, the succession/disturbance regimes of sites dominated by exotic annual grasses typically changed to a short-cycle regime due to the preponderance of grass flash-fuels and an associated increase in fire frequency.

On slope landform sites lacking exotic species, the structure and composition of the native community have generally changed to a dense, decadent, shrub-dominated community having a sparse understory of grasses and forbs. In these areas, high livestock use during the growing season typically increased the dominance of shrubs because of the reduced competition from grasses and forbs. Conifer and juniper encroachment has commonly occurred on slope landforms having higher precipitation levels. The implications of the increased dominance of these sites by trees is similar to the ridge landforms. High livestock use during the growing season has increased the rate of tree encroachment; grazing results in decreased competition by grasses and removes fine fuels that are typically required to carry fire across the slope.

The potential for restoration of slope landforms to their native disturbance regime is dependent on the dominance and composition of exotic plants. Without human intervention on slope landforms, fire will eventually cycle the shrub-dominated communities back to an early-seral herb-dominated community, thereby returning the disturbance regime back to a moderate-cycle regime after one cycle. The potential for conifer- and juniper-dominated communities to return to their native disturbance regime and community is similar to the ridge landform. Those communities dominated by exotic forbs and annual grasses have virtually no potential to be restored to their native disturbance regime and communities without human intervention. Active human intervention will be required to replace the exotic species with competitive native herbs or with desirable exotic grasses that produce structures that are similar to the native system. In addition, without intervention, exotic communities will continue to expand into adjacent susceptible native communities. Even with active human intervention, there are many exotic species-dominated communities and many dry sites where there is low probability of successful restoration.

Because of their slope position, water developments have commonly been established on footslope landforms. In addition, footslopes typically have relatively high production of desirable grasses that remain palatable to livestock later into the summer. Consequently, footslopes commonly have experienced substantial grazing pressure during the growing season. High grazing use during the growing season has converted the native maintenance disturbance regime to a retrogressive regime. In these situations, the large, robust grasses and forbs, and small patches of shrubs and broadleaf trees common in native communities, have been replaced by smaller grass and forb species that are more typical of the slope landforms.

Restoration of the native landscape pattern maintenance regime could be achieved relatively easily by altering livestock distribution and decreasing growing season grazing use. A reprieve from livestock use would allow accumulation of fine fuels, which when followed by prescribed fire could be used to give the robust grasses a competitive advantage. Exotic, rhizomatous, perennial grasses (such as Kentucky bluegrass) with relatively shallow roots and low productivity commonly become established in footslope landforms and are difficult to control with current technology. However, livestock grazing could be managed to promote deep root development, thereby increasing vegetation cover and reducing soil erosion. In the higher precipitation zones, footslope landforms may have the potential to support conifer- or juniper-dominated communities. On these more productive sites, fire suppression has caused a trend and response similar to that described for the ridge and slope landforms. However, because of the higher availability of moisture in footslope environments, the domination by shrubs and conifers typically occurs much faster on footslope landforms.

High livestock use during the growing season has been common on terrace and plains landforms due to their relatively flat terrain and proximity to water. In conjunction with fire suppression, growing-season grazing has generally converted the native moderate-cycle disturbance regime to a retrogressive regime. In turn, the retrogressive-cycle regime has decreased the overall density of grasses, and increased the dominance of smaller grasses and forbs. Terrace and plains landforms are susceptible to invasion by exotics and have had responses and implications similar to those of the slope, ridge, and footslope landforms. In cases where the plains/terrace landforms have the potential to support shrub-, juniper-, or conifer-dominated communities, the changes of disturbance regime and response of the vegetation have been similar to those of the slope landforms.

A considerable amount of plains/terrace landforms has been planted to exotic perennial grasses, primarily crested wheatgrass. Although the seeded grassland communities have a structure similar to the native grasslands, they do not have the compositional diversity of the native herb communities. Traditionally, grazing systems on these seeded exotic-grass communities maintained the grassland, and because of the effects of the grazing system or lack of a seed source for shrubs, the successional cycle may have been extended. There is considerable opportunity for restoration of the native succession/disturbance regime in the moister precipitation zones of terrace or plains environments. This could be accomplished through changing grazing systems, control of exotic species, and restoration of fire. Currently, technology is not available to allow restoration of the native communities and succession/disturbance regimes in the drier precipitation zones, however.

In the toeslope and channel zone/draw landforms, traditional grazing practices, fire exclusion, changing hydrologic disturbance (for example, dams, removal of beavers, and the construction of roads that constrict the floodplain) have caused substantial changes in the disturbance/succession regimes. The moderate-cycle regimes has typically been replaced by a retrogressive-cycle regime, primarily due to excessive grazing pressure during the summer, which has resulted in the demise of broadleaf tree and riparian shrub regeneration. Consequently, the structure of the resulting communities has changed to a single-layered overstory of trees or shrubs with an herbaceous understory.

In lower gradient streams, the loss of riparian vegetation and the physical impacts associated with excessive livestock grazing pressure have often resulted in unstable streams and a subsequent lowering of the water table. As the water table was lowered, the disturbance regime commonly shifted to a retrogressive regime in which overstory trees and shrubs were replaced by rhizomatous exotic grasses, such as Kentucky bluegrass. Roads in these environments have a short-cycle regime. Channel stability generally declines in association with the loss of effective woody and herbaceous root systems, and flows are often reduced such that channels are no longer maintained. Toeslope and channel zone/draw landforms that have retrogressive disturbance regimes tend to be less able to buffer the effects of flood events or to store water that maintains late-season flows. Consequently, floods typically further degrade the stability of the channel. Furthermore, degradation of the channel may be exacerbated by traditional forestry and grazing practices that occur upstream.

Traditional reserve management practices in the rangeland landscape pattern typically result in cycling regimes having longer disturbance intervals of more severe events. Consequently, plant communities often respond with an increase in woody species dominance. An increase of woody species, and concomitant increase in transpiration rates may result in lower water tables and the declining flow of springs within footslope landforms. The probability of invasion by exotic plants into reserve areas is generally much lower than in the areas with excessive livestock grazing pressure. However, recreationists, wildlife, and streams may act as important vectors for the dispersal of exotic plants. Exotic plants have a higher probability of invading disturbed sites located within drier precipitation zones.

Forest-Rangeland Landscape Patterns

Landscapes that are dominated by a mosaic of forest and rangeland PVGs have inherently more diverse biophysical templates, succession/disturbance regimes and vegetation patterns, than do forest-dominated or rangeland-dominated landscapes (fig. 3.13a, b, and c; table 3.22). Although the individual landform, potential vegetation group, and succession/disturbance regime relationships are generally the same as in the forest-dominated or rangeland-dominated landscapes, the effects at the landscape level are substantially different. The forest-rangeland landscape pattern has many complex ecotonal and disturbance related contagion relationships among its varied environments and communities.

Traditional forestry and grazing practices, introduction of blister rust, introduction of exotic plants, and exclusion of fire, have substantially changed the succession/disturbance regimes and associated vegetation structure and composition in the forest-rangeland landscape pattern. Typically, the change of disturbance regimes are associated with longer intervals between cycling disturbances, and an increase of area affected by the retrogressive regime.

Traditional reserve management practices, in conjunction with fire exclusion and introduction of blister rust and exotic plants, have also substantially changed the succession/disturbance regimes and associated vegetation structures and composition. Once again, these disturbances typically have longer intervals and are more severe than the disturbance regimes of the native pattern. In general, the changes that occurred in forest-rangeland landscape patterns have been more substantial than those observed in either the forest or rangeland landscape patterns. This is because the energy gradients are steeper, topography is more rugged, the disturbance regimes are more dynamic due to the forest/rangeland mosaic, and the diversity of species are higher in the forest/rangeland landscape pattern.

Trends of Fine-scale Forest Conditions

An analysis of forest plot data was conducted to evaluate trends of selected elements of forest composition and structure (Hann and others 1997). These elements included tree density, tree basal area, number of snags, fuel loadings, amount of litter, and density of pole-sized and larger trees (≥ 13 cm diameter at breast height or dbh). A large volume of data were initially compiled from various sources within the management and research agencies, but only a subset warranted analysis due to errors, inconsistencies, and illogical relationships between attributes and variable formats. For this analysis, Forest Service Northern Fire Laboratory Research Plots had the highest consistency between different administrative units and the most complete set of information. Consequently, Forest Service Northern Fire Laboratory Research Plots were used for the trend analysis.

Due to the inability to apply computer model outputs to fine-scale analysis much of our discussion of fine-scale forest conditions and trends is based on interpretation of the trends in plot data, comment discussions from field notes, and photographs collected from the plots.

Plot data was stratified by potential vegetation group, structural stage, and size class. Multiple plot comparisons were made between non-harvest with no fire, harvest, non-harvest with fire, partial stand replacement with fire or harvest, and stand replacement with fire or harvest. Non-harvest regimes included plots affected by fire exclusion as well as plots with recent and historical fire, insect, and disease disturbances. Harvested regimes included plots affected by various harvest treatments.

Non-harvest regimes without recent fire had higher densities and basal areas of snags and trees relative the harvest regime treatments (table 3.177). In contrast, harvest regime treatments produced higher amounts of down fuel than occurred in non-harvest regimes without recent fire. Stand replacement non-harvest with fire had higher densities of trees and snags, more litter/duff depth, but less fuel, than stand replacement with harvest.

Table 3.177—Comparative analysis for density of live trees for all size classes, density for size classes ≥ pole-size trees, basal area, snag density, fuel loading, and litter/duff depth by two management regimes (non-harvest and harvest) and by two disturbance types (partial stand replacement and stand replacement). Summarized trends are stratified by potential vegetation group (PVG), structural stage (SS), and size class (SC).

Comparison	Strata[1]	Density All[2]	Density-Pole+ >13cm[3]	Basal Area	Snag Density[4]	Surface Fuel Loading	Litter/Duff Depth
Non-harvest—No fire and Harvest	All Plots	+Harvest[5]	*Non-harvest[6]	*Harvest	*Harvest	*Harvest	NT[7]
Non-harvest—No fire and Harvest	SS	NT	*Non-harvest	*Non-harvest	*Non-harvest	*Harvest	NT
Non-harvest—No fire and Harvest	SC	*Non-harvest	*Non-harvest	*Non-harvest	*Non-harvest	NA[8]	NA
Non-harvest—No fire and Harvest	PVG / SS	NT	*Non-harvest	*Non-harvest	*Non-harvest	+Harvest	NT
Non-harvest—No fire and Harvest	PVG / SC	NT	*Non-harvest	*Non-harvest	*Non-harvest	NA	NA
Non-harvest—No fire and Harvest	SS / SC	+Non-harvest	*Non-harvest	+Non-harvest	*Non-harvest	NA	NA
Non-harvest—No fire and Harvest	PVG / SS / SC Dry	+Harvest	NT	NT	*Non-harvest	NA	NA
Non-harvest—No fire and Harvest	PVG / SS / SC Moist	+Non-harvest	*Non-harvest	*Non-harvest	*Non-harvest	NA	NA
Non-harvest—No fire and Harvest	PVG / SS / SC Cold	+Non-harvest	+Non-harvest	*Non-harvest	*Non-harvest	NA	NA
Non-harvest—Fire Partial Stand Replacement to Non-harvest—Fire Stand Replacement	All Plots	NT	*Stand Replacement	*Partial Stand Replacement	*Stand Replacement	*Stand Replacement	NT
Non-harvest—Fire Partial Stand Replacement to Non-harvest—Fire Stand Replacement	SS	*Stand Replacement	*Stand Replacement	+Partial Stand Replacement	*Stand Replacement	+Stand Replacement	NT
Non-harvest—Fire Partial Stand Replacement to Non-harvest—Fire Stand Replacement	SC	+Stand Replacement	NT	+Partial Stand Replacement	NT	NA	NA
Non-harvest—Fire Partial Stand Replacement to Non-harvest—Fire Stand Replacement	PVG / SS	+Stand Replacement	+Stand Replacement	NT	+Stand Replacement	NT	NT
Non-harvest—Fire Partial Stand Replacement to Non-harvest—Fire Stand Replacement	PVG / SC	NT	NT	+Partial Stand Replacement	*Partial Stand Replacement	NA	NA
Non-harvest—Fire Partial Stand Replacement to Non-harvest—Fire Stand Replacement	SS / SC	NT	+Partial Stand Replacement	NT	NT	NA	NA
Non-harvest—Fire Partial Stand Replacement to Non-harvest—Fire Stand Replacement	PVG / SS / SC Dry	NT	NT	+Partial Stand Replacement	NT	NA	NA
Non-harvest—Fire Partial Stand Replacement to Non-harvest—Fire Stand Replacement	PVG / SS / SC Moist	NT	+Partial Stand Replacement	+Partial Stand Replacement	NT	NA	NA

Table 3.177 (continued).

Comparison	Strata[1]	Density All[2]	Density-Pole+ >13cm[3]	Basal Area	Snag Density[4]	Surface Fuel Loading	Litter/Duff Depth
Non-harvest—Fire Partial Stand Replacement to Non-harvest—Fire Stand Replacement	PVG / SS / SC Cold	NT	NT	NT	NT	NA	NA
Harvest Partial Stand Replacement to Harvest Stand Replacement	All Plots	+Partial Stand Replacement	*Partial Stand Replacement	*Partial Stand Replacement	+Partial Stand Replacement	+Stand Replacement	+Partial Stand Replacement
Harvest Partial Stand Replacement to Harvest Stand Replacement	SS	+Partial Stand Replacement	*Partial Stand Replacement	*Partial Stand Replacement	+Partial Stand Replacement	+Stand Replacement	NT
Harvest Partial Stand Replacement to Harvest Stand Replacement	SC	*Partial Stand Replacement	*Partial Stand Replacement	*Partial Stand Replacement	+Partial Stand Replacement	NA	NA
Harvest Partial Stand Replacement to Harvest Stand Replacement	PVG / SS	+Partial Stand Replacement	*Partial Stand Replacement	*Partial Stand Replacement	+Partial Stand Replacement	NT	+Partial Stand Replacement
Harvest Partial Stand Replacement to Harvest Stand Replacement	PVG / SC	*Partial Stand Replacement	*Partial Stand Replacement	*Partial Stand Replacement	+Partial Stand Replacement	NA	NA
Harvest Partial Stand Replacement to Harvest Stand Replacement	SS / SC	*Partial Stand Replacement	*Partial Stand Replacement	*Partial Stand Replacement	NT	NA	NA
Harvest Partial Stand Replacement to Harvest Stand Replacement	PVG / SS / SC Dry	+Partial Stand Replacement	*Partial Stand Replacement	+Partial Stand Replacement	+Partial Stand Replacement	NA	NA
Harvest Partial Stand Replacement to Harvest Stand Replacement	PVG / SS / SC Moist	*Partial Stand Replacement	*Partial Stand Replacement	*Partial Stand Replacement	+Stand Replacement	NA	NA
Harvest Partial Stand Replacement to Harvest Stand Replacement	PVG / SS / SC Cold	*Partial Stand Replacement	+Partial Stand Replacement	+Partial Stand Replacement	NT	NA	NA
Partial Stand Replacement Non-harvest—Fire to Partial Stand Replacement Harvest	All Plots	+Harvest	+Harvest	*Non-harvest	*Non-harvest	*Harvest	NT
Partial Stand Replacement Non-harvest—Fire to Partial Stand Replacement Harvest	SS	*Non-harvest	*Non-harvest	*Non-harvest	*Non-harvest	*Harvest	NT
Partial Stand Replacement Non-harvest—Fire to Partial Stand Replacement Harvest	SC	NT	*Non-harvest	*Non-harvest	*Non-harvest	NA	NA
Partial Stand Replacement Non-harvest—Fire to Partial Stand Replacement Harvest	PVG / SS	+Harvest	NT	+Non-harvest	*Non-harvest	+Harvest	NT
Partial Stand Replacement Non-harvest—Fire to Partial Stand Replacement Harvest	PVG / SC	NT	*Non-harvest	NT	+Non-harvest	NA	NA
Partial Stand Replacement Non-harvest—Fire to Partial Stand Replacement Harvest	SS / SC	NT	NT	NT	*Non-harvest	NA	NA

Table 3.177 (continued).

Comparison	Strata[1]	Density All[2]	Density-Pole+ >13cm[3]	Basal Area	Snag Density[4]	Surface Fuel Loading	Litter/Duff Depth
Partial Stand Replacement Non-harvest—Fire to Partial Stand Replacement Harvest	PVG / SS / SC Dry	+Harvest	NT	NT	*Non-harvest	NA	NA
Partial Stand Replacement Non-harvest—Fire to Partial Stand Replacement Harvest	PVG / SS / SC Moist	+Non-Harvest	*Non-harvest	*Non-harvest	*Non-harvest	NA	NA
Partial Stand Replacement Non-harvest—Fire to Partial Stand Replacement Harvest	PVG / SS / SC Cold	+Non-harvest	*Non-harvest	*Non-harvest	*Non-harvest	NA	NA
Stand Replacement Non-harvest—Fire to Stand Replacement Harvest	All Plots	NT	*Non-harvest	*Non-harvest	*Non-harvest	+Harvest	+Non-harvest
Stand Replacement Non-harvest—Fire to Stand Replacement Harvest	SS	NT	*Non-harvest	*Non-harvest	*Non-harvest	+Harvest	NT
Stand Replacement Non-harvest—Fire to Stand Replacement Harvest	SC	*Non-harvest	*Non-harvest	*Non-harvest	*Non-harvest	NA	NA
Stand Replacement Non-harvest—Fire to Stand Replacement Harvest	PVG / SS	+Non-harvest	+Non-harvest	*Non-harvest	*Non-harvest	NT	+Non-harvest
Stand Replacement Non-harvest—Fire to Stand Replacement Harvest	PVG / SC	+Non-harvest	*Non-harvest	*Non-harvest	*Non-harvest	NA	NA
Stand Replacement Non-harvest—Fire to Stand Replacement Harvest	SS / SC	+Non-harvest	*Non-harvest	+Non-harvest	*Non-harvest	NA	NA
Stand Replacement Non-harvest—Fire to Stand Replacement Harvest	PVG / SS / SC Dry	NT	+Non-harvest	NT	+Non-harvest	NA	NA
Stand Replacement Non-harvest—Fire to Stand Replacement Harvest	PVG / SS / SC Moist	+Non-harvest	*Non-harvest	*Non-harvest	*Non-harvest	NA	NA
Stand Replacement Non-harvest—Fire to Stand Replacement Harvest	PVG / SS / SC Cold	*Non-harvest	+Non-harvest	+Non-harvest	*Non-harvest	NA	NA

[1]Strata codes: PVG = Potential Vegetation Group, SS = Stand Structure, SC = Size Class.

[2]Density encompasses tree density for all size classes.

[3]Density ≥ 13 encompasses tree density for size classes ≥ pole-size trees (d.b.h. ≥ 13 cm).

[4]Snag = dead-standing tree >13 cm d.b.h.

[5]+ indicates a positive trend (≥20% and <60% difference in frequency).

[6]* indicates a positive substantial trend (≥60% difference in frequency).

[7]NT = No Trend (<20% difference in frequency).

[8]NA = Not Applicable; no data available for analysis.

The trends in density fit a logical outcome relative to the disturbance regime in non-harvest without fire, non-harvest with fire, harvest, stand replacement, and partial stand replacement conditions. Stands in the non-harvest with fire and non-harvest without fire regimes typically had more diverse size classes and higher densities of trees in each size class, than did stands in the harvest regime.

In the native system (HRV), stands were typically under the influence of repeated gap disturbances such as fire, disease, and insects, as well as physical damages such as wind and snow breakage. Low to moderate density stands developed with structures composed of diverse size classes that were dominated by shade-intolerant tree species that were better adapted to survive insect, disease, fire, and stress disturbances. The gap disturbances provided regeneration sites for tree seedlings. When lethal fire (stand replacing) disturbances occurred, they seldom consumed all the trees in a stand; they commonly left larger trees in the overstory as individuals or clumps. However, the non-harvest without fire regime lacked the effects of the repeated non-lethal and mixed fires. Consequently, non-harvested without fire stands were more dense and had a higher composition of shade-tolerant species that were typically insect-, disease-, fire-, and stress-susceptible.

In contrast, harvest practices commonly occur as single disturbances that are either lethal to the entire overstory (for example clearcuts) or selectively remove the larger, shade-intolerant trees (for instance selective cuts). Even-age treatments, such as clearcuts or seed tree cuts, remove individuals in the larger size class. Non-commercial and commercial thinning practices did not result in compositions or structures similar to those produced by non-lethal and mixed fire disturbances of the native system. At a regional scale, thinning did not affect a substantial portion of the landscape, in comparison to what would be required to simulate native disturbance effects. In addition, the five year regeneration policy practiced by the Forest Service was found to increase the rate of succession in the early-seral stage, and often to eliminate herb and shrub structures from the seral sequence. In the absence of fire disturbances or thinning in the early- and mid-seral stages, tree planting in combination with natural regeneration resulted in very dense stands that lack selection against the shade-tolerant species (that is, against species that tend to be more vulnerable to insect and disease attacks when in dense stands).

The non-harvest with fire and non-harvest without fire regimes developed more snags, particularly in the large size class, than did the harvest regime. This is due to the availability of large trees that provided recruitment of snags in the non-harvest regime. Disturbances in non-harvested stands favor snag development. In contrast, harvest disturbances resulted in fewer snags, fewer large trees with the potential of being recruited as snags, and likely an increased probability that snags in the surrounding area would be used for firewood. Harvest methods often removed standing live cull trees (poor quality, non-merchantable timber) and left them as ground fuels. Potential snag recruits were affected by prescribed burning treatments that reduced the longevity of snags. In comparison, the native system probably had fewer small snags than in the non-harvest regime, but substantially more than in the harvest regime.

Harvest regimes generally produced substantially higher fuel loads than the non-harvest regime. In the short term (< 40 to 50 years), post-harvest treatments increase fuel loading. Typical harvest treatments leave dead fuel on the ground rather than standing as in non-harvest (with fire and without fire) or native disturbance regimes. Many harvest treatments do not include broadcast burning, but rather leave all fuels either spread on the ground or in piles. Even when they are broadcast burned, large-diameter fuels remain intact for long periods of time. Non-harvested stands can also contain high fuel loadings. For example, epidemic outbreaks of disease or insects, wind storms, or stands transitioning from stem exclusion to understory reinitiation often have high fuel loadings.

Through interpretations of the trends in plot data, data comments in the on-plot disturbances and plot photos, we determined that at the regional and landscape levels, traditional harvest treatments generally resulted in a greater abundance of larger-sized, dead fuel on the ground. In the non-harvest regime, this type of fuel tended to fall to the ground at a steady rate through time. In the native

system, our models indicated that much of the surface fuel was consumed by intermittent non-lethal and mixed fires, whereas dead-standing trees (snags), which were the result of lethal fires or other disturbance events, fell to the ground over a period of time.

Based on interpretations of trends from plot data and photos, it appeared that very-high fuel loadings were a common condition in non-harvested, dense, lodgepole pine stands that had experienced high levels of mountain pine beetle or root rot mortality. These infestations left many pole-, small-, and medium-size class, dead trees leaning into live or other dead-standing individuals. Fallen dead trees stacked up on the forest floor in a manner known as "jack-straw" condition. Most of the dead trees were of the same size class, and not all of the trees died or fell to the ground in the same year. Once the trees died, they tended to fall within a 15- to 20-year period, depending on how well they were protected by other trees and the stability of their root systems.

When a stand burned while in the above-stated condition, a stand-replacement fire event was generally the result. Because the fuels were not all on the ground, as they would be following a harvest, a more thorough consumption of the various fuel size classes occurred. Some trees were not killed by the fire, and the stand proceeded into stand initiation with low fuel loading and a diversity of size classes for residual, live, larger, trees.

It was determined that the post-stand replacement fire pattern of residual trees and regeneration was relatively random, rather than regular, based on further plot data interpretation. In contrast, when stands were harvested using traditional treatments, most of the standing live trees were removed. Those considered to be culls or too small for harvest were dropped to the ground along with the tops and limbs from harvested trees. Pile or broadcast burning usually followed in the spring or fall when fuel moistures were highest. This practice, in combination with the size and density of fuels, resulted in a very different type of fuel consumption than in the non-harvest or native systems. Larger-sized ground fuels were often only charred, potentially slowing their decay rates in comparison to trees that had fallen to the forest floor after having burned while standing. Post-harvest pile or broadcast burns have the potential to produce some effects similar to native systems; however, in general, the two regimes appeared to have been quite different.

The amount of litter and duff found on forested lands is highly variable; yet, there was little difference between the harvest and non-harvest regimes when evaluated at the regional and landscape levels. At the individual plot level however, there generally appeared to be less litter and duff from harvest regimes than non-harvest without fire regimes. The native system on uplands with cycling and maintenance regimes would have tended to maintain litter and duff at fairly thin but continuous coverage levels as a result of lethal, mixed, and non-lethal fire disturbances. The native system of moist footslopes, draws, and valleys, having irregular maintenance and very-long cycle regimes, would tend to have had deep litter and duff cover in a mosaic with small patches of thin duff or bare soil. Cover of bare soil by litter, duff, moss, vegetation root crowns, and wood would have followed similar patterns. In general, we found bare soil to be substantially higher in harvest regimes, than in non-harvest without fire regimes.

Dominant characteristics of forest composition and structure were somewhat predictable for physiognomic types if stratified by PVG and management class (table 3.178). Trend analysis of the plot data indicated that there was less variation within the physiognomic type stratified by PVG and management class/history, than within physiognomic type, cover type, size class, and density or canopy closure, with or without PVG. We hypothesize that this is because there is a high level of variation introduced into the latter types of stratification by the history of management. For the broad-scale stratification, we used three stratifications of management history/class: (1) roaded areas with history of timber harvest and fire exclusion, (2) unroaded areas with no history of timber harvest and history of fire exclusion, and (3) no history of roads, harvest, or fire exclusion.

Table 3.178—Dominant[1] characteristics of seral stages by potential vegetation group (PVG).

PVG	Seral Stage	Size Classes[2]	Canopy Closure[3]	Layers[4]	Large Emergent Trees[5]	Large Snags[6]	Fuel Model[7]	Large Down Logs[8]	Deep Duff/ Litter[9]	Bare Soil[10]	Age Class[11]	Shrubs[12]
Roaded with History of Timber Harvest and Fire Exclusion												
Dry Forest	Early-seral	Seedling	Open	1	No	No	11	Yes	No	Yes	Regen	No
	Mid-seral Shade-intolerant	Sapling-Pole	Closed	1	No	No	9	No	No	Yes	Young	No
	Mid-seral Shade-tolerant	Sapling	Open	2	No	No	10	No	Yes	No	Mature	No
	Late-seral Multi-layer	Medium	Closed	3	No	No	10	Yes	Yes	No	Mature	No
	Late-seral Single-layer	Medium	Open	2	No	No	11	Yes	No	No	Mature	No
Moist Forest	Early-seral	Seedling-Sapling	Closed	2	No	No	12	Yes	No	Yes	Regen-Young	No
	Mid-seral Shade-intolerant	Sapling-Pole-Medium	Closed	2	No	No	10	No	Yes	No	Young	Yes
	Mid-seral Shade-tolerant	Sapling - Pole	Closed	3	No	No	10	Yes	Yes	No	Mature	No
	Late-seral Multi-layer	Medium-Large	Closed	4	No	Yes	10	Yes	Yes	No	Mature	Yes
	Late-seral Single-layer	Large	Open	2	No	No	10	Yes	No	Yes	Mature	Yes
Cold Forest	Early-seral	Seedling	Open	1	Yes	No	12	No	No	Yes	Regen	No
	Mid-seral Shade-intolerant	Sapling	Open	2	No	No	8	No	No	Yes	Young	No
	Mid-seral Shade-tolerant	Sapling	Closed	3	No	No	8	No	No	Yes	Mature	No
	Late-seral Multi-layer	Pole	Open	3	No	No	10	No	Yes	No	Old	Yes
	Late-seral Single-layer	Pole-Medium	Open	2	No	No	8	No	No	Yes	Old	No

Table 3.178 (continued).

PVG	Seral Stage	Size Classes[2]	Canopy Closure[3]	Layers[4]	Large Emergent Trees[5]	Large Snags[6]	Fuel Model[7]	Large Down Logs[8]	Deep Duff/ Litter[9]	Bare Soil[10]	Age Class[11]	Shrubs[12]
Unroaded with Fire Exclusion and No History of Timber Harvest												
Dry Forest	Early-seral	Seedling	Open	2	Yes	Yes	2	Yes	No	Yes	Regen	No
	Mid-seral Shade-intolerant	Seedling-Pole	Closed	2	Yes	Yes	9	No	No	Yes	Young	No
	Mid-seral Shade-tolerant	Sapling	Open	3	No	No	10	Yes	Yes	No	Mature	No
	Late-seral Multi-layer	Medium	Closed	4	Yes	Yes	10	Yes	Yes	No	Old	No
	Late-seral Single-layer	Medium	Open	2	Yes	Yes	9	Yes	No	No	Old	No
Moist Forest	Early-seral	Seedling-Sapling	Closed	3	Yes	Yes	2	No	No	Yes	Regen	Yes
	Mid-seral Shade-intolerant	Sapling-Pole-Medium	Closed	3	Yes	Yes	8	Yes	Yes	No	Young	Yes
	Mid-seral Shade-tolerant	Sapling-Pole	Closed	4	No	No	10	Yes	Yes	No	Mature	No
	Late-seral Multi-layer	Large-Very Large	Closed	5	Yes	Yes	10	Yes	Yes	No	Old	Yes
	Late-seral Single-layer	Large-Very Large	Open	3	Yes	Yes	2	Yes	Yes	No	Old	Yes
Cold Forest	Early-seral	Seedling	Open	2	No	No	5	No	No	Yes	Regen	No
	Mid-seral Shade-intolerant	Sapling	Open	2	No	No	5	No	No	No	Young Mature	No
	Mid-seral Shade-tolerant	Sapling	Closed	3	No	No	10	No	Yes	No	Mature	No
	Late-seral Multi-layer	Pole	Open	3	No	No	10	No	Yes	No	Old	Yes
	Late-seral Single-layer	Pole-Medium	Open	2	No	No	5	No	No	No	Old	No

Table 3.178 (continued).

PVG	Seral Stage	Size Classes[2]	Canopy Closure[3]	Layers[4]	Large Emergent Trees[5]	Large Snags[6]	Fuel Model[7]	Large Down Logs[8]	Deep Duff/ Litter[9]	Bare Soil[10]	Age Class[11]	Shrubs[12]
No History of Roads, Harvest, or Fire Exclusion												
Dry Forest	Early-seral	Seedling	Open	2	Yes	Yes	1	Yes	No	Yes	Regen	No
	Mid-seral Shade-intolerant	Sapling-Pole	Open	2	Yes	Yes	2	No	No	Yes	Mature	No
	Mid-seral Shade-tolerant	Sapling	Open	2	Yes	Yes	2	Yes	No	Yes	Young	No
	Late-seral Multi-layer	Medium-Large	Open	3	Yes	Yes	9	Yes	Yes	No	Old	No
	Late-seral Single-layer	Large-Very Large	Open	2	Yes	Yes	2	No	No	Yes	Old	No
Moist Forest	Early-seral	Seedling-Sapling	Open	3	Yes	Yes	5	Yes	No	Yes	Regen	Yes
	Mid-seral Shade-intolerant	Sapling-Pole-Medium	Open	3	Yes	Yes	2	Yes	No	No	Young	Yes
	Mid-seral Shade-tolerant	Sapling-Pole	Open	3	Yes	Yes	5	Yes	No	No	Mature	No
	Late-seral Multi-layer	Large-Very Large	Closed	4	Yes	Yes	10	Yes	Yes	No	Old	Yes
	Late-seral Single-layer	Very Large	Open	2	Yes	Yes	2	Yes	No	No	Old	Yes
Cold Forest	Early-seral	Seedling	Open	2	Yes	Yes	5	Yes	No	Yes	Regen	No
	Mid-seral Shade-intolerant	Sapling-Pole	Open	2	No	No	5	No	No	No	Young-Mature	No
	Mid-seral Shade-tolerant	Sapling	Open	3	No	No	8	No	No	No	Mature	No
	Late-seral Multi-layer	Pole-Medium	Open	3	No	No	8	No	Yes	No	Old	Yes
	Late-seral Single-layer	Medium-Large	Open	2	Yes	No	5	No	No	Yes	Old	No

[1]Dominant: dominance based on the most frequent class within the seral stage and management history, and PVG based on plot data with adjustment and estimates based on reconnaissance data and modeling.

[2](Tree) Size Classes: Seedling = < 2.5 centimeters diameter at breast height (dbh), Sapling = 2.5 to 12.6 centimeters dbh, Pole tree = 12.7 to 22.6 centimeters dbh, Medium tree = 22.7 to 53.1 centimeters dbh, Large tree = 53.2 to 83.6 centimeters dbh, Very large tree = 83.7+ centimeters dbh.

[3]Canopy Closure: Open = <50% overstory tree canopy closure, Closed = > 50% overstory tree canopy closure.

[4]Layers = number of vegetation layers.

[5]Large Emergent Tree ≥ 53.2 centimeters dbh that emerges from forest canopy to receive sunlight from above and all sides.

[6]Large Snags = standing dead tree ≥ 53.2 centimeters dbh.

[7]Fuel models as defined by Anderson 1982.

[8]Presence of logs on the ground equivalent in diameter to large and very large trees.

[9]Presence of duff; depth ≥ 10.0 centimeters.

[10]Bare Soil; ≥20% more than undisturbed condition.

[11]Age Classes as defined by Oliver and Larson 1996.

[12]Presence of shrubs.

The PVG strata varied by larger-size classes and canopy cover. In general, the moist forest PVG had larger trees and a denser canopy cover than the dry and cold forest PVGs. In addition, the moist forest PVG had a higher tendency for large emergent live trees and snags, large down logs, and deep duff and litter. The primary differences between the management history strata were increased probability for larger size classes, open canopies, large emergent live trees and snags, and large down logs due to the lack of influence from roads, timber harvest, and fire exclusion.

Forest and Rangeland Integrity

Forest and rangeland integrity indices are based on a relative scale. Consequently, a high integrity index simply indicates that the integrity of that forest or rangeland subbasin was among the highest detected in the Basin during the current period. This does not imply that the subbasin has high integrity of ecological systems at finer scales. It also does not imply that higher levels of absolute integrity could not be attained in the future.

Subbasins having the highest forest integrity index were largely unroaded, and comprised cold forest PVGs or a mixture of moist and cold forest PVGs. Most (59%) of the forest subbasins were classified as having low forest integrity, 18 percent had moderate integrity, and 23 percent had high integrity (table 3.179; map 3.8). Of the five indicator variables used to assess forest integrity (described in detail in the "Overview of Methods" section of this chapter), the proportion of a subbasin composed by wilderness or roadless areas (indicator variable, "Wild") appears to be the most closely associated with subbasins having the highest integrity index. For example, 81 percent of the subbasins classified as having the highest forest integrity had relatively large compositions of wilderness and roadless areas. On the other hand, three variables were highly associated with the subbasins that were classified as having the lowest forest integrity. Nearly all of the subbasins (97%) that were classified as having the lowest forest integrity had a

relatively high composition of dry and moist forest PVGs. Similarly, 89 percent of the subbasins classified with a low integrity had a relatively low composition of wilderness and roadless areas, and 83 percent had a relatively high composition of areas having at least moderate road densities. The two indicator variables pertaining to fire regime were not nearly as associated with forest subbasins classified as having low integrity, as were the indicator variables pertaining to the composition of dry and moist forest PVGs, moderate or higher road densities, and wilderness and roadless areas.

Most (69%) of the rangeland subbasins were classified as having low rangeland integrity; 23 percent were classified as moderate, and 8 percent were classified as having relatively high rangeland integrity (table 3.180, map 3.9). With the exception of four subbasins, all subbasins that were classified as having low rangeland integrity had relatively high compositions of the agriculture PVG, or the dry grass and dry shrub PVGs. On the other hand, none of the seven subbasins that had the highest rangeland integrity indices had substantial compositions of agricultural conversion, juniper encroachment, or areas having at least moderate road densities.

Regional and Landscape Similarities of Historical and Current Vegetation Conditions

The regional similarity between the current physiognomic type composition for the HRV in the Basin as a whole was 29 percent (table 3.181). However, at the landscape level, only 2 percent of the Basin had conditions similar to the native landscape pattern. Most of the Basin (64%) had conditions that were similar to the traditional commodity landscape pattern, whereas conditions that would be expected from the traditional reserve landscape pattern were observed on 16 percent of the Basin. Those areas that had conditions similar to native landscape patterns were generally dominated by wilderness, non-roaded, or semi-primitive areas that were in steep, mid-elevation terrain where the effects of fire exclusion and exotic plant invasion had not been substantial. The attributes used to assess landscape similarity were less variable within HRV simulations than they were for traditional reserve and traditional commodity landscape patterns.

The regional similarity of physiognomic types on BLM/FS lands in the Basin to their HRV conditions was 35 percent, somewhat higher than the regional similarity of the Basin as a whole (table 3.182). However, the degree of similarity between current conditions and historical conditions was not nearly as high at the landscape (subbasin) level. At the landscape level, the current conditions of 5 percent of BLM/FS lands were similar to the native landscape pattern. Most (66%) BLM/FS lands within the Basin had current conditions that were similar to those projected for the traditional commodity landscape pattern.

Although the regional similarities of BLM/FS lands were similar when stratified by the two management regions (EEIS and UCRB), the relationships of the landscape similarities of BLM/FS lands differed by management region (table 3.183). Both management regions were dominated by conditions that were similar to the conditions expected under a traditional commodity landscape pattern, and both areas had relatively small extents similar to native landscape pattern. The most obvious difference between the EEIS and UCRB areas was their proportion of BLM/FS lands within the Basin that had current conditions similar to the those expected under a traditional reserve landscape pattern. Relative to the EEIS area, the UCRB area contained approximately three times the areal extent of BLM/FS lands that were similar to lands in the traditional reserve pattern.

Landscape similarities of BLM/FS lands seem to be associated with the type of landscape pattern (table 3.184). All landscape patterns on BLM/FS lands were dominated by conditions that would be expected from the traditional commodity management pattern. Conversely, a relatively small proportion of each landscape pattern was composed of BLM/FS lands that resembled native landscape patterns.

Table 3.179—Forest integrity of subbasins within the Basin.

Subbasin Number	Subbasin Name	Indicator Variables					Departure Average[6]	Integrity Index[7]
		D+M/ TOT[1]	Rd_ Mod+[2]	F_Sev[3]	F_freq[4]	Wild[5]		
17040101	Snake Headwaters	3	3	3	3	3	3.00	H
17040102	Gros Ventre	3	3	3	3	3	3.00	H
17040103	Greys-Hobock	3	3	3	3	3	3.00	H
17040104	Palisades	2	3	3	2	3	2.60	H
17040203	Lower Henrys	3	2	3	3	2	2.60	H
17060201	Upper Salmon	3	3	2	2	3	2.60	H
17060202	Pahsimeroi	2	3	3	2	3	2.60	H
17060205	Upper Middle Fork Salmon	3	3	2	2	3	2.60	H
17020009	Lake Chelan	2	3	2	2	3	2.40	H
17040219	Big Wood	2	2	3	3	2	2.40	H
17060203	Middle Salmon-Panther	2	2	3	2	3	2.40	H
17060206	Lower Middle Fork Salmon	2	3	2	2	3	2.40	H
17060208	South Fork Salmon	2	3	2	2	3	2.40	H
17010206	North Fork Flathead	1	3	2	2	3	2.20	H
17010207	Middlefork Flathead	1	3	2	2	3	2.20	H
17010209	South Fork Flathead	1	3	2	2	3	2.20	H
17020007	Similkameen	2	2	2	2	3	2.20	H
17040105	Salt	2	2	3	2	2	2.20	H
17040202	Upper Henrys	3	1	3	3	1	2.20	H
17040215	Medicine Lodge	2	2	3	2	2	2.20	H
17040218	Big Lost	2	2	2	2	3	2.20	H
17050111	North and Middle Forks Boise	2	2	2	2	3	2.20	H
17050120	South Fork Payette	2	3	1	2	3	2.20	H
17060204	Lemhi	2	2	3	2	2	2.20	H
17060207	Middle Salmon-Chamberlain	1	3	2	2	3	2.20	H
17060301	Upper Selway	2	3	1	2	3	2.20	H
17010202	Flint-Rock	2	2	2	2	2	2.00	M
17010205	Bitterroot	2	2	2	2	2	2.00	M
17020008	Methow	2	2	2	2	2	2.00	M
17020010	Upper Columbia-Entiat	1	2	3	2	2	2.00	M
17030002	Naches	2	2	2	2	2	2.00	M
17040214	Beaver-Camas	3	1	3	2	1	2.00	M
17050113	South Fork Boise	2	2	2	2	2	2.00	M

Table 3.179 (continued).

Subbasin Number	Subbasin Name	Indicator Variables					Departure Average[6]	Integrity Index[7]
		Dry /TOT[1]	Ag /TOT[2]	JUN /TOT[3]	RD_ Mod+[4]			
17060302	Lower Selway	1	2	2	2	3	2.00	M
17010203	Blackfoot	2	1	2	2	2	1.80	M
17020005	Chief Joseph	1	2	3	2	1	1.80	M
17020011	Wenatchee	1	2	2	2	2	1.80	M
17040204	Teton	1	1	3	2	2	1.80	M
17050116	Upper Malheaur	1	1	3	3	1	1.80	M
17050201	Brownlee Reservoir	1	2	2	2	2	1.80	M
17060101	Hells Canyon	1	3	1	1	3	1.80	M
17060102	Imnaha	1	2	2	1	3	1.80	M
17060307	Upper North Fork Clearwater	1	1	2	3	2	1.80	M
17120005	Summer Lake	1	1	3	3	1	1.80	M
17120006	Lake Abert	1	2	3	2	1	1.80	M
18010203	Upper Klamath Lake	1	2	2	2	2	1.80	M
17010201	Upper Clark Fork	2	1	2	2	1	1.60	L
17010208	Flathead Lake	1	2	2	2	1	1.60	L
17010211	Swan	1	2	1	2	2	1.60	L
17030001	Upper Yakima	1	2	2	2	1	1.60	L
17050122	Payette	1	1	3	2	1	1.60	L
17050203	Powder	1	1	3	2	1	1.60	L
17060105	Wallowa	1	2	2	1	2	1.60	L
17060303	Lochsa	1	2	1	2	2	1.60	L
17070304	Upper Crooked	1	1	3	2	1	1.60	L
17070305	Lower Crooked	1	1	3	2	1	1.60	L
17120002	Silvies	1	1	3	2	1	1.60	L
17010101	Upper Kootenai	1	1	2	2	1	1.40	L
17010102	Fisher	1	1	2	2	1	1.40	L
17010103	Yaak	1	1	2	2	1	1.40	L
17010104	Lower Kootenai	1	1	2	2	1	1.40	L
17010204	Middle Clark Fork	1	1	2	2	1	1.40	L
17010212	Lower Flathead	1	2	2	1	1	1.40	L

Table 3.179 (continued).

Subbasin Number	Subbasin Name	Indicator Variables					Departure Average[6]	Integrity Index[7]
		D+M/ TOT[1]	Rd_ Mod+[2]	F_Sev[3]	F_freq[4]	Wild[5]		
17010213	Lower Clark Fork	1	1	2	2	1	1.40	L
17010214	Pend Oreille Lake	1	1	2	2	1	1.40	L
17010215	Priest	1	1	2	2	1	1.40	L
17010216	Pend Oreille	1	1	2	2	1	1.40	L
17010301	Upper Coeur d'Alene	1	1	2	2	1	1.40	L
17010302	South Fork Coeur d'Alene	1	1	2	2	1	1.40	L
17010304	St. Joe	1	1	2	2	1	1.40	L
17010307	Lower Spokane	1	2	2	1	1	1.40	L
17020002	Kettle	1	1	2	2	1	1.40	L
17040205	Willow	2	1	2	1	1	1.40	L
17050112	Boise-Mores	1	1	2	1	2	1.40	L
17050121	Middle Fork Payette	1	1	2	1	2	1.40	L
17050124	Weiser	1	1	2	2	1	1.40	L
17050202	Burnt	1	1	3	1	1	1.40	L
17060106	Lower Grande Ronde	1	1	2	1	2	1.40	L
17060308	Lower North Fork Clearwater	1	1	2	2	1	1.40	L
17070105	Middle Columbia-Hood	1	2	2	1	1	1.40	L
17070201	Upper John Day	1	1	3	1	1	1.40	L
17070202	North Fork John Day	1	1	3	1	1	1.40	L
17070301	Upper Deschutes	1	1	2	2	1	1.40	L
17070302	Little Deschutes	1	1	2	2	1	1.40	L
17070306	Lower Deschutes	1	1	2	2	1	1.40	L
18010201	Williamson	1	1	2	2	1	1.40	L
18010204	Lost	1	1	3	1	1	1.40	L
18010205	Butte	1	1	3	1	1	1.40	L
18020001	Goose Lake	1	1	3	1	1	1.40	L
17010105	Moyie	1	1	1	2	1	1.20	L
17010303	Coeur d'Alene Lake	1	1	2	1	1	1.20	L
17010305	Upper Spokane	1	1	2	1	1	1.20	L
17010306	Hangman	1	2	1	1	1	1.20	L
17010308	Little Spokane	1	1	2	1	1	1.20	L
17020001	Franklin D. Roosevelt Lake	1	1	2	1	1	1.20	L
17020003	Colville	1	1	2	1	1	1.20	L

Table 3.179 (continued).

Subbasin Number	Subbasin Name	Indicator Variables					Departure Average[6]	Integrity Index[7]
		D+M/ TOT[1]	Rd_ Mod+[2]	F_Sev[3]	F_freq[4]	Wild[5]		
17020004	Sanpoil	1	1	2	1	1	1.20	L
17020006	Okanogan	1	1	2	1	1	1.20	L
17050123	North Fork Payette	1	1	2	1	1	1.20	L
17060103	Lower Snake-Asotin	1	2	1	1	1	1.20	L
17060104	Upper Grande Ronde	1	1	2	1	1	1.20	L
17060210	Little Salmon	1	1	1	1	2	1.20	L
17060304	Middle Fork Clearwater	1	1	2	1	1	1.20	L
17060305	South Fork Clearwater	1	1	1	2	1	1.20	L
17070103	Umatilla	1	2	1	1	1	1.20	L
17070106	Klickitat	1	1	2	1	1	1.20	L
17070203	Middle Fork John Day	1	1	2	1	1	1.20	L
18010202	Sprague	1	1	2	1	1	1.20	L
18010206	Upper Klamath	1	1	2	1	1	1.20	L
17010210	Stillwater	1	1	1	1	1	1.00	L
17060209	Lower Salmon	1	1	1	1	1	1.00	L
17060306	Clearwater	1	1	1	1	1	1.00	L

[1]D+M/TOT = proportion of forests within the subbasin comprised of dry and moist forest PVGs. Values: 1 = high departure; 2 = moderate departure; 3 = low departure.

[2]Rd_MOD+ = proportion of subbasin comprised of road densities exceeding 0.43 kilometer per square kilometer. Values: 1 = high departure; 2 = moderate departure; 3 = low departure.

[3]F_sev = proportion of subbasin comprised of increased fire severity. Values: 1 = high departure; 2 = moderate departure; 3 = low departure.

[4]F_freq = proportion of subbasin comprised of decreased fire interval. Values: 1 = high departure; 2 = moderate departure; 3 = low departure.

[5]Wild = proportion of subbasin comprised of wilderness or roadless areas. Values: 1 = high departure; 2 = moderate departure; 3 = low departure.

[6]Departure Average = average subbasin categorical score of D+M/TOT, Rd_MOD+, F_sev, F_freq, and WILD.

[7]Integrity Index = ecological integrity class; H = high, M = moderate, L = low.

Table 3.180—Rangeland integrity of subbasins within the Basin.

Subbasin Number	Subbasin Name	Indicator Variables				Departure Average[5]	Integrity Index[6]
		Dry /TOT[1]	Ag /TOT[2]	JUN /TOT[3]	RD_ Mod+[4]		
17060109	Rock	–	–	–	–	1.00	L
17060107	Lower Snake-Tucannon	–	–	–	–	1.00	L
17020013	Upper Crab	–	–	–	–	1.00	L
17060108	Palouse	–	–	–	–	1.00	L
17070102	Walla Walla	–	–	–	–	1.00	L
17070203	Middle Fork John Day	1	1	1	1	1.00	L
17070204	Lower John Day	1	2	1	1	1.00	L
17070306	Lower Deschutes	1	2	1	1	1.00	L
18010204	Lost	2	1	1	1	1.00	L
18020001	Goose Lake	2	1	1	1	1.00	L
17070201	Upper John Day	2	2	1	1	1.00	L
17070303	Beaver-South Fork	1	3	1	1	1.00	L
17070307	Trout	1	3	1	1	1.00	L
17020006	Okanogan	1	1	3	1	1.00	L
17040201	Idaho Falls	1	1	3	1	1.00	L
17040206	American Falls	1	1	3	1	1.00	L
17040212	Upper Snake-Rock	1	1	3	1	1.00	L
17060106	Lower Grande Ronde	1	1	3	1	1.00	L
17030001	Upper Yakima	1	1	2	2	1.00	L
17030003	Lower Yakima	1	1	2	2	1.00	L
17050114	Lower Boise	1	1	2	2	1.00	L
17070101	Middle Columbia-Lake Wallula	1	1	2	2	1.00	L
17020010	Upper Columbia-Entiat	1	1	3	2	1.33	L
17020012	Moses Coulee	1	1	3	2	1.33	L
17040208	Portneuf	2	1	3	1	1.33	L
17040209	Lake Walcott	1	1	3	2	1.33	L
17040214	Beaver-Camas	1	2	3	1	1.33	L
17050115	Middle Snake-Payette	1	1	3	2	1.33	L
17050119	Willow	1	2	3	1	1.33	L
17050122	Payette	2	1	3	1	1.33	L
17050202	Burnt	2	1	3	1	1.33	L
17060103	Lower Snake-Asotin	1	1	3	2	1.33	L
17070103	Umatilla	1	1	3	2	1.33	L

Table 3.180 (continued).

Subbasin Number	Subbasin Name	Indicator Variables				Departure Average[5]	Integrity Index[6]
		Dry /TOT[1]	Ag /TOT[2]	JUN /TOT[3]	RD_ Mod+[4]		
17070104	Willow	1	1	3	2	1.33	L
17040210	Raft	1	2	2	2	1.33	L
17040211	Goose	1	2	2	2	1.33	L
17050108	Jordan	1	3	2	1	1.33	L
17070304	Upper Crooked	3	3	1	1	1.67	L
17070305	Lower Crooked	3	3	1	1	1.67	L
17020005	Chief Joseph	2	1	3	2	1.67	L
17020014	Banks Lake	1	1	3	3	1.67	L
17020015	Lower Crab	1	1	3	3	1.67	L
17020016	Upper Columbia-Priest Rapids	1	1	3	3	1.67	L
17040203	Lower Henrys	2	1	3	2	1.67	L
17040204	Teton	3	1	3	1	1.67	L
17040205	Willow	2	2	3	1	1.67	L
17040207	Blackfoot	3	1	3	1	1.67	L
17040221	Little Wood	1	2	3	2	1.67	L
17050101	Central Strike Reservoir	1	3	3	1	1.67	L
17050103	Middle Snake-Succor	1	2	3	2	1.67	L
17050113	South Fork Boise	1	2	3	2	1.67	L
17050116	Upper Malheur	1	3	3	1	1.67	L
17050117	Lower Malheur	1	3	3	1	1.67	L
17050118	Bully	1	3	3	1	1.67	L
17050124	Weiser	3	1	3	1	1.67	L
17060102	Imnaha	1	2	3	2	1.67	L
17060110	Lower Snake	1	1	3	3	1.67	L
17120001	Harney-Malheur Lakes	1	3	3	1	1.67	L
17120002	Silvies	2	2	3	1	1.67	L
17120004	Silver	1	3	3	1	1.67	L
17120005	Summer Lake	1	3	3	1	1.67	L
17120003	Donner and Blitzen	1	3	2	2	1.67	L
17120006	Lake Abert	1	3	2	2	1.67	L
16040201	Upper Quinn	1	3	3	2	2.00	M
17040202	Upper Henrys	2	3	3	1	2.00	M
17040215	Medicine Lodge	2	2	3	2	2.00	M

Table 3.180 (continued).

Subbasin Number	Subbasin Name	Indicator Variables				Departure Average[5]	Integrity Index[6]
		Dry /TOT[1]	Ag /TOT[2]	JUN /TOT[3]	RD_ Mod+[4]		
17040219	Big Wood	2	2	3	2	2.00	M
17040220	Camas	3	2	3	1	2.00	M
17050109	Crooked-Rattlesnake	1	3	3	2	2.00	M
17050110	Lower Owyhee	1	3	3	2	2.00	M
17050201	Brownlee Reservoir	2	2	3	2	2.00	M
17060101	Hells Canyon	1	2	3	3	2.00	M
17060203	Middle Salmon-Panther	1	3	3	2	2.00	M
17060204	Lemhi	2	2	3	2	2.00	M
17120007	Warner Lakes	1	3	3	2	2.00	M
17120008	Guano	1	3	3	2	2.00	M
17120009	Alvord Lake	1	3	3	2	2.00	M
16040205	Thousand-Virgin	1	3	3	3	2.33	M
17040213	Salmon Falls	1	3	3	3	2.33	M
17040216	Birch	2	3	3	2	2.33	M
17040218	Big Lost	2	3	3	2	2.33	M
17050102	Bruneau	2	3	3	2	2.33	M
17050107	Middle Owyhee	2	3	3	2	2.33	M
17060201	Upper Salmon	1	3	3	3	2.33	M
17040104	Palisades	2	3	3	3	2.67	H
17040217	Little Lost	2	3	3	3	2.67	H
17050104	Upper Owyhee	2	3	3	3	2.67	H
17050105	South Fork Owyhee	2	3	3	3	2.67	H
17050106	East Little Owyhee	2	3	3	3	2.67	H
17060202	Pahsimeroi	2	3	3	3	2.67	H
17040103	Greys-Hobock	3	3	3	3	3.00	H

[1]DRY/TOT = proportion of rangelands within the subbasin comprised of dry grass and dry shrub PVGs. Values: 1 = high departure; 2 = moderate departure; 3 = low departure.

[2]AG/TOT = proportion of subbasin comprised of agricultural PVG. Values: 1 = high departure; 2 = moderate departure; 3 = low departure.

[3]JUN/TOT = proportion of subbasin comprised of juniper-sagebrush cover type. Values: 1 = high departure; 2 = moderate departure; 3 = low departure.

[4]Rd_MOD+ = proportion of subbasin comprised of road densities exceeding 0.43 kilometer per square kilometer. Values: 1 = high departure; 2 = moderate departure; 3 = low departure.

[5]Departure Average = average subbasin categorical score of DRY/TOT, AG/TOT, and Rd_MOD+.

[6]Integrity Index = ecological integrity class; H = high, M = moderate, L = low.

Table 3.181—Regional and subbasin landscape similarity to native (HRV), other, traditional reserve, and traditional commodity patterns for All land ownerships.

Type of Pattern[1]	Similarity[2] All Land Ownerships (Percent)
Landscape Native	2
Landscape Other	17
Landscape Traditional Reserve	16
Landscape Traditional Commodity	64
Regional HRV[3]	29

[1]Landscape Patterns: Native = pre-Euro-American settlement landscape; Other = non-wildland landscape (for example, large bodies of water); Traditional Reserve = traditional preservation, fire protection, and unroaded landscape; Traditional Commodity = traditional commodity extraction landscape.

[2]Similarity for landscapes is based on predicted pattern of physiognomic types and succession/disturbance regimes within general landscape patterns.

[3]Regional HRV - similarity is based on physiognomic types, independent of general landscape pattern based on comparison of physiognomic type composition.

Table 3.182—Regional and subbasin landscape similarity to native(HRV), other, traditional reserve, and traditional commodity landscape patterns for BLM/FS land ownerships.

Type of Pattern[1]	Similarity[2] All Land Ownerships (Percent)
Landscape Native	5
Landscape Other	0
Landscape Traditional Reserve	29
Landscape Traditional Commodity	66
Regional HRV[3]	35

[1]Landscape Patterns: Native = pre-Euro-American settlement landscape; Other = non-wildland landscape (for example, large bodies of water); Traditional Reserve = traditional preservation, wilderness and unroaded landscapes; Traditional Commodity = traditional commodity extraction landscape.

[2]Similarity for landscapes is based on predicted pattern of physiognomic types and succession/disturbance regimes within general landscape patterns.

[3]Regional HRV - similarity is based on physiognomic types, independent of general landscape pattern based on comparison of physiognomic type composition.

Table 3.183—Regional and subbasin landscape similarity to native (HRV), other, traditional reserve, and traditional commodity landscape patterns for BLM/FS land ownerships by management region.

Management Region	Type of Pattern[1]	Similarity[2] BLM/FS Land Ownerships
EEIS	Landscape Native	1
EEIS	Landscape Other	T[3]
EEIS	Landscape Traditional Reserve	7
EEIS	Landscape Traditional Commodity	31
EEIS Regional Similarity		34
UCRB[4]	Landscape Native	7
UCRB	Landscape Other	T
UCRB	Landscape Traditional Reserve	36
UCRB	Landscape Traditional Commodity	57
UCRB Regional Similarity		35

[1]Landscape Patterns: Native = pre-Euro-American settlement landscape; Other = non-wildland landscape (for example, large bodies of water); Traditional Reserve = traditional preservation, wilderness and unroaded landscapes; Traditional Commodity = traditional commodity extraction landscape.

[2] Similarity for landscapes is based on predicted pattern of physiognomic types and succession/disturbance regimes within general landscape patterns; Regional similarity is based on physiognomic types, independent of landscape patterns based on comparison of physiognomic type composition.

[3]T = Trace, >0.01%.

[4]UCRB = UCRB and GYE management regions combined.

Table 3.184—Subbasin landscape similarity to native (HRV), other, traditional reserve, and traditional commodity landscape patterns for BLM/FS land ownerships by type of landscape mosaic.

Landscape Pattern	Type of Pattern[1]	Similarity[2] Percent of BLM/FS Land Ownerships
Forest	Landscape Native	1
Forest	Landscape Other	0
Forest	Landscape Traditional Reserve	13
Forest	Landscape Traditional Commodity	16
Rangeland	Landscape Native	1
Rangeland	Landscape Other	0
Rangeland	Landscape Traditional Reserve	5
Rangeland	Landscape Traditional Commodity	30
Forest-Rangeland	Landscape Native	3
Forest-Rangeland	Landscape Other	0
Forest-Rangeland	Landscape Traditional Reserve	11
Forest-Rangeland	Landscape Traditional Commodity	20

[1]Landscape Patterns: Native = pre-Euro-American settlement landscape; Other = non-wildlandlandscape (for example, large bodies of water); Traditional Reserve = traditional preservation, wilderness and unroaded landscapes; Traditional Commodity = traditional commodity extraction landscape.

[2] Similarity for landscapes is based on predicted pattern of physiognomic types and succession/disturbance regimes within general landscape patterns; Regional similarity is based on physiognomic types, independent of landscape patterns based on comparison of physiognomic type composition.

Relative to forest-dominated landscapes, a greater proportion of BLM/FS lands rangeland landscapes had vegetation conditions that were similar to conditions expected from the traditional commodity landscape pattern. Rangeland landscapes also had a lower proportion of the BLM/FS lands that had vegetation conditions similar to the traditional reserve landscape pattern. The observed difference in landscape similarities of BLM/FS lands between forest and rangeland landscapes was most likely a result of fewer wilderness and non-roaded areas in rangelands, as well as the high proportion of rangeland landscapes affected by excessive livestock grazing practices and exotic plant infestations. Not surprisingly, the composition of BLM/FS lands resembling those of the traditional reserve landscape pattern was highest in forest landscapes, followed in ranking by the forest/rangeland landscapes, and lastly, by the rangeland landscapes. The association with the landscape pattern likely follows the distribution of wilderness and non-roaded areas which tend to be disproportionately located in higher elevations. The forest/rangeland-dominated landscapes had a somewhat higher proportion of BLM/FS lands that had vegetation conditions similar to native landscape patterns than either the forest or rangeland landscape patterns. The forest/rangeland landscapes are more likely to have steeper energy gradients, and subsequently, more dynamic disturbance regimes. Consequently, we speculate that fires and other disturbances have likely been more influential in these subbasins, and thus, vegetation conditions would have a higher probability of being similar to the native landscape pattern.

Table 3.185—Subbasin landscape similarity to native (HRV), other, traditional reserve, and traditional commodity landscape patterns for BLM/FS land ownerships by subbasin group.

Subbasin Group	Type of Pattern[1]	Similarity[2] Percent of BLM/FS Land Ownership
Central Rocky Mountains	Landscape Native	4
	Landscape Other	0
	Landscape Traditional Reserve	16
	Landscape Traditional Commodity	13
Columbia Plateau	Landscape Native	0
	Landscape Other	0
	Landscape Traditional Reserve	0
	Landscape Traditional Commodity	1
Intermountain Basin	Landscape Native	0
	Landscape Other	0
	Landscape Traditional Reserve	3
	Landscape Traditional Commodity	27
Northern Cascade Mountains	Landscape Native	0
	Landscape Other	0
	Landscape Traditional Reserve	3
	Landscape Traditional Commodity	2
Northern Rocky Mountains	Landscape Native	0
	Landscape Other	0
	Landscape Traditional Reserve	4
	Landscape Traditional Commodity	11
Southern Cascade and Blue Mountains	Landscape Native	1
	Landscape Other	0
	Landscape Traditional Reserve	3
	Landscape Traditional Commodity	13

[1]Landscape Patterns: Native = pre-Euro-American settlement landscape; Other = non-wildland landscape (for example, large bodies of water); Traditional Reserve = traditional preservation, wilderness and unroaded landscapes; Traditional Commodity = traditional commodity extraction landscape.

[2] Similarity for landscapes is based on predicted pattern of physiognomic types and succession/disturbance regimes within general landscape patterns; Regional similarity is based on physiognomic types, independent of landscape patterns based on comparison of physiognomic type composition.

Table 3.186—Regional similarity of the average historical (HRV[1]) composition of physiognomic type groups and the current and average future[2] composition by management scenario.

Management Region	Land Ownership Group	Current	Scenario[3]		
			CD	AM	PM
EEIS	BLM/FS	0.34	0.44	0.70	0.55
UCRB	BLM/FS	0.36	0.46	0.71	0.59
EEIS	Other	0.22	0.27	0.27	0.26
UCRB	Other	0.24	0.29	0.29	0.28

[1]HRV = average composition of 400-year historical simulation.

[2]Future = average composition of 100-year scenario simulation

[3]Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management.

Landscape similarities of BLM/FS lands were somewhat variable by subbasin group (table 3.185). Very little of the BLM/FS lands had vegetation conditions similar to the native landscape patterns in any of the six subbasin groups. Four of six subbasin groups were dominated (at least 70% composition) by vegetation conditions on BLM/FS lands that were similar to that expected from the traditional commodity landscape pattern. Vegetation conditions resembling traditional reserve landscape pattern dominated BLM/FS lands within the Central Rocky Mountains and Northern Cascade Mountains subbasin groups. The proportion of BLM/FS lands that were similar to a native landscape pattern ranged from less than 1 percent in the Columbia Plateau, Intermountain Basin, and Northern Rocky Mountains subbasin groups, to nearly 12 percent of the Central Rocky Mountains subbasin group. The large proportion of BLM/FS lands resembling those expected from traditional reserve landscape pattern in the Central Rocky Mountains and Northern Cascade Mountains subbasin groups was likely associated with their relatively high composition of wilderness and nonroaded lands. The relatively high proportion of BLM/FS lands that resembled those expected in the native landscape pattern within the Central Rocky Mountains subbasin group was probably a result of the complex, rugged topographic gradients and lower efficacy of fire exclusion within that subbasin group.

The projected effects of the consumptive demand, active, and passive management scenarios upon regional similarities with native systems varied substantially by ownership strata within the Basin (table 3.186). On BLM/FS lands, the 100-year projections of all three management scenarios substantially increased the regional similarities with the native systems. The increased similarity was attributable to the steady increase of wildfire in wildland environments as a result of further fuel accumulation. Consequently, it appears that the energy exerted to exclude fire and otherwise manipulate vegetation that are not in concert with the biogeochemical processes, are only successful for a limited time period. Over the long term, we believe the system will accumulate enough energy such that the trend will eventually reverse, regardless of the energy expended by society to maintain the existing trajectory. On BLM/FS lands, the projections of the active management scenario had the highest similarity to the native system, followed in rank by the passive management scenario, and lastly by the consumptive demand scenario. The regional similarity index was based solely upon the composition of broad-scale physiognomic types. As such, it does not reflect projections pertaining to landscape patterns.

Response of Modeling Scenarios

Model outcomes generated from CRBSUM runs were used to evaluate successional and disturbance regimes for each scenario response across land areas within the Basin. The outcomes were stratified by PVG, generalized subbasin group[17] (table 3.1), and management class across the Basin.

For wilderness-like[18] lands, we designed probability sets to simulate various kinds of management that would be expected in areas not managed for commodities, such as wilderness-like, primitive, or semi-primitive areas that are roadless (appendix 3-K). Figures 3.18, 3.19, 3.20, 3.21, 3.22 and 3.23 are examples of responses on wilderness-like lands for three PVGs in the generalized subbasin groups.

For non-wilderness lands, we designed probability sets to simulate management that produced high levels of commodities. These probabilities were appropriate in areas dominated by human-related disturbance processes (appendix 3-L). Figures 3.24, 3.25, 3.26, 3.27, 3.28 and 3.29 display scenario responses on non-wilderness lands for three PVGs in the generalized subbasin groups.

Rocky Mountains cold forest PVGs on wilderness-like lands—Figures 3.18 and 3.19 show the results of CRBSUM scenario responses on wilderness-like lands in the Rocky Mountains generalized subbasin portion of the Basin within the cold forest PVG. The Rocky Mountains cold forest PVG (2,569,800 ha) was dominated by high-elevation spruce-fir and whitebark pine/subalpine larch PVTs. Fire was the principal disturbance group operating in these types and was disaggregated into wildfire or prescribed fire, depending on the scenario (fig. 3.18).

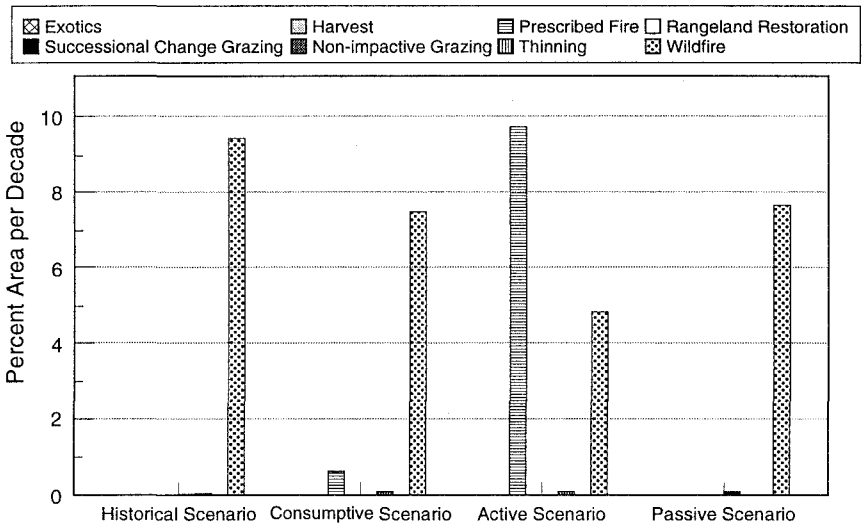
The overall effects on the physiognomic type distributions are presented in figure 3.19. In the historical scenario, fire maintained late-seral multi-layer and mid-seral shade-intolerant forests as the dominant types, and held mid-seral shade-tolerant, early-seral, and late-seral single-layer forests at low levels. The consumptive demand and passive management scenarios caused a shift toward mid-seral shade-tolerant, and away from mid-seral shade-intolerant and late-seral multi-layer forests. These scenarios applied little, if any, prescribed fire and reduced natural wildfire to about 75 percent of its historical level (fig. 3.18). The active management scenario reduced wildfire by almost 50 percent. In this scenario, prescribed fire reduced levels of mid-seral shade-tolerant forests to near historical levels and increase levels of early-seral forests substantially above historical levels.

Rocky Mountains moist forest PVGs on wilderness-like lands—Figures 3.20 and 3.21 show the results of CRBSUM scenario responses on wilderness-like lands in the Rocky Mountains generalized subbasin portion of the Basin within the moist forest PVG. This area comprised approximately 1,561,200 hectares and was dominated by the low- and mid-elevation, wet, spruce-fir and grand fir PVTs. Fire was also the principal disturbance group operating in the Rocky Mountains moist forest PVG and was partitioned among either prescribed fire or wildfire (fig. 3.20).

Figure 3.21 shows physiognomic type distributions that resulted from these disturbance regimes. Historical fire maintained late-seral multi-layer and mid-seral shade-intolerant forests as the dominant types, and held mid-seral shade-tolerant and early-seral types at low levels. The consumptive demand scenario reduced fire occurrence from the historical scenario by 50 percent, using no prescribed fire. This increased late-seral multi-layer types to levels above historical averages, allowed for somewhat escalated levels of mid-seral shade-tolerant forests, and reduced levels of mid-seral shade-intolerant forests. The passive management scenario had wildfire levels close to historical levels but with higher levels of mortality in late-seral

[17] Stratifying by generalized subbasin groups was necessary to minimize variation of results among individual PVGs, which may dominate these different generalized subbasin groups.

[18] The term "wilderness-like" is synonymous with the terms "wilderness" and "non-roaded" lands or areas throughout this chapter.



	Historical Scenario	Consumptive Scenario	Active Scenario	Passive Scenario
Exotics	NA	0	0	0
Harvest	NA	NA	NA	NA
Prescribed Fire	NA	0.630010	9.719823	0
Rangeland Restoration	NA	NA	NA	NA
Successional Change Grazing	0.000237	0	0	0.002724
Non-impactive Grazing	0/002373	0.002335	0.00428	0
Thinning	NA	NA	NA	NA
Wildfire	9.394031	7.504364	4.794147	7.621605

Figure 3.18—Response of scenarios for disturbance area within wilderness-like lands (also referred to as wilderness and non-roaded lands, or semi-primitive, natural process and natural/human process management regions) in the cold forest PVG of the Rocky Mountains generalized subbasin group.

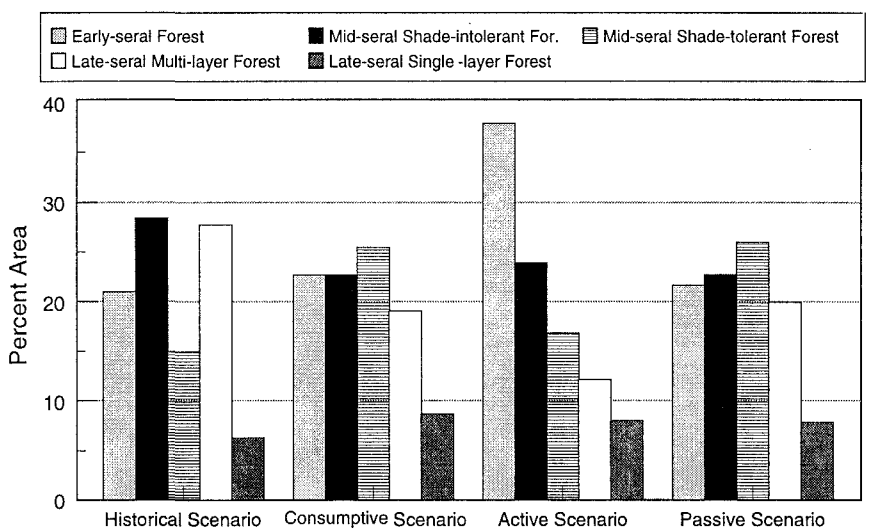
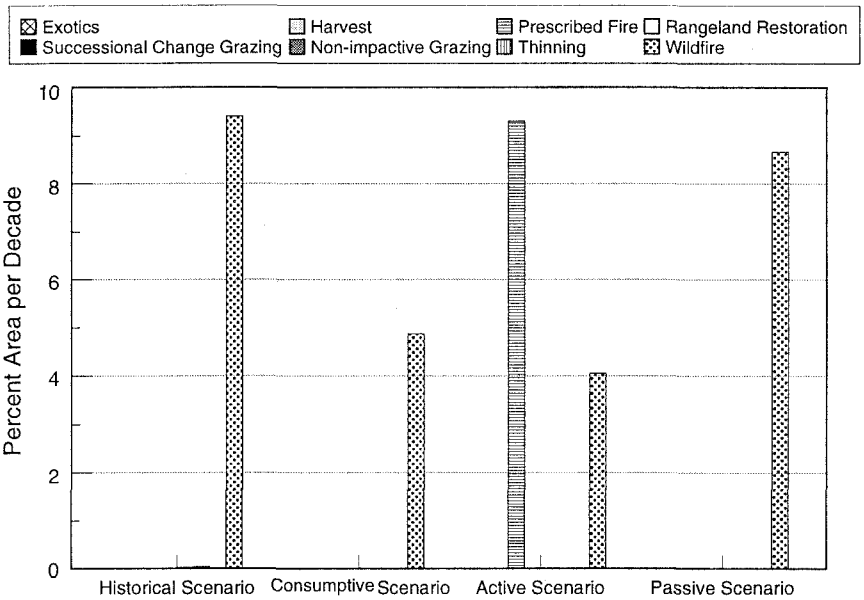


Figure 3.19—Response of scenarios for physiognomic types within wilderness-like lands (also referred to as wilderness and non-roaded lands, or semi-primitive, natural process and natural/human process management regions) in the cold forest PVG of the Rocky Mountains generalized subbasin group.



	Historical Scenario	Consumptive Scenario	Active Scenario	Passive Scenario
Exotics	NA	0	0	0
Harvest	NA	NA	NA	NA
Prescribed Fire	NA	0	9.302500	0
Rangeland Restoration	NA	NA	NA	NA
Successional Change Grazing	0.000237	0	0	0
Non-impactive Grazing	0.002373	0	0	0
Thinning	NA	NA	NA	NA
Wildfire	9.394031	4.830900	4.027700	8.650400

Figure 3.20—Response of scenarios for disturbance area within wilderness-like lands (also referred to as wilderness and non-roaded lands, or semi-primitive, natural process and natural/human process management regions) in the moist forest PVG of the Rocky Mountains generalized subbasin group.

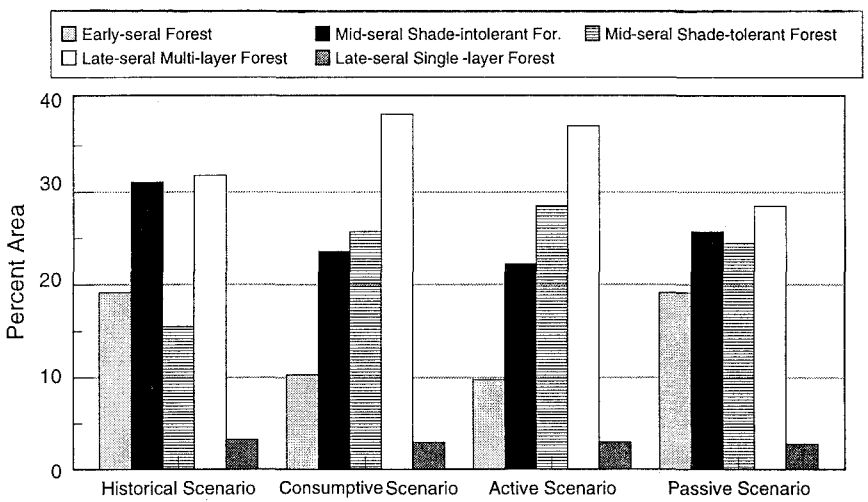


Figure 3.21—Response of scenarios for physiognomic types within wilderness-like lands (also referred to as wilderness and non-roaded lands, or semi-primitive, natural process and natural/human process management regions) in the moist forest PVG of the Rocky Mountains generalized subbasin group.

types. This resulted in a reduction (slightly below historical averages) of late-seral multi-layer types, and allowed for somewhat escalated levels of mid-seral shade-tolerant forests. In the active management scenario, prescribed fire targeted mid-seral shade-intolerant forests and reduced their levels compared to historical levels; maintained late-seral multi-layer types above historical maximums; and allowed for somewhat escalated levels of mid-seral shade-tolerant forests.

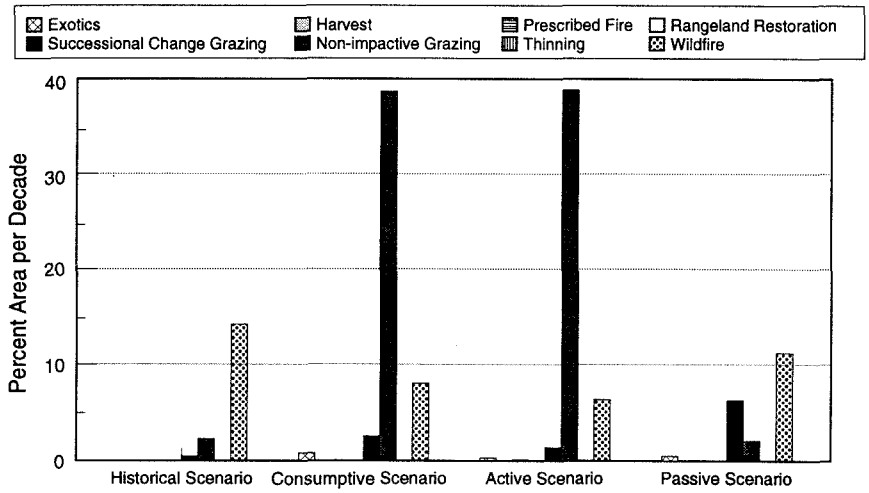
Intermountain dry shrub PVG on wilderness-like lands—Figures 3.22 and 3.23 show CRBSUM scenario responses on wilderness-like lands in the Intermountain generalized subbasin portion of the Basin within the dry shrub PVG. This area comprised approximately 1,588,600 hectares and was dominated by the big sagebrush-warm PVT. Grazing and fire were the principal disturbance agents operating in Intermountain dry shrub PVG (fig. 3.22). All scenarios in this land area resulted in wildfire levels below historical averages (fig. 3.22). Lower wildfire levels permitted substantial shrub encroachment, particularly for the active management and consumptive demand scenarios. The passive management scenario had close to historical burning levels, which was caused by elevated levels of exotic plants on these lands. Exotic annual grasses are more prone to burning in wildfire conditions compared with shrub physiognomic types, and burning tends to favor the regeneration of exotic species.

There was little effect on physiognomic type distributions as a result of grazing pressure, compared with the effects of fire. The active management and consumptive demand scenarios had substantially higher levels of grazing pressure than historical averages. This was most likely due to an underestimation of historical grazing levels. Most grazing regimes in these prescriptions were considered to be non-impactive. In the case of the consumptive demand scenario, we assumed that there would be heavier levels of vegetation successional change due to grazing, for example on winter range and other grazing areas where animals tend to concentrate. However, in the case of the big sagebrush PVT, these changes still did not generally cause transitions between herb, shrub, and exotics; levels of exotics were assumed to have remained relatively low in these generally remote settings.

Cascade Mountains dry forest PVG on non-wilderness lands—Figures 3.24 and 3.25 show the results of a CRBSUM scenario responses on non-wilderness lands in the Cascade Mountains generalized group portion of the Basin within the dry forest PVG. This area comprised approximately 1,979,900 hectares, and was dominated by dry Douglas-fir with ponderosa pine PVTs, as well as lesser amounts of interior ponderosa pine and dry grand fir/white fir PVTs. Wildfire was the principal disturbance group operating in the Cascade Mountains dry forest PVG in the historical scenario (fig. 3.24). In the consumptive demand scenario, combined amounts of prescribed fire, wildfire, harvest, and thinning were close to the levels of wildfire modeled in the historical scenario for this land area (fig. 3.24). The same trend was evident in the active management scenario, while the combined disturbance area of the passive management scenario amounted to approximately 60 percent of the historical wildfire area (fig. 3.24).

The overall effects on the physiognomic type distributions are shown in figure 3.25. Historical fire maintained late-seral single-layer and early-seral forests as the dominant types and held other types at low levels. The consumptive demand scenario allowed for a shift toward mid-seral shade-tolerant and late-seral multi-layer forests, as wildfires were suppressed and harvest techniques emphasized conversion to mid-seral shade-intolerant forests or partial cutting in late-seral multi-layer types.

The passive management scenario had the lowest levels of harvest and highest amounts of wildfire, creating roughly the same outcome as the consumptive demand scenario. The active management scenario emphasized prescribed fire, mainly in the late-seral stages, which increased levels of late-seral single-layer forests and decreased levels of mid-seral shade-intolerant and late-seral multi-layer types.



	Historical Scenario	Consumptive Scenario	Active Scenario	Passive Scenario
Exotics	NA	0.5313	0.1423	0.1473
Harvest	NA	NA	NA	NA
Prescribed Fire	NA	0	0.0516	0
Rangeland Restoration	NA	NA	NA	NA
Successional Change Grazing	0.2044	2.4852	1.2716	6.1381
Non-impactive Grazing	2.0438	39.0463	39.1842	1.6883
Thinning	NA	NA	NA	NA
Wildfire	14.2726	7.9812	6.3716	11.1104

Figure 3.22—Response of scenarios for disturbance area within wilderness-like lands (also referred to as wilderness and non-roaded lands, or semi-primitive, natural process and natural/human process management regions) in the dry shrub PVG of the Intermountain generalized subbasin group.

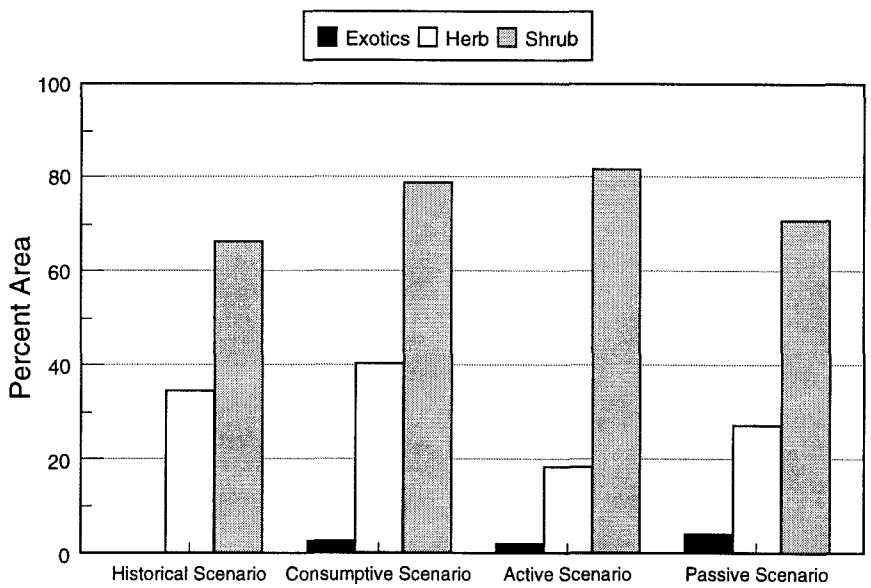
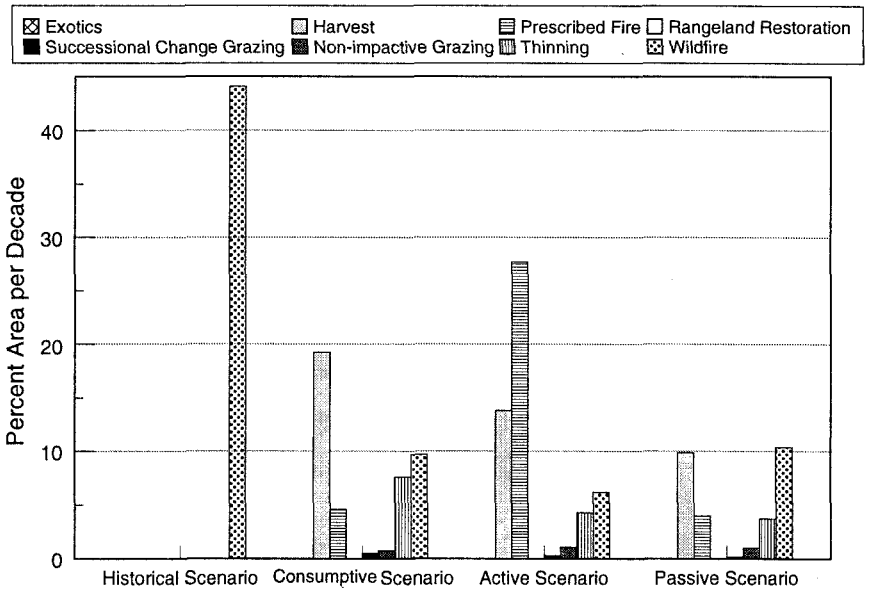


Figure 3.23—Response of scenarios for physiognomic types within wilderness-like lands (also referred to as wilderness and non-roaded lands, or semi-primitive or natural process and natural/human process management regions) in the dry shrub PVG of the Intermountain generalized subbasin group.



	Historical Scenario	Consumptive Scenario	Active Scenario	Passive Scenario
Exotics	NA	0	0	0
Harvest	NA	19.073791	13.710094	9.696521
Prescribed Fire	NA	4.236073	27.433709	3.806758
Rangeland Restoration	NA	0	0	0
Successional Change Grazing	0	0.134350	0.052528	0.116167
Non-impactive Grazing	0	0.501540	0.877822	0.775797
Thinning	NA	7.304409	4.082024	3.530986
Wildfire	43.958465	9.344916	5.935653	10.3323400

Figure 3.24—Response of scenarios for disturbance area within non-wilderness lands (also referred to as traditional commodity management, consumptive demand management and roaded lands, or natural/human and human process management regions) in the dry forest PVG of the Cascade Mountains generalized subbasin group.

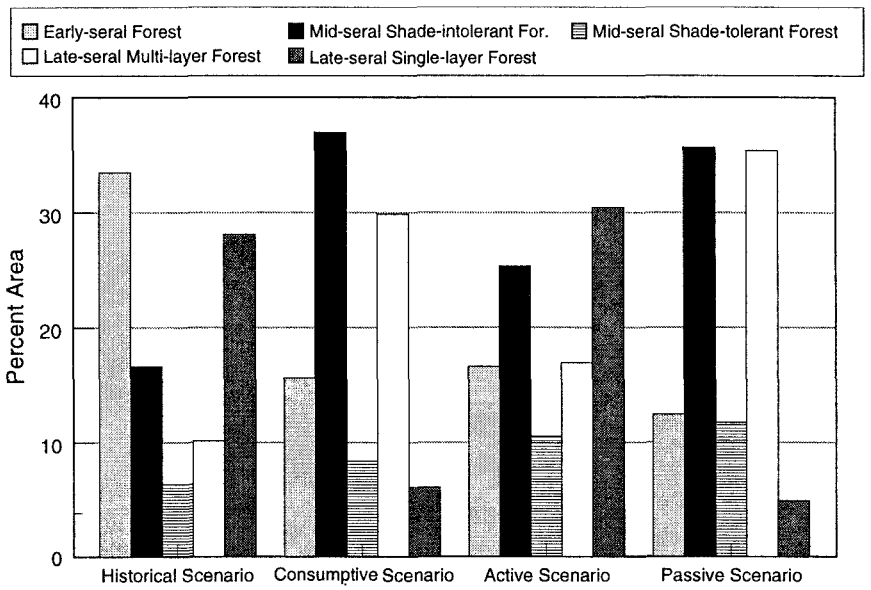


Figure 3.25—Response of scenarios for physiognomic types within non-wilderness lands (also referred to as traditional commodity management, consumptive demand management and roaded lands, or natural/human and human process management regions) in the dry forest PVG of the Cascade Mountains generalized subbasin group.

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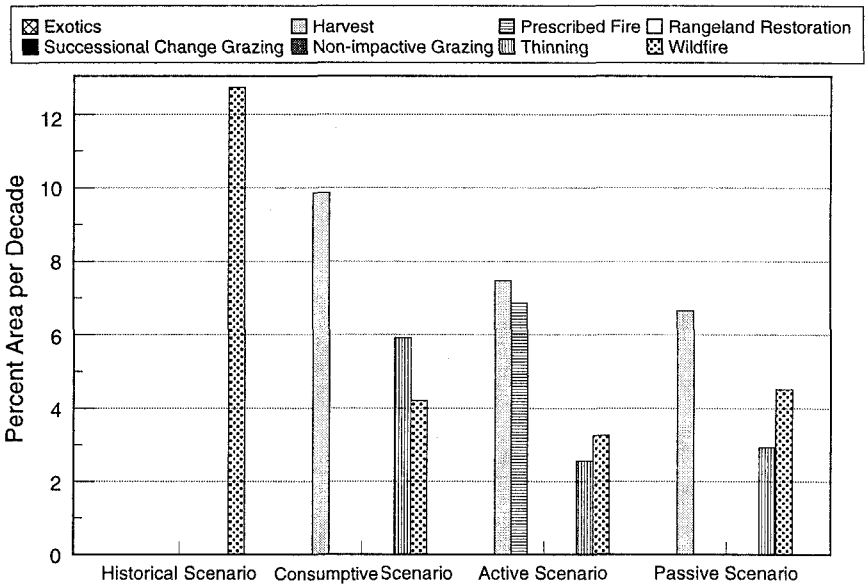
This file was created by scanning the printed publication.
Mis-scans identified by the software have been corrected;
however, some errors may remain.

Rocky Mountains moist forest PVG on non-wilderness lands—Figures 3.26 and 3.27 show the results of CRBSUM scenario responses on non-wilderness lands in the Rocky Mountains generalized group portion of the Basin within the moist forest PVG. This area comprised approximately 30,108,900 hectares and was dominated by the low- and mid-elevation, wet, spruce-fir and grand fir PVTs. All scenarios invoked some level of prescribed fire, wildfire, harvest, and thinning but in different proportions (fig. 3.26). The passive management scenario had the lowest levels of harvest and thinning activities, compared to the consumptive demand scenario. Both the passive management and consumptive demand scenarios allowed the same amount of wildfire, and used no prescribed fire. The active management scenario had greater levels of harvest than the passive management scenario, lower levels than the consumptive demand scenario, used almost as much prescribed fire, and had the lowest levels of wildfire and thinning.

Figure 3.27 shows physiognomic type distributions that resulted from these disturbance regimes. Historical fire maintained an even mixture of mid-seral shade-intolerant and late-seral multi-layer forest types, and held mid-seral shade-tolerant and early-seral types at low levels. Management under the consumptive demand scenario caused a shift toward mid-seral shade-tolerant and early-seral forests as fires were suppressed and priority was placed on harvest in late-seral forest types. The passive management scenario applied less harvest and thinning activities than the consumptive demand scenario, and also caused a shift toward mid-seral shade-tolerant and early-seral forests. The active management scenario maintained higher levels of late-seral multi-layer forest types, lower levels of mid-seral shade-intolerant forest types, and the lowest levels of mid-seral shade-tolerant forest types.

Intermountain dry shrub PVG on non-wilderness lands—Figures 3.28 and 3.29 show CRBSUM scenario responses on non-wilderness lands in the Intermountain generalized group portion of the Basin within the dry shrub PVG. This area comprised approximately 5,239,500 hectares and was dominated by the big sagebrush-warm PVT. All scenarios had grazing pressures well above historical averages, although most grazing in these scenarios was considered non-impactive. The consumptive demand and passive management scenarios had combined prescribed fire and wildfire levels that slightly exceeded historical wildfire levels, as well as increased levels of exotic plants (fig. 3.28). The active management scenario allowed a minimum amount of fire, minimized the spread of exotic plants, and employed minor levels of rangeland restoration, which further minimized the amount of exotic vegetation (fig. 3.28).

Figure 3.29 shows physiognomic type distributions that resulted from these disturbance regimes. The active management scenario, with minimal amounts of either wildfire or prescribed fire, permitted some shrub encroachment in comparison to the historical scenario, while the consumptive demand and passive management scenarios allowed for less shrub encroachment than the historical scenario due to more burning (fig. 3.28). A further consequence in the consumptive demand and passive management scenarios was elevated levels of exotic plants on Intermountain dry shrub PVG lands, since exotic annual grasses are more prone to burning in wildfire conditions compared with shrub physiognomic types, and burning tends to favor regeneration of exotic species.



	Historical Scenario	Consumptive Scenario	Active Scenario	Passive Scenario
Exotics	NA	0	0	0
Harvest	NA	9.818550	7.414842	6.625901
Prescribed Fire	NA	0	6.820100	0
Rangeland Restoration	NA	0	0	0
Successional Change Grazing	0	0	0	0
Non-impactive Grazing	0	0	0	0
Thinning	NA	5.901160	2.471335	2.899066
Wildfire	12.688706	4.187577	3.175579	4.442487

Figure 3.26—Response of scenarios for disturbance area within non-wilderness lands (also referred to as traditional commodity management, consumptive demand management and roaded lands, or natural/human and human process management regions) in the moist forest PVG of the Rocky Mountains generalized subbasin group.

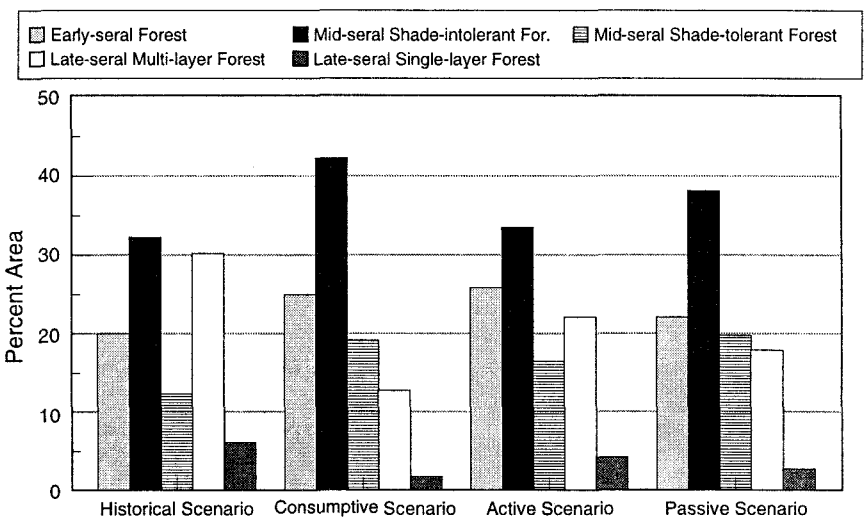
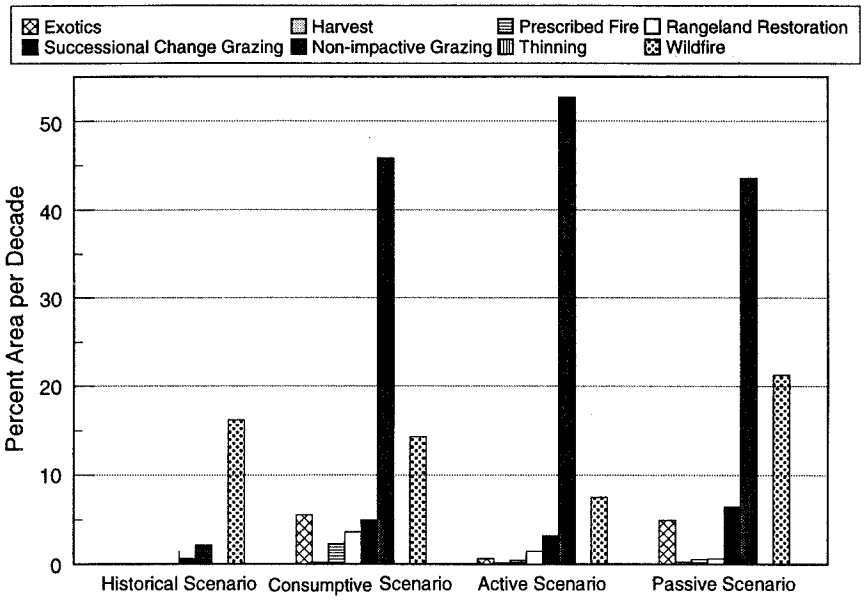


Figure 3.27—Response of scenarios for physiognomic types within non-wilderness lands (also referred to as traditional commodity management, consumptive demand management and roaded lands, or natural/human and human process management regions) in the moist forest PVG of the Rocky Mountains generalized subbasin group.



	Historical Scenario	Consumptive Scenario	Active Scenario	Passive Scenario
Exotics	NA	5.185418	0.317206	4.509400
Harvest	NA	0.002481	0.004771	0.002672
Prescribed Fire	NA	1.921748	0.152495	0.183224
Rangeland Restoration	NA	3.186754	0.993225	0.228075
Successional Change Grazing	0.196323	4.447753	2.729650	5.989503
Non-impactive Grazing	1.766903	45.724019	52.641664	43.384674
Thinning	NA	0	0	0
Wildfire	16.035624	14.060884	7.004103	20.868213

Figure 3.28—Response of scenarios for disturbance area within non-wilderness lands (also referred to as traditional commodity management, consumptive demand management and roaded lands, or natural/human and human process management regions) in the dry shrub PVG of the Intermountain generalized subbasin group.

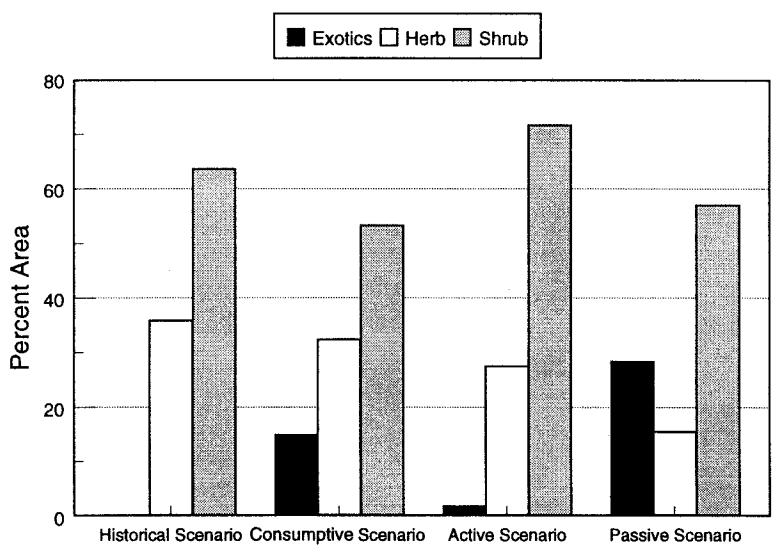


Figure 3.29—Response of scenarios for physiognomic types within non-wilderness lands in the dry shrub PVG of the Intermountain generalized subbasin group.

Table 3.187—General decade levels of wildfire on BLM/FS lands in the Basin.

BLM/FS lands in Management Region	Prior to Fire Exclusion	Time Period			
		1920 -1930s	1950 -1960s	1980 -1990s	2090s
		Millions of hectares			
Basin	6.4	3.9	1.2	2.3	3.4
EEIS	3.0	1.5	0.5	1.0	1.5
UCRB	3.4	2.4	0.7	1.3	1.9
BLM/FS lands Wildfire Variable					
		Ratio of Current Value compared with 1920 - 1930s			
Fire Suppression Cost Per Unit Area	0	1.0	2.0	4.0	8.0
Firefighter Accident Hazard	0	1.0	0.5	1.0	3.0
Hazard to Life and Property	0	1.0	0.3	1.5	3.0

Trends and Ecology of Wildland Fire

The changes of vegetation structures and composition in forests and rangelands that occurred between the historical and current periods have substantially increased the risks of wildland wildfires at landscape and regional levels. Fire suppression efforts since the early- to mid-1900s have been largely successful in reducing the area disturbed by wildfires (table 3.187). Even during the last two decades, the area burned by wildfire was still well below the average experienced prior to fire suppression. However, the trend seems to be changing as the area burned during the 1980s exceeded the area burned in the 1950s.

The history and possible future of wildfire disturbance in the Basin is very similar to the rest of the western United States (Agee 1993). Prior to fire suppression activities, fuels were generally maintained at relatively low levels, and areas having high fuel loads were restricted to relatively small, isolated patches. As access to wildlands increased and mechanical equipment and air support became more available, areas burned by wildfire declined through the 1960s. However, by the 1980s, fuel accumulations had generally increased, and areas having moderate to high fuel loadings became larger and more contiguous. In addition, the indirect effects of increased access into wildlands began to increase the role of human-caused ignitions. As human-caused ignitions increased, so too did the expansion of urban and rural development into wildland interfaces. Future projections suggest a steady increase in fuel loads, fire susceptibility in forest structures and patterns, human-caused ignitions, and development within the rural/wildland interface.

The costs of wildfire suppression (on a per unit area basis) have doubled at approximately 30-year intervals. Although it is difficult to predict future wildfire suppression costs as fuels increase and wildfires become more severe, the associated hazards to life and property will likely increase, as will wildfire suppression costs.

Fire regimes are a relatively useful indicator of changes in fire behavior as a result of changes in vegetation composition, structure, and fuels.

Fire regimes in the Basin changed substantially between historical and current periods. Lethal fire regimes, that kill the upper layer of vegetation, increased 17 percent in the Basin (table 3.188). In contrast, mixed regimes decreased by 3 percent, and non-lethal regimes declined by 22 percent. We can not directly infer that the potential of severe fire behavior and severe fire effects would increase because of an observed increase in the areal extent of lethal fire regimes, however. First of all, the current period fire regimes were predicted from fire behavior modeling and recent history of wildfire occurrence and extrapolated using cover type and subsection stratifications. Consequently, current period fire regimes were not as accurate as the historical regimes, which were based upon empirical fire history (fire scars) and associated data. Secondly, in addition to the biophysical environment and cover types, fire behavior and fire effects are perhaps more influenced by other variables including landform, topographic relief, climate, and local weather patterns. Consequently, the observed changes between the historical and current periods should only be used as one indicator of the trend for assessing fire risks and effects.

Fire severity (that is, lethal, non-lethal, and mixed) may not be as useful an indicator of changes in fuels, fire behavior, and fire effects compared with fire frequency (that is, very frequent, frequent, infrequent, very infrequent, extremely infrequent). Estimating changes of fire severity is subject to errors in modeling fire behavior, whereas estimating changes of fire frequency is not. Consequently, changes in fire frequency are probably more precise. Reductions in fire frequency are also generally associated with an increase in fuel accumulations.

Changes of fire severity in the Basin were dominated by an increase of lethal regimes and the subsequent decline of non-lethal regimes (table 3.188). Over all, fire frequency declined (that is, fire-return intervals were lengthened) across nearly one-third of the Basin. Longer fire-return intervals suggest that fuel accumulations have increased across those areas that historically had a frequent fire regime, but had a infrequent fire regime during the current period. Changes of fire regime classes were dominated by the areal declines of the non-lethal very-frequent and lethal frequent classes, and areal increase of the lethal infrequent class. We detected a 3 percent increase in the extremely infrequent and very-infrequent classes at the Basin level. The overall decline of the very frequent classes across 9 percent of the Basin was likely a result of less fire in the grassland environments due to the removal of fine fuels from livestock grazing pressure and agricultural practices.

The trends of fire regimes between historical and current periods varied regionally within the Basin (table 3.189). The EEIS management region was dominated by the decline of the lethal frequent and non-lethal very-frequent regimes, and the associated increase of the mixed infrequent and non-lethal infrequent regimes. The aggregation of lethal regimes had a projected increase across approximately 8 percent of the EEIS management region, whereas the non-lethal regimes declined across 15 percent of the area. Very frequent and frequent regimes declined across about 31 percent of the EEIS region, whereas infrequent regimes increased by 28 percent.

The changes in fire regimes in the UCRB management region were dominated by the increase of the lethal very-infrequent regime and the decline of the non-lethal very-frequent regime (table 3.189). Changes in severity were dominated by an increase of lethal regimes across 19 percent of the UCRB region, and the decline of non-lethal regimes across approximately 12 percent of the UCRB region. Thus, proportionately, we projected a more substantial increase of lethal fire regimes in the UCRB region relative to the EEIS region. The detected changes of fire frequency were not nearly as dramatic in the UCRB as they were in the EEIS. The very-frequent and frequent fire regimes increased across approximately 15 percent of the UCRB region, whereas the infrequent, very infrequent, and extremely infrequent regimes declined across 15 percent of the region.

Table 3.188—Fire regime severity and frequency classes within the Basin.

Severity / Frequency Class	Historical	Current	Absolute Change	Proportional Change
	Percent			
Lethal extremely infrequent	2.2	1.5	-0.8	-33.8
Lethal frequent	21.5	6.0	-15.6	-72.2
Lethal infrequent	20.4	34.5	14.1	69.3
Lethal very frequent	0	14.2	14.2	NA[1]
Lethal very infrequent	3.2	8.1	4.9	157.1
Mixed frequent	6.2	3.8	-2.5	-39.3
Mixed infrequent	9.3	16.8	7.5	81.3
Mixed very frequent	0.6	0	-0.6	-100.0
Mixed very infrequent	1.3	0	-1.3	-100.0
Non-lethal frequent	6.9	2.3	-4.6	-66.5
Non-lethal infrequent	2.7	10.0	7.3	269.3
Non-lethal very frequent	24.3	1.4	-22.9	-94.4
No Data	0.1	0.1	0	0
Rarely	1.3	1.5	0.2	12.3
Total	100.0	100.0	NA	NA

[1]NA = Not Applicable, since the regime did not occur historically.

Although the dominant changes of fire regimes varied among subbasin groups, the overall trends were consistent (table 3.190). With the exception of the Columbia Plateau subbasin group, we projected an increase of lethal fire regimes and a subsequent decrease of non-lethal fire regimes in all subbasin groups. The most substantial proportionate increases of lethal fire regimes occurred in the Northern Rocky Mountains (46%), the Northern Cascade Mountains (31%), and the Central Rocky Mountains (22%) subbasin groups. Conversely, the most substantial declines of non-lethal fire regimes occurred in the Columbia Plateau (30%), the Southern Cascade and Blue Mountains (26%), and the Central Rocky Mountains (21%) subbasin groups. As a whole, fire severity projections changed the least in the Intermountain Basin subbasin group. We feel this may be due to a lack in sensitivity of the fire severity and frequency predictions in the rangeland PVGs which dominate the Intermountain Basin subbasin group. The areal extent of more frequent fire regimes was projected to decline throughout all subbasin groups, whereas the extent of infrequent fire regimes increased. The Intermountain Basin subbasin group had the least overall change with respect to fire frequency.

Table 3.189—Fire regime severity and frequency classes by management region for BLM/FS lands within the Basin.

Management Region	Severity / Frequency	Historical	Current	Absolute Change	Proportional Class Change
		Percent			
EEIS	Lethal extremely infrequent	5.5	5.1	-0.4	-7.8
	Lethal frequent	33.7	4.3	-29.4	-87.4
	Lethal infrequent	7.9	13.9	6.1	76.9
	Lethal very frequent	0	27.2	27.2	NA[1]
	Lethal very infrequent	2.4	7.0	4.6	195.9
	Mixed frequent	5.3	3.4	-1.9	-35.0
	Mixed infrequent	11.0	21.2	10.2	93.1
	Mixed very frequent	0.1	0	-0.1	-100.0
	Mixed very infrequent	1.0	0	-1.0	-100.0
	Non-lethal frequent	4.6	0.8	-3.7	-81.6
	Non-lethal infrequent	2.5	14.4	11.9	475.3
	Non-lethal very frequent	24.7	1.3	-23.4	-94.8
	No Data	0.5	0.5	0	0
	Rarely	0.9	0.9	0	0.1
EEIS Total		100.0	100.0	NA	NA
UCRB[2]	Lethal extremely infrequent	0.6	0.5	-0.1	-22.8
	Lethal frequent	15.3	10.6	-4.6	-30.3
	Lethal infrequent	22.4	27.4	5.0	22.3
	Lethal very frequent	0	8.8	8.8	NA
	Lethal very infrequent	6.3	16.7	10.3	163.9
	Mixed frequent	8.9	4.5	-4.4	-49.0
	Mixed infrequent	17.5	18.8	1.3	7.2
	Mixed very frequent	1.0	0	-1.0	-100.0
	Mixed very infrequent	2.9	0	-2.9	-100.0
	Non-lethal frequent	6.7	2.6	-4.0	-60.9
	Non-lethal infrequent	4.6	6.8	2.2	47.7
	Non-lethal very frequent	12.8	2.3	-10.5	-81.7
	No Data	0	0	0	0
	Rarely	1.0	1.0	0	0.1
UCRB Total		100.0	100.0	NA	NA

[1]NA = Not Applicable.

[2]GYE and UCRB areas are combined into the UCRB region.

Table 3.190—Fire regime severity and frequency classes by subbasin group for BLM/FS lands within the Basin.

Subbasin Group	Severity Frequency Class	Historical	Current	Absolute Change	Proportional Change
		..... Percent			
Central Rocky Mountains Subbasin Group	Lethal extremely infrequent	0.2[1]	0.1	-0.1	-50.0
	Lethal frequent	8.2	5.7	-2.5	-30.5
	Lethal infrequent	15.6	24.6	9.0	57.7
	Lethal very frequent	0	1.8	1.8	NA[2]
	Lethal very infrequent	5.5	18.9	13.3	243.6
	Mixed frequent	6.2	6.2	0.1	T[3]
	Mixed infrequent	23.7	25.0	1.3	5.5
	Mixed very frequent	0.1	0	-0.1	-100.0
	Mixed very infrequent	1.7	0	-1.7	-100.0
	Non-lethal frequent	11.7	3.2	-8.4	-7.3
	Non-lethal infrequent	7.4	11.2	3.8	51.4
	Non-lethal very frequent	18.0	1.7	-16.4	-90.6
	No Data	0	0	0	0
	Rarely	1.7	1.7	0	0
Central Rocky Mountains Total		100.0	100.0	NA	NA
Columbia Plateau	Lethal extremely infrequent	T	0	-T	-T
	Lethal frequent	20.0	3.3	-16.7	-83.5
	Lethal infrequent	17.7	25.4	7.6	43.5
	Lethal very frequent	0	15.8	15.8	NA
	Lethal very infrequent	5.0	5.5	0.5	10.0
	Mixed frequent	3.5	8.7	5.1	148.6
	Mixed infrequent	5.9	25.7	19.8	335.6
	Mixed very frequent	1.6	0	-1.6	-100.0
	Mixed very infrequent	0.7	0	-0.7	-100.0
	Non-lethal frequent	10.4	4.1	-6.3	-60.6
	Non-lethal infrequent	4.3	10.4	6.1	141.9
	Non-lethal very frequent	30.6	1.0	-29.6	-96.7
	No Data	0	0	0	0
	Rarely	0.2	0.2	0	0
Columbia Plateau Total		100.0	100.0	NA	NA

Table 3.190 (continued).

Subbasin Group	Severity Frequency Class	Historical	Current	Absolute Change	Proportional Change
		Percent			
Intermountain Basin	Lethal extremely infrequent	7.8	7.1	-0.7	-9.0
	Lethal frequent	56.0	15.0	-41.1	-73.2
	Lethal infrequent	27.3	17.1	-10.2	-37.4
	Lethal very frequent	0	46.2	46.2	NA
	Lethal very infrequent	T	0.1	0.1	T
	Mixed frequent	0.8	3.4	2.6	325.0
	Mixed infrequent	1.7	4.0	2.3	135.3
	Mixed very infrequent	0.1	0	-0.1	-100.0
	Non-lethal frequent	0.5	1.9	1.4	280.0
	Non-lethal infrequent	T	1.2	1.2	T
	Non-lethal very frequent	5.4	3.7	-1.7	-31.5
	No Data	0	0	0	0
	Rarely	0.4	0.4	0	0
Intermountain Basin Total		100.0	100.0	NA	NA
Northern Cascade Mountains	Lethal extremely infrequent	T	0	-T	-T
	Lethal frequent	2.0	0.4	-1.6	-80.0
	Lethal infrequent	3.0	12.0	9.0	300.0
	Lethal very frequent	0	0.8	0.8	NA
	Lethal very infrequent	10.6	32.9	22.3	210.4
	Mixed frequent	12.2	0.9	-11.3	-92.6
	Mixed infrequent	31.7	33.4	1.8	5.4
	Mixed very frequent	0.4	0	-0.4	-100.0
	Mixed very infrequent	4.0	0	-4.0	-100.0
	Non-lethal frequent	8.2	1.1	-7.1	-86.6
	Non-lethal infrequent	6.1	15.3	9.2	150.8
	Non-lethal very frequent	18.9	0.1	-18.8	-99.5
	No Data	1.1	1.1	0	0
	Rarely	1.9	1.9	0	0
Northern Cascade Mountains Total		100.0	100.0	NA	NA

Table 3.190 (continued).

Subbasin Group	Severity Frequency Class	Historical	Current	Absolute Change	Proportional Change
		Percent			
Northern Rocky Mountains	Lethal frequent	0.4	6.8	6.4	1600.0
	Lethal infrequent	10.8	35.6	24.8	229.6
	Lethal very infrequent	15.4	30.2	14.8	96.1
	Mixed frequent	26.3	0.1	-26.2	-99.6
	Mixed infrequent	19.4	22.0	2.6	13.4
	Mixed very frequent	4.0	0	-4.0	-100.0
	Mixed very infrequent	9.1	0	-9.1	-100.0
	Non-lethal frequent	1.2	0	-1.2	-100.0
	Non-lethal infrequent	4.4	4.8	0.5	9.1
	Non-lethal very frequent	8.7	T	-8.6	-98.9
	No Data	0.1	0.1	0	0
	Rarely	0.4	0.4	0	0
Northern Rocky Mountains Total		100.0	100.0	NA	NA
Southern Cascade and Blue Mountains	Lethal extremely infrequent	0.5	0.5	T	T
	Lethal frequent	14.5	4.4	-10.1	-69.7
	Lethal infrequent	8.6	17.3	8.7	101.2
	Lethal very frequent	0	6.5	6.5	NA
	Lethal very infrequent	0.9	4.1	3.2	355.6
	Mixed frequent	4.7	5.4	0.7	14.9
	Mixed infrequent	14.1	32.0	17.8	127.0
	Mixed very frequent	T	0	-T	-T
	Mixed very infrequent	0.5	0	-0.5	-100.0
	Non-lethal frequent	7.2	1.1	-6.0	-84.7
	Non-lethal infrequent	2.3	25.4	23.1	1004.3
	Non-lethal very frequent	45.0	1.6	-43.4	-96.4
	No Data	0.8	0.8	0	0
	Rarely	0.9	0.9	0	0
Southern Cascade and Blue Mountains Total		100.0	100.0	NA	NA

[1]Percents have been rounded.
[2]NA = Not Applicable.
[3]T = Trace; <0.05%.

Current fire occurrence probabilities were based upon recent historical fire records of the 1980s, and then assigned to appropriate geographic areas. The occurrence probabilities represent the recent historical and current periods. Because the BLM/FS land and Other land ownerships are generally intermingled, the fire occurrence levels did not vary substantially between the two ownerships. Approximately 39 percent of the Basin was categorized as having a high or very-high fire-occurrence probability, whereas 19 and 43 percent of the Basin were in moderate and low classes, respectively (table 3.191). Relative to other areas of the western United States, fire occurrence probabilities of the Basin rank below only those within the chaparral and annual grassland types of California.

The composition of fire occurrence classes within the two management regions (EEIS and UCRB) was not substantially different (table 3.192). The primary difference between the two regions was that the EEIS area had a greater proportion of lands having a high probability of ignition, whereas the UCRB area had a larger proportion of lands having a low probability of ignition. Although the composition of fire occurrence classes within the two regions was similar, there were substantial differences among the six subbasin groups within the Basin (table 3.193). The Southern Cascade and Blue Mountains, and the Northern Rocky Mountains subbasin groups had the highest fire occurrence probabilities within the Basin. The two subbasin groups dominated by rangelands (that is, the Columbia Plateau and Intermountain Basin) had the lowest fire occurrence probabilities within the Basin. However, the observed difference of fire occurrence probability between the five forest-dominated subbasin groups and the two rangeland-dominated subbasin groups may be attributable to a bias of our data. For example, reporting rates of fires are probably different between forest- and rangeland-dominated systems. Fires in forest systems are often perceived as more catastrophic, and are consequently more frequently reported than fires in rangeland systems.

We detected a consistent decline in the areal extent of non-lethal fire regimes and an increase in the extent of lethal fire regimes regardless of the current management strategy of BLM/FS lands. However, we believe the observed changes of fire severity are somewhat associated with the current management strategies of BLM/FS lands. In areas dominated in the current period by human-influenced processes, we detected a 25 percent decline of non-lethal fire regimes and a 25 percent increase of lethal fire regimes. In areas dominated by natural processes in the current period, we observed a 19 percent decline in areal extent of non-lethal and mixed regimes, whereas the extent of lethal

Table 3.191—Current fire occurrence risks for the Basin by land ownership group.

Land Ownership Group	Fire Occurrence Class	Percent of Basin[1]
BLM/FS	Very Low	12
Other	Very Low	11
	Very Low Total	23
BLM/FS	Low	9
Other	Low	11
	Low Total	20
BLM/FS	Moderate	11
Other	Moderate	8
	Moderate Total	19
BLM/FS	High	10
Other	High	10
	High Total	20
BLM/FS	Very High	10
Other	Very High	9
	Very High Total	19
	Grand Total	100

[1]Percents may not add up to 100 due to rounding.

Table 3.192—Current fire occurrence risks in the Basin by management region and land ownership group.

Management Region	Fire Occurrence Class	Land Ownership Group	Percent of Management Region
EEIS	Very Low	BLM/FS	10[1]
		Other	14
		Total Very Low	24
	Low	BLM/FS	3
		Other	12
		Total Low	15
	Moderate	BLM/FS	10
		Other	8
		Total Moderate	18
	High	BLM/FS	12
		Other	14
		Total High	25
	Very High	BLM/FS	7
		Other	10
		Total Very High	17
Total EEIS			100
UCRB	Very Low	BLM/FS	14
		Other	8
		Total Very Low	22
	Low	BLM/FS	14
		Other	10
		Total Low	25
	Moderate	BLM/FS	12
		Other	8
		Total Moderate	20
	High	BLM/FS	8
		Other	5
		Total High	13
	Very High	BLM/FS	14
		Other	7
		Total Very High	21
Total UCRB			100

[1]Percents have been rounded.

Table 3.193—Current fire occurrence risks by subbasin group and land ownership group for the Basin.

Subbasin Group	Land Ownership Group	Fire Occurrence Class	Percent of Subbasin Group[1]
Central Rocky Mountains	BLM/FS	Very Low	7
	Other	Very Low	4
		Very Low Total	11
	BLM/FS	Low	15
	Other	Low	9
		Low Total	24
	BLM/FS	Moderate	19
	Other	Moderate	10
		Moderate Total	29
	BLM/FS	High	5
	Other	High	1
		High Total	7
	BLM/FS	Very High	22
	Other	Very High	7
		Very High Total	29
Central Rocky Mountains Total			100
Columbia Plateau	BLM/FS	Very Low	1
	Other	Very Low	45
		Very Low Total	45
	BLM/FS	Low	3
	Other	Low	31
		Low Total	34
	BLM/FS	Moderate	1
	Other	Moderate	9
		Moderate Total	10
	BLM/FS	High	0
	Other	High	3
		High Total	3
	BLM/FS	Very High	1
	Other	Very High	8
		Very High Total	9
Columbia Plateau Total			100

Table 3.193 (continued).

Subbasin Group	Land Ownership Group	Fire Occurrence Class	Percent of Subbasin Group[1]
Intermountain Basin	BLM/FS	Very Low	42
	Other	Very Low	21
		Very Low Total	62
	BLM/FS	Low	15
	Other	Low	12
		Low Total	27
	BLM/FS	Moderate	8
	Other	Moderate	3
		Moderate Total	11
Intermountain Basin Total			100
Northern Cascade Mountains	BLM/FS	Low	0
	Other	Low	21
		Low Total	21
	BLM/FS	Moderate	10
	Other	Moderate	12
		Moderate Total	22
	BLM/FS	High	29
	Other	High	28
		High Total	57
Northern Cascade Mountains Total			100
Northern Rocky Mountains	BLM/FS	Low	7
	Other	Low	3
		Low Total	10
	BLM/FS	Moderate	9
	Other	Moderate	9
		Moderate Total	18
	BLM/FS	High	18
	Other	High	23
		High Total	41
	BLM/FS	Very High	12
	Other	Very High	20
		Very High Total	31
Northern Rocky Mountains Total			100

Table 3.193 (continued).

Subbasin Group	Land Ownership Group	Fire Occurrence Class	Percent of Subbasin Group[1]
Southern Cascade and Blue Mountains	BLM/FS	Low	0
	Other	Low	4
		Low Total	4
	BLM/FS	Moderate	12
	Other	Moderate	9
		Moderate Total	22
	BLM/FS	High	21
	Other	High	21
		High Total	41
	BLM/FS	Very High	17
	Other	Very High	16
		Very High Total	33
Southern Cascade and Blue Mountains Total			100

[1]Percents were rounded to the nearest decimal.

regimes increased by approximately 37 percent. Therefore, human activities seem to have dampened the increase of lethal fire regimes that we observed in more natural settings, but they worsened the decline of non-lethal fire regimes. The most substantial difference in trends among areas currently influenced by different management strategies was that the areal extent of mixed regimes in areas dominated by human-influenced processes did not change between historical and current periods, whereas the extent of mixed regimes declined substantially in areas currently influenced by more natural processes.

The amount of crown fire resulting from wildfires in forest settings is of concern in terms of severe fire behavior and the accompanying danger to lives and property, as well as the effects on soil and watershed values. Current period levels of projected crown fire in forests were well below historical levels within all ownership classes of all regional strata of the Basin (table 3.194). The projections of the current period were below historical levels across Other lands because of fire suppression activities as well as the conversion of wildlands into agricultural lands. On BLM/FS lands, the reduction of crown fires was attributable to fire suppression activities. For the Basin as a whole, the future projections of crown fires resulting from consumptive demand and passive management scenarios were 27 to 32 percent greater, respectively, than the amount of crown fire projected for the current period. Conversely, the projection resulting from an active management scenario was 14 percent less than the projection for the current period. On BLM/FS lands within the Basin, the consumptive demand and passive management scenarios also increased the amount of area disturbed by crown fires, whereas an active management scenario reduced the area affected by crown fire.

We detected similar trends when the Basin was stratified by management region; both consumptive demand and passive management scenarios increased the projected amount of area disturbed by crown fire, whereas an active management scenario decreased the area expected to be affected

Table 3.194—Historical and projected future (100-year) trends of potential forest crown fires in the Basin.

Management Region	Land Ownership Group	Percent Change from Historical	Historical	Current	Scenario[1]		
					CD	AM	PM
			..... Percent of Area Disturbed Per Decade				
EEIS	BLM/FS	-30	3.6	2.5	3.3	1.1	3.0
	Other	-43	2.9	1.7	2.3	2.3	2.2
	All	-37	3.2	2.0	2.7	1.8	2.6
UCRB	BLM/FS	-39	4.3	2.6	3.1	1.6	3.8
	Other	-48	3.3	1.7	2.4	2.4	2.4
	All	-42	3.9	2.3	2.8	1.9	3.3
Basin	BLM/FS	-36	4.0	2.6	3.2	1.4	3.5
	Other	-45	3.1	1.7	2.4	2.4	2.3
	All	-39	3.6	2.2	2.8	1.9	2.9

[1]Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management.

by crown fires. The level of crown fire disturbance was projected to decline under active management scenarios largely because the level of wildfire disturbances was reduced due to vegetation treatment activities (for example, tree thinning and fuel reductions resulting from harvest and prescribed fire treatments). To the contrary, the area affected by wildfire disturbances, and consequently crown fire disturbances, were projected to increase under the consumptive demand and passive management scenarios.

To this point, our assessment of the projected trends of fire regimes does not adequately address the risks of wildfire and severe fire effects. Subtle differences in the composition, structure, and pattern of vegetation and fire occurrence probabilities may have substantial affects on the risks and severity of wildfires. Consequently, we quantified the extent of the following five variables to better address the potential risks and severity of fires on BLM/FS lands by ERU: (1) historical mixed and lethal fire regimes; (2) an index that incorporated the changes in the susceptibility to more lethal regimes and increased fuel accumulation between historical and current periods; (3) the presence of high and very-high fire-occurrence probabilities; (4) an index of severe fire behavior based upon terrain and climate; and (5) the presence of rural and urban/wildland interface.

The extent of mixed and lethal fire regimes that existed historically provided an estimate of the areal extent that had the biogeochemical potential of more lethal regimes. Areas that have higher inherent levels of these regimes generally have higher potential for severe fire behavior and severe fire effects, regardless of whether these regimes have changed between historical and current periods. The second variable was an index that averaged the net change of mixed and lethal fire regimes with the net change of infrequent fire regimes for an ERU. We believe this index indicated the changes that occurred between historical and current periods in the susceptibility to more severe fire behavior, as well as the changes of

potentially more severe fire due to fuel accumulations. Fire occurrence probabilities were used as an indicator of the probability of ignitions. As stated previously, we believe this variable is biased toward low values in rangeland settings. Our index of severe fire behavior attempted to capture the relationships among topography, climate, and fire behavior. For example, ERUs having more dissected terrain, steeper gradients of seasonal climates, higher potentials for flammable fuels (such as annual grasses), and higher probabilities of erratic wind events have much higher risks of severe fire behavior. The extent of the rural and urban/wildland interface indicated the risks and costs associated with the protection of human lives and property. An overall index was calculated by averaging the five variables for each ERU.

The overall index of the risks of severe fire behavior and effects did not vary substantially among ERUs (range = 39 to 67; table 3.195). However, we detected more substantial variation of the individual indicator variables among the ERUs. The dry-shrub-PVG-dominated Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs had the highest proportions of mixed and lethal regimes during the historical period. The remaining ERUs had intermediate levels of the more lethal fire regimes. The change of fire regimes between the historical and current periods was most extensive in the Upper Klamath ERU, but almost nonexistent in the Owyhee Uplands ERU. In general, the ERUs dominated by rangeland PVGs had relatively low fire regime changes. However, the BLM/FS lands within the Columbia Plateau ERU changed substantially. Due to the inherent bias within our methodology, fire occurrence probabilities were relatively low within the ERUs that had a relatively high composition of rangeland PVGs. The Southern Cascades and Upper Klamath ERUs had the highest probability of fire ignitions. The Lower Clark Fork, Northern Cascades, and Northern Glaciated Mountains ERUs also had relatively high fire occurrence probabilities with respect to the other ERUs dominated by forest PVGs. The BLM/FS lands within the Upper Klamath and Upper Snake ERUs had substantially higher risks of severe fire behavior relative to the other ERUs. The highest levels of urban/rural interface with BLM/FS lands were located within the Columbia Plateau and Northern Cascades ERUs. Because of the compensating factors of the five variables, the overall index of the risks of severe fire behavior and severe effects on BLM/FS lands did not vary substantially among the 13 ERUs. Although our assessment of the risks of severe fire behavior and severe fire effects provides regional context, we believe the overall index may have more discriminating power if it were applied at the subbasin level.

Wildland fire management on BLM/FS lands will likely become more challenging in the future. Our future projections indicated that the area burned by wildfire would be greatest under a passive management scenario, and least under an active management scenario (table 3.196). The area burned under a consumptive demand scenario would be intermediated between the passive and active management scenarios. We believe the costs, hazards to life and property (including firefighters), and risks of smoke would be directly associated with the amount of area burned under each management scenario (tables 3.197 and 3.198).

In the modeling of scenarios, we projected that continuation of the consumptive demand scenario would result in an average of 2.6 million hectares of wildfire per decade in the coming 100-year period, as compared to 4.4 million hectares with the passive management scenario. If the active management scenario were successfully implemented, this could be reduced to 1.7 million hectares of wildfire per decade. For the EEIS region, continuation of the consumptive demand scenario would mean 1.1 million hectares of wildfire per decade, as compared with 1.8 million with implementation of the passive management scenario, and 0.7 million with successful implementation of the active management scenario. For the UCRB region, the passive management scenario might result in 2.4 million hectares or more of wildfire per decade, while continuation of the

Table 3.195—Biophysical characteristics that influence wildfire behavior and effect risk by Ecological Reporting Unit (ERU).

ERU	Historical Mixed / Lethal	Fire Regime Change[1]	High Fire Occurrence[2]	Severe Fire Behavior[3]	Rural / Wildland Interface Risk[4]	Overall Risk[5]
	Percent of ERU					
Blue Mountains	41	70	62	70	32	55
Central Idaho Mountains	54	50	46	67	24	48
Columbia Plateau	54	63	24	51	80	54
Lower Clark Fork	73	43	73	46	40	55
Northern Cascades	61	48	69	58	72	62
Northern Glaciated Mountains	62	59	71	44	48	57
Northern Great Basin	88	12	5	84	8	39
Owyhee Uplands	92	3	5	89	40	46
Snake Headwaters	74	27	5	77	16	40
Southern Cascades	46	65	95	72	56	67
Upper Clark Fork	50	56	58	81	64	62
Upper Klamath	27	88	95	91	32	67
Upper Snake	91	17	5	90	48	50

[1]Changes in mixed- and lethal-fire severity, and infrequent and very-frequent fire intervals.
[2]High Fire Occurrence = From the 1980s; wildfire frequency data for high fire occurrence.
[3]Severe Fire Behavior = Severe Fire Behavior based on topography and severe fire weather conditions.
[4]Rural/Wildland Interface Risks = Amount of urban and rural interface with hazardous fuel conditions.
[5]Overall Risk = Risk of severe wildfire behavior and effects based on the average of the other variables.

consumptive demand scenario might produce an average of 1.4 million. This is compared with the choice presented by the active management scenario, which projects an average of 0.7 million hectares average per decade. The costs, hazards to life and property, and hazards to wildland firefighters are associated with the choice of scenarios.

Results from modeling of rangeland wildfire scenarios indicated that active management on BLM/FS lands would cut the amount of wildfire in half, compared to the consumptive demand and passive scenarios (table 3.199). In the rangelands there was little difference between the consumptive demand and passive scenarios. Reduction of wildfires in forest PVGs was twice as much in the active management scenario compared with the consumptive demand and passive management scenarios (table 3.200). However, in the forest PVGs the amount of wildfire projected in the passive scenario was somewhat above that projected for the consumptive demand scenario. We believe this is primarily caused by higher efficacy of wildfire suppression in the consumptive demand scenario. The trends within management regions followed the same trend as the Basin, and there was little total difference between management regions.

There was substantial difference in the amount of crown fire on BLM/FS lands in forest PVGs between scenarios (table 3.194). Crown fire in the active management scenario was approximately

Table 3.196—Historical and projected future (100-year) trends of potential net wildfire in the Basin.

Management Region	Land Ownership Group	Percent Change from Historical	Historical	Current	Scenario[1]		
					CD	AM	PM
			..... Percent of Area Disturbed Per Decade				
EEIS	BLM/FS	-72.3	3.0	0.8	0.9	0.5	0.9
	Other	-84.5	4.1	0.6	0.7	0.7	0.7
	All	-80.4	3.7	0.7	0.8	0.6	0.8
UCRB	BLM/FS	-68.4	2.4	0.7	0.8	0.4	0.9
	Other	-83.5	3.3	0.5	0.6	0.6	0.6
	All	-75.4	2.7	0.7	0.7	0.5	0.8
Basin	BLM/FS	-70.2	2.6	0.8	0.9	0.4	0.9
	Other	-84.2	3.8	0.6	0.7	0.7	0.7
	All	-78.2	3.2	0.7	0.8	0.5	0.8

[1]Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management

Table 3. 197—Current and projected future net fire cost within the Basin.

Management Region	Land Ownership Group	Current	Scenario[1]		
			CD	AM	PM
			..... Millions of Dollars		
EEIS	BLM/FS	11.9[2]	12.5	5.3	13.6
	Other	14.7	14.7	14.7	15.3
	Total	26.6	27.2	20.0	29.0
UCRB	BLM/FS	31.1	31.9	16.0	38.8
	Other	12.7	14.8	14.7	14.6
	Total	43.9	46.7	30.8	53.4
Basin	BLM/FS	43.1	44.5	21.3	52.5
	Other	27.4	29.4	29.4	29.9
	Total	70.5	73.9	50.7	82.4

[1]Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management.
[2]Numbers are rounded.

Table 3.198—Historical and projected future (100-year) trends of potential net smoke within the Basin.

Management Region	Land Ownership Group	Percent Change[1]			
			Scenario[2]		
		Current	CD	AM	PM
		..... % of Area with Emissions >448.3 kg / hectare / decade ...			
EEIS	BLM/FS	-15.36	-7.69	-69.23	-7.69
	Other	-32.60	-5.00	-5.00	-10.00
	All	-24.26	-4.54	-36.36	-9.09
UCRB	BLM/FS	-58.47	-33.33	-63.33	-10.00
	Other	-70.93	-22.73	-22.73	-27.27
	All	-62.44	-29.63	-51.85	-14.81
Basin	BLM/FS	-43.08	-21.43	-64.29	-7.14
	Other	-49.52	-14.29	-14.29	-19.05
	All	-45.69	-20.00	-44.00	-12.00

[1]Change compared to HRV smoke production.
[2]Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management.

Table 3.199—Historical and projected future (100-year) trends of potential net wildfire within rangeland potential vegetation groups (PVGs).

Management Region	Land Ownership Group	Percent Change from Historical			Scenario[1]		
			Historical	Current	CD	AM	PM
			..... Percent of Area Disturbed Per Decade				
EEIS	BLM/FS	-65.2	2.6	0.9	1.1	0.5	0.9
	Other	-73.2	3.6	1.0	1.2	1.2	1.3
	All	-69.9	3.1	0.9	1.2	0.9	1.1
UCRB	BLM/FS	-65.7	3.0	1.0	1.2	0.5	1.2
	Other	-72.7	3.2	0.9	1.1	1.1	1.1
	All	-68.1	3.0	1.0	1.2	0.7	1.1
Basin	BLM/FS	-65.5	2.8	1.0	1.1	0.5	1.1
	Other	-73.1	3.5	0.9	1.2	1.2	1.2
	All	-69.0	3.1	1.0	1.2	0.8	1.1

[1]Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management

Table 3.200—Historical and projected future (100-year) trends of potential net wildfire on forest potential vegetation groups (PVGs).

Management Region	Land Ownership Group	Percent Change from Historical	Historical	Current	Scenario[1]		
					CD	AM	PM
			..... Percent of Area Disturbed Per Decade				
EEIS	BLM/FS	-77.5	3.5	0.8	0.8	0.4	0.9
	Other	-74.2	4.1	1.1	1.0	1.0	1.0
	All	-75.9	3.7	0.9	0.9	0.7	0.9
UCRB	BLM/FS	-70.8	2.0	0.6	0.6	0.3	0.8
	Other	-74.0	2.9	0.8	0.8	0.8	0.7
	All	-72.0	2.3	0.6	0.7	0.4	0.8
Basin	BLM/FS	-74.0	2.5	0.7	0.7	0.3	0.8
	Other	-74.1	3.5	0.9	0.9	0.9	0.9
	All	-74.0	2.9	0.7	0.8	0.5	0.8

[1]Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management.

Table 3.201—Historical and projected future (100-year) trends of potential net surface and mixed wildfire.

Management Region	Land Ownership Group	Percent Change from Historical	Historical	Current	Scenario[1]		
					CD	AM	PM
			..... Percent of Area Disturbed Per Decade				
EEIS	BLM/FS	-44.0	1.1	0.6	0.7	0.3	0.7
	Other	-73.3	1.8	0.5	0.5	0.5	0.6
	All	-64.4	1.5	0.5	0.6	0.4	0.6
UCRB	BLM/FS	-36.0	0.8	0.5	0.6	0.2	0.5
	Other	-72.8	1.4	0.4	0.4	0.4	0.4
	All	-55.1	1.0	0.5	0.5	0.3	0.5
Basin	BLM/FS	-39.8	0.9	0.6	0.6	0.3	0.6
	Other	-73.1	1.6	0.4	0.4	0.4	0.5
	All	-60.6	1.3	0.5	0.5	0.3	0.5

[1]Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management.

one third that of either the consumptive demand or passive management scenarios for the Basin level and for the EEIS area. However, the reduction in amount of crown fire in the active management scenario for the UCRB was only about one half that of the consumptive demand and passive management scenarios. This is related to the larger component of cooler and moister forest PVGs, and complex terrain and climate conditions in the UCRB, as compared to the EEIS area. The amount of surface and mixed wildfire in forest PVGs is projected to respond in a somewhat similar trend as for crown fire, since all three types of fire behavior add to total wildfire (table 3.201). However, we emphasize that the ratios between crown and surface/mixed wildfires follow somewhat different trends. The projections indicate that there would be almost five to six times as much crown fire as surface/mixed wildfires in the consumptive demand and passive management scenarios, respectively, as compared to the active management scenario.

Air Quality and Effects

We evaluated air quality and effects in the context of the biophysical template and relative to the standards of the Clean Air Act of 1955 (42 U.S.C. 7401-7626). The primary air pollutants that can cause detrimental effects to ecosystems or impair visual quality of the Basin include sulfur, nitrogen, ozone, radionuclides, toxic air contaminants, and particles. Effects were assessed for aquatic and terrestrial ecosystems, visibility, and implications relative to the dynamics of climate change and scenarios of land management. Methods were based on review of the literature, available data, and modeling of scenarios. More detailed information is provided by Ferguson (1996a, b, c, d), Holsapple and Snell (1996), Schoettle and others (1996), and Chapter 2 of this document, Biophysical Environments.

Biophysical template and air quality

Most of the agents of air pollution that have damaged ecosystems and impaired visual conditions existed to some extent within native systems. Thus, native species and ecosystem processes evolved in the presence of these agents. In fact, trace amounts of many of these agents are required for many biogeochemical processes. However, changed availabilities (including amount and timing), and changed frequency and duration of exposure has had deleterious effects on ecosystem elements and processes. The important distinction between these differing effects occurred when amounts of air pollutants became greater than historical levels.

Sulfur compounds (oxides, sulfuric acid, and sulfates) were present in the air in the native regime as a result of seasalt, biogenic gases, and volcanic emissions (Brimblecombe and others 1989). Globally, human industrial emissions have almost doubled the amount of sulfur inputs to air compared to pre-industrial levels (Schoettle and others 1996). Sulfur compounds can cause acidification of water and soils, and can affect cryptogams and visibility.

The primary release of nitrogen compounds (oxides, ammonium, and nitrates) to the air in the native regime was from microbial activity, lightning, and wildfires. The historical levels have almost doubled on a global basis, as a result of fossil fuel combustion and fertilization (Schoettle and others 1996). Nitrogen compounds in air have increased substantially in, and downwind of, urban areas from combustion of fossil fuels, particularly in the areas east of Seattle-Tacoma, Washington, and Portland, Oregon. There has been an overall increase in nitrogen compounds in the air both in, and upwind of, the Basin compared to the native system, but the total amount has not been quantified. Nitrogen compounds do not cause negative effects to plants at these levels, but can shift the competitive balance between plant species by increasing growth of those that are nitrogen limited. These compounds can negatively affect aquatic systems, can affect visibility, and are a precursor compound to ozone, which is toxic to plants.

Ozone is formed when emissions of volatile organic compounds combine with nitrogen compounds in the presence of sunlight and warm temperatures. It can be transported long distances. Ozone was present in small quantities in the native regime.

Amounts of ozone at monitoring sites have increased substantially as a result of increased levels of nitrogen compounds and volatile organic compounds (Schoettle and others 1996). However, there are inadequate monitoring data to extrapolate to a Basin level. A compounding set of factors has developed over the past two decades as a result of an increase in average annual temperatures, drought frequency, and total amounts of wildfire. Theoretically, increased volatization of organic compounds due to an increasing extent of wildfires and warmer temperatures would suggest that ozone may also be increasing.

Radionuclides

There are two nuclear technology facilities within the Basin, the Hanford Nuclear Reservation in south-central Washington and the Idaho National Engineering Lab in south-central Idaho. Extensive air monitoring at the Hanford site suggests that all applicable standards have been met (Gray 1995). However, levels may increase in response to cleanup activities that are projected for the next 30 years. This risk would be in the form of airborne radionuclides and toxins that would bioaccumulate in aquatic and terrestrial biota. Increasing levels of radionuclides could harm organisms that have higher trophic status within susceptible food webs.

Toxic Air Contaminants

Mercury has been the primary air contaminant that has been tied to toxic effects (Watras and Huckabee 1994). Mercury is commonly released into the atmosphere from coal combustion, incineration operations, smelting, and landfill operations. Microbes can convert mercury to a compound that bioaccumulates in fish, other aquatic biota, and humans. Because of scattered industrial development, Schoettle and others (1996) concluded that it is unlikely that the Basin is a contributor of substantial amounts of mercury. However, they concluded that site-specific contaminations occur and that little is known concerning accumulations in soil, water, and biota in the Basin. Persistent organic pollutants, such as polychlorinated biphenyls (PCBs), dioxins, and chlordane are by-products of industrial activities and pesticides (Schoettle and others 1996). These compounds can be transported in air and deposited where they may bioaccumulate. Little information is available on source and depositional areas of organic pollutants within the Basin.

Particles

Airborne particles can affect both visibility and biota. In the native system, particles were present from wind-blown dust, forest and rangeland fires, and volcanic eruptions, as were small amounts of nitrogen and sulfur oxides that would form nitrate and sulfate particles. Human development has changed the composition and abundance of airborne particulates. These changes resulted predominantly from burning croplands, forest, and rangelands; dust originating from agricultural practices and roads; combustion of fossil fuels; and nitrate and sulfate particulates attributable to industrial emissions (Schoettle and others 1996).

Effects of Air Pollution on Aquatic and Terrestrial Systems

Air pollution can be transported and deposited long distances to affect lakes, streams, and ground water (Schoettle and others 1996). The susceptibility of these systems to air pollution effects is controlled by the ecological relationships of the biophysical template. Bedrock and parent material, soils, climate, and the biotic communities influence the magnitude of air pollution effects. Threats to different ecosystems are highly related to the amounts and duration of exposure, and the ability of a system to neutralize or buffer the pollutant.

Lower elevation aquatic systems tend to be less sensitive to acid rain than higher elevation systems (Schoettle and others 1996). Many lakes in the Basin have a low capacity to buffer the effects of acidification and other pollutants but, to-date, no lakes or streams have been sampled that were considered acidic. High elevation lakes and streams in the Basin generally have pH levels between 6 and 8 during the typical sampling periods of summer and fall. This level of acidity is not high enough to cause mortality to amphibians or fish common to the Basin. However, the spring snowmelt period, which generally has not been monitored, may be a critical time of acidification and subsequent deleterious effects to biota. Nevertheless, based on existing data we concluded that there are no chronically acidified lakes or streams due to acidic deposition in the Basin. Some high elevation lakes and streams may be susceptible to episodic acidification associated with spring snowmelt and intense rain storms.

The lowest concentrations of pollutants found in snowpacks across the Basin occurred in the Cascade Mountains, northern Sierra Nevada Mountains, and in the northern Rocky Mountains of Montana (Schoettle and others 1996). In contrast, the highest concentrations were found in the central Rocky Mountains of western Wyoming, in areas to the west of Yellowstone National Park, and in a small area along the Montana-Idaho border in the northern Rocky Mountains. Concentrations of pollutants in the snowpack were generally greater at lower elevations. However, the lakes, ephemeral pools, and streams with the lowest acid-neutralizing capacity, and thus greatest risk, were generally found in higher-elevation mountains, and often in Class I air quality areas (for example, national parks and wilderness areas) as defined by the Clean Air Act of 1955 (42 U.S.C. 7401-7626). Our ability to project the effects of air pollution on aquatic systems was limited by the lack of deposition monitoring sites across the range of ecological conditions in the Basin (Schoettle and others 1996).

The three primary pollutants that interact at a broad scale across the Basin and have been demonstrated to impact terrestrial systems include sulfur dioxide, nitrogen oxides, and ozone (Schottle and others 1996). Sulfur oxides originated from sources both within and outside of the Basin. Nitrogen oxides were produced predominantly from sources inside the Basin including fossil fuel combustion, agricultural and wildland fires (both wild and prescribed), microbial activity, and lightning. Microbial production of nitrogen compounds can be very high in fertilized agricultural areas. Ozone was found to have the highest rate of transport, and originated from sources both inside and outside the Basin.

The relationships among the toxic interactions of sulfur compounds and ozone, the stimulating effect of nitrogen on nitrogen-limited species, and increased ozone production were complex (Schoettle and others 1996). In addition, the lack of monitoring information across the range of biophysical conditions made it difficult to distinguish the effects of pollutants from those that were due to biological variation. However, many native species, particularly ponderosa pine and a host of lichens and mosses are susceptible to increasing levels of ozone. In addition, high-elevation plant communities were found to be at substantial risk to ozone effects. Low-elevation native plant communities that are intermingled with agricultural lands may be affected by elevated nitrogen levels. Most plant communities adjacent to urban areas have or will be affected by nitrogen compounds, ozone, and sulfur compounds. The highest potential for risk of injury to plants are in those communities already stressed by drought, insect and pathogen attacks, and soil acidification. Of the small amount of monitoring and research that has been conducted, most has been concentrated in forest and high-elevation communities; almost no information is available from rangeland settings. Class I areas within the Basin have air quality values that are to be protected from air pollution. With the lack of monitoring and research information, proactive management in Class I areas to reduce or avoid air pollution is problematic.

Visibility

Across the Basin, the more northerly monitoring sites have lower visual ranges than southerly sites (Schoettle and others 1996). The northern parts of the Basin were found to have much higher levels of organic aerosols and sulfate particles. These areas also have higher humidities, which enhances particle growth and intensifies the reduction in visibility. Also, areas immediately downwind of pollutant sources in western Washington and Oregon have a higher potential for reduced visibility. All areas of the Basin are substantially affected by particles from burning of agricultural fields, forests, and rangelands.

Wild and Prescribed Fire Smoke

Smoke emissions were simulated across the Basin to assess relative differences among historical, current, and future management scenarios (table 3.198). Smoke emissions were expressed as the percent change in decade average compared to HRV that encountered PM10[19] emissions greater than 448.3 kilograms per hectare. For the Basin as a whole, we detected a 46 percent reduction in smoke emissions between the historical and current periods. We detected a 43 percent decline of smoke emissions from BLM/FS lands between historic and current periods. The projected smoke emissions varied substantially among management scenarios for the Basin as a whole. The consumptive demand and passive management scenarios were projected to substantially increase smoke emissions above current levels. Whereas, the active management scenario was projected to result in a decrease of current levels.

Holsapple and Snell (1996), and Snell (1996) modeled mid-scale modal wildfire and prescribed fire scenarios for the Basin. They concluded that the prescribed fire scenarios did not exceed the PM10 standard of 150 micrograms per cubic meter in a 24-hour period (40 C.F.R. 50.6). Conversely, all wildfire scenarios exceeded the standard. Similar projections were observed for a PM2.5 threshold of 60 micrograms per cubic meter in a 24-hour period. For the 18 Class I air quality areas, all scenarios caused reduced visibility at different periods and for different lengths of time. The fire scenario most similar to an active management scenario resulted in a 6 percent reduction in visibility in the Basin. However, the smallest projection for effects on visibility from wildfire exceeded the effects of the greatest projections from prescribed fire. Within a subbasin although smoke from prescribed fire occurs more frequently within and among years than does wildfire, wildfire effects on visibility are less frequent and more acute. However, when prescribed fires occur, they produce much less smoke for comparatively shorter periods—during weather conditions that provide for more rapid smoke dispersion—than do wildfires. Similar responses were reported by Huff and others (1995) and Ottmar and others (1996) when they compared the effects of wildfire to prescribed fire disturbances on air quality.

Interrelationships With Global Climate Change

Our assessment used a climate change scenario in which carbon dioxide levels were doubled within the next 50 to 100 years (Ferguson 1996b, and Chapter 2 of this document, Biophysical Environments). The changing climate was predicted to strongly affect the Basin because it is in a northerly latitude that has moderate climatic influence from the Arctic. Projected climate changes included warmer temperatures (similar marine influences, but warmer Arctic and Continental influences), decreased snow cover particularly in the central portions of the Basin, increased summer lightning storms, increased late-summer precipitation particularly in the south and eastern portions of the Basin, decreased soil moisture during summer, more frequent summer droughts, and less frequent but more intense winter wind storms.

[19] PM10 indicates particulate matter ≤10 microns in size.

Based on our work and the summary of implications by Ryan (1991) we projected that there will be a shift in vegetation conditions in which the drier PVGs will compose a greater proportion of the Basin. Increased drought stress and associated mortality from insect and pathogen attacks would likely occur. Fuel levels and connectivity would increase, average fuel moisture would decline, and potential ignitions would increase. Thus, we would expect higher levels of wildfire than we projected for any of the scenarios.

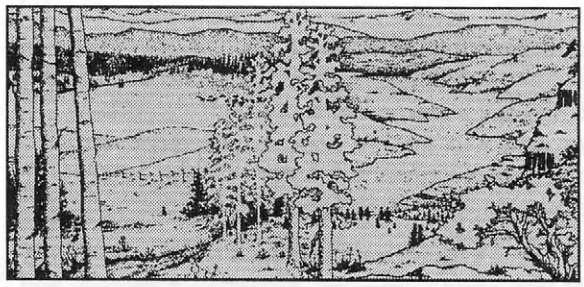
Effects of Management Scenarios

Controlling the sources of anthropogenic air pollutants is out of the hands of BLM and FS public land managers. Public lands may be affected by air pollutants, but the ability of agencies to protect resources on agency-administered lands is limited by the lack of monitoring and research information. It is likely that the active management scenario would result in an improved ability to respond to air quality issues, as compared with the consumptive demand and passive management scenarios. Proactive management within the active management scenario to reduce stress from drought, insects, and pathogens would provide considerable buffering from potential effects of air pollutants. Although the BLM and FS have little influence on management of smoke on agricultural lands or private forest and rangelands, they can reduce the effects of smoke emissions originating from BLM/FS lands by controlling the timing and type of burning. The active management scenario substantially showed a reduction in smoke emissions through the increased use of prescribed burning.

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SUMMARY

Ecological processes are ultimately driven by incident solar radiation that flows through, and is eventually dissipated from, the biosphere. As Allen and Hoekstra (1992) noted, ecosystems cycle material to a considerable degree; without cycles, the ecosystem would soon run out of resources and be directly constrained by the physical system. However, recycling resources requires the dissipation of energy. Energy flows drive the biogeochemical processes that in turn regulate hydrologic and carbon-nutrient cycles, ecosystem food webs, and ultimately, evolution and biological diversity. Alteration of cause-and-effect relationships between these key ecological systems results in disequilibrium and departure from native system responses. In such cases, the altered system becomes dysfunctional, and the probability of predictable disturbance response and resiliency declines.

Ecosystems are dynamic, and they can best be perceived as sequences of events rather than as elements in place (Allen and Hoekstra 1992). We refined the concept of the biophysical template to provide a framework to facilitate the interpretation of complex spatial and temporal relationships. The biophysical template is the current expression of evolutionary processes, and can be perceived as the biological, physical, and disturbance characteristics of a spatially and temporally explicit environment. We characterized the dominant relationships between biophysical conditions and processes of change in the absence of anthropogenic activities to better understand the dominant relationships. We could not characterize the myriad of biophysical templates that have been historically or currently expressed in the Basin. Consequently, we used potential vegetation types, in an aggregate form (potential vegetation groups), as an indicator of the biophysical environment and site potential. In addition, we further resolved the complexity of biophysical templates through classification of general landscape patterns and succession/disturbance regimes.

The conceptual notion of the biophysical template (including its physical and biological environment, as well as its disturbance regimes) was used to characterize a temporally and spatially explicit historical range of variability.[1] Conceptually, the HRV serves as a baseline for characterizing the native regime. The native regime, with some departure dependent on the amount of alteration and constraints imposed by effects of anthropogenic changes, provides the basis for characterizing proper functioning landscapes. The proper functioning landscape then provides the basis for the coarse-filter option, for evaluating change in biological diversity. We used the concept of HRV and the native regime to evaluate the departures of vegetation communities (for example, cover types, terrestrial communities, and physiognomic types) and landscape patterns (that is, the composition of vegetation communities across landscapes). Thus the departures from, or similarity to, the HRV were used as indices to rank condition or risk to

[1] As defined in this chapter, historical range of variability or HRV refers to the pre-Euro-American settlement or "native" regime. It is not synonymous with the historic or historical time period which we define as occurring in the post-Euro-American settlement time period.

ecosystem integrity, resilience, and health. This understanding, along with identification of altered biophysical templates, and limitations of current landscape patterns and succession/disturbance regimes were used to assess management scenarios and their potential outcomes with the concept of proper functioning landscapes as a base.

We used a multi-scale approach to evaluate trends of vegetation conditions, disturbance regimes, and landscape patterns within the Basin. The scales varied spatially and temporally. For example, our broad-scale assessment evaluated trends at regional and landscape scales. The regional scale included the changes that occurred across the Basin as a whole, as well as the changes that occurred within the 13 Ecological Reporting Units or within the 6 subbasin groups. Landscape changes were evaluated for the 164 subbasins that compose the Basin. Broad-scale trends were determined from continuous, 1-square-kilometer resolution data for early historical (circa 1850) and current (early-1990s) time periods. In contrast, mid-scale trends were assessed from sampled, 4-hectare resolution data for more recent historical (1930s-1960s) and current (1987-1991) time periods and summarized for ERUs. Our fine-scale assessment of vegetation conditions was derived from 375-square-meter plots, and summarized for the Basin as a whole.

Broad-scale data enabled us to correlate vegetation, soils, and other variables with gradients of physical parameters such as temperature, precipitation (see map 3.24), and elevation (see map 3.2). These relationships allowed the sampled, fine-, and mid-scaled data to be extrapolated across the Basin, using continuous broad-scale data themes such as management class, PVG, and terrestrial community. Inferences regarding fine- and mid-scaled data could then be made for the Basin as a whole. In addition, the mechanisms behind many of the broad-scale changes were refined when the data was stratified by management region and management class (see table 3.4).

Broad-scale Changes of Biophysical Templates

The Basin contains a complexity of biophysical environments and associated disturbance dynamics. The complexity of biophysical templates was strongly correlated to the diversity of geomorphologic and climatic regimes in the Basin. Glaciation dominated geomorphologic processes to the north, whereas volcanic processes were a dominant process to the west. The interspersion of valley and plains landforms among foothills and mountain landforms produced a large gradient of topographic relief. A climatic gradient extending from west to east generally produced less snow in winter in western areas, but more rain in summer in eastern portions of the Basin. Similarly, a climatic gradient extending north to south became warmer and drier toward southern latitudes. Not surprisingly, the variability of these climatic regimes and geomorphologic types resulted in a great diversity of vegetation composition, structure, and pattern within the Basin. The wide variety of Basin succession/disturbance regimes is a consequence of the interaction of climate with geomorphology and vegetation.

Humans have expended energy between the historical and current periods to control or suppress natural events or to maximize particular values. This expenditure of energy on selected elements has resulted in alteration of the complex syncronized cause-and-effect relationships that developed through evolutionary time in our wildlands (figure 3.30). Anthropogenic activities that changed the relationships between the biophysical environment and succession/disturbance regimes included efforts intended to exclude disturbances associated with wildfires, insects, pathogens, and floods, as well as efforts to produce commodities and values such as timber products, livestock forage, visual conditions, and habitats oriented to specific species (for example, big game cover).

When humans change biophysical processes by altering topography, soils, or composition of biotic communities, the succession/disturbance regimes are altered as well. Human alteration of these

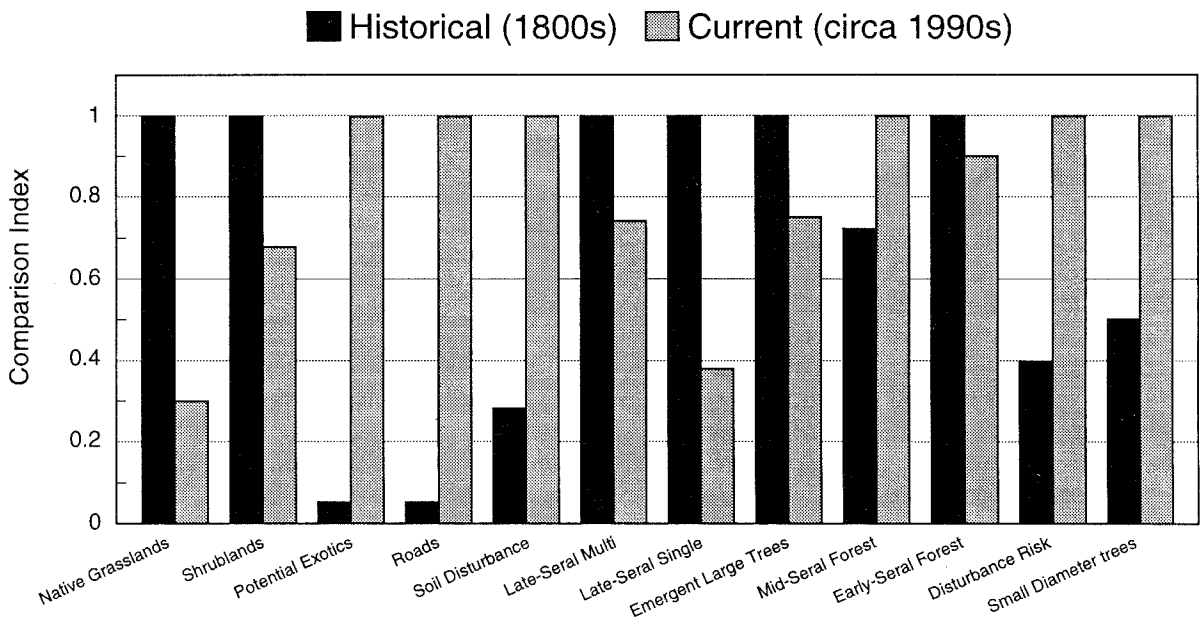


Figure 3.30—A comparison of historical (circa 1800-1900) and current (circa 1990) selected landscape elements. The comparison index is based on a relative scale from zero to 1.0. The higher value of the historical or current landscape element is portrayed by a 1.0, and the lesser value of the historical and current is then relativized to the higher (that is, the index of the smaller to the larger is calculated by dividing the smaller amount by the larger amount). For example, native grasslands extent was about 30 percent of its historical extent. On the other hand, roads during the historical period were about 5 percent of their current density.

ecosystem processes has been so great within some of the Basin's biophysical templates that the systems are currently in a state of disequilibrium. Systems in disequilibrium are less resilient in response to disturbance, and their responses are less predictable than the responses of systems in equilibrium.

Potential vegetation groups and landforms were used to characterize and stratify broad-scale biophysical templates. We evaluated the trends of PVGs and succession/disturbance regimes as indicators of biophysical template change rather than using landforms, because PVGs are more sensitive to change that is detectable within short temporal periods.

The areal extent and composition of PVGs changed substantially between the historical and current periods (see maps 3.8 and 3.9). Basin-wide, the greatest alteration of PVGs was attributable to agriculture and urban development. Biophysical templates on wildlands have been converted to agricultural and urban development across 17 percent of the Basin. Livestock grazing, timber harvest, fire exclusion, flood control practices, and road construction, as well as the introductions of exotic plants and pathogens have not had nearly the effect on biophysical templates as agricultural and urban development; however, their effects have been extensive on biophysical templates with respect to areal extent.

Exotic plants have altered potentials of the biophysical templates (primarily on the rangeland PVGs and the dry forest PVG) across approximately 47 percent of the Basin. Introduced forest pathogens have altered the potentials of the biophysical templates (particularly the vegetation composition of the moist and cold forest PVGs) across approximately 22 percent of the Basin.

Within the Basin, the rangeland biophysical templates have changed to the greatest extent. Agricultural development, primarily on the dry shrub, cool shrub, dry grass, and riparian PVGs, is the most intensive change that occurred within rangeland systems. Most agricultural practices have substantially altered key ecological processes such as geomorphologic development (that is, soil development and erosion), hydrologic and carbon-nutrient cycles, composition of floral and faunal communities, and ecological food webs. Excessive livestock grazing pressure, invasion of exotic plants, and drought can also alter these primary ecological processes and succession/disturbance regimes. Excessive livestock grazing pressure has been implicated in the lengthening of fire-return intervals and can permit the succession of herbland and shrubland physiognomic types to woodland types (for example, western juniper woodlands). Invasion of exotic annual grasses, for example cheatgrass and medusahead, has shortened fire-return intervals and permitted succession of herbland and shrubland physiognomic types to an exotic physiognomic type. In both of these instances, alteration of primary ecological processes and succession/disturbance regimes has resulted in a decline in floral and faunal diversity, and a less predictable production of vegetation that can serve as forage for livestock.

Biophysical templates within forest systems have been less altered than those within rangeland systems. In forest systems, fire exclusion, timber harvest practices, and introductions of white pine blister rust within the moist forest PVGs have (1) nearly eliminated western white pine as a dominant species, (2) increased intervals between fires, (3) and increased fire severity. Fire exclusion and blister rust have had a similar effect on biophysical templates in the cold forest PVG, except that whitebark pine is the dominant species in decline within this PVG. Although the changes within the cold forest PVG have been less extensive in area, the affect is likely more severe compared to the moist forest PVG. To date, whitebark pine composes the entire forest physiognomy within many cold, high-elevation settings where it dominates the early- as well as late-seral stages. Potentially, the entire forest physiognomy may be replaced by shrubland or herbland physiognomies, which could cause considerable disruption of snowpack patterns and associated water routing.

Road density classes were found to be strongly correlated with the observed changes of extant PVGs because roads were closely associated with modern anthropogenic activities. This correlation was based on the sampled watersheds and then extrapolated to the Basin.

The road density class characterized as "none" was largely coincident with biophysical templates in wilderness areas, semi-primitive roadless areas, and National Parks. "Very low" classes occurred primarily on rangeland biophysical templates within the valleys and plains landform. The "low" density class was largely associated with biophysical templates that had been converted to agricultural lands, whereas the "high" class was associated with biophysical templates on forested lands managed for timber products. The "very high" density class typically occurred on biophysical templates in urban or rural areas, or on intensively managed forests.

Road density was found to be indirectly correlated with (1) the distribution and spread of exotic plants, (2) many forest composition and structural changes, (3) efficacy of fire suppression activities, and (4) the probability of fire occurrence due to human-caused ignitions. In forest systems, roads were associated with timber-management practices and thus, correlated with the transition of shade-intolerant to shade-tolerant species, the loss of late-seral structures, reduced densities of large trees and snags, and increased fuel loadings. In rangeland systems, roads appear to function as vectors for dispersing exotic species. Exotic plants show an affinity for areas with soil-surface disturbance, such as roads. Regardless of the biophysical setting, roads appear to increase the efficacy of fire-suppression activities.

Broad-scale Changes of Succession/ Disturbance Regimes

Succession/disturbance regimes changed substantially between historical and current periods. Four succession/disturbance regimes (accelerated cycle, frequent maintenance, infrequent maintenance, irregular maintenance) have virtually disappeared from the systems of the current period that were common in the native regime. Two other regimes (retrogressive cycle, very long cycle) that did not exist historically at the broad scale became predominant as a result of anthropogenic activities. The accelerated-cycling regime has all but disappeared because the disturbances that would thin susceptible species, thereby promoting the development of resistant species, have been removed from many communities. For example, frequent, low-intensity fires in the dry forest PVG would thin shade-tolerant species from the community. However, fire exclusion has allowed the multi-layer development and increased densities of shade-tolerant species in these environments. In a similar manner, the disturbances that would constrain the development of shade-tolerant understory species, thereby maintaining a structural stage comprised by the overstory, have also all but disappeared from many systems. Consequently, the three maintenance regimes are no longer dominant components of the Basin.

Non-native retrogressive and very long-cycling succession/disturbance regimes have developed due to fire exclusion and excessive grazing pressure by domestic livestock. A retrogressive regime is one in which annual disturbances (for example, excessive livestock grazing pressure in rangeland PVGs, or white pine blister rust in the cold forest PVG) gradually reverse succession to earlier structural stages. The very long-cycling regime developed primarily due to the removal of the lethal fires that occurred more frequently in native systems. Other changes that substantially affected the Basin include the general shift to longer-cycling regimes within dry and moist forest PVGs due to fire exclusion and the subsequent lengthening of fire-return intervals, and the shift to shorter-cycling regimes in the dry shrub and dry grass PVGs due to the introduction of exotic annual grasses and the subsequent shortening of fire-return intervals.

Future projections of succession/disturbance regimes indicated that an active (ecological) management scenario would most closely approximate the native succession/disturbance regimes that were evident across BLM- and FS-administered lands, and produce human commodities and amenities, as well. The regimes projected under the traditional consumptive demand and passive management scenarios would differ substantially from those that are evident for native systems and would result in an unpredictable flow of human commodities and amenities. In general, there were only subtle differences between the projections of the consumptive demand and passive management scenarios. None of the scenarios seemed effective in emulating the extents of the frequent-maintenance and moderate-cycle regimes which had substantially more dominant roles in the native systems. For the active management scenario, this was a result of planned departure to more desirable regimes in order to achieve human values and account for altered biophysical templates. In contrast, the consumptive demand and passive management scenarios did not represent these regimes because their focus is on other elements.

Broad-scale Changes of Biogeochemical Relationships

The observed transitions of succession/disturbance regimes, and vegetation structure and composition were directly associated with changes of biogeochemical processes. Net primary productivity increased in forests that experienced transitions from shade-intolerant species to shade-tolerant species. In rangeland settings, net primary productivity declined in areas invaded by exotic grasses and forbs, whereas net primary productivity increased in areas converted to agricultural uses. Although carbon stress is inherently associated with moisture availability, it fluctuated with observed transitions of vegetation conditions.

In forest settings, shade-intolerant forests have higher carbon stress than shade-tolerant forests because shade-tolerant forests have lower respiration rates. Carbon stress increased as single-layered structures developed into multi-layered structures, particularly in the drier environments. Water stress increased in association with successional development due to increasing amounts of live biomass respiration. Nutrient availability declined with successional development, and as single-layered forests developed multiple layers. Nutrient availability also declined as herblands developed into shrublands, and as herblands or shrublands transitioned to woodlands and forests.

Potential Vegetation Groups (PVGs)

Woodland PVG

The woodland PVG is a relatively rare type, and during the current period composed no more than 1 percent of the Basin. There was essentially no loss of this PVG from the historical to the current period. Fire severity in this PVG increased as fire frequency declined. The upland herbland physiognomic type declined dramatically as a result of fire exclusion and the subsequent development of upland shrubland. In addition, the areal extent of the mid-seral woodland physiognomic type increased at the expense of the early- and late-seral woodland. Productivity declined as a result of changed disturbance regimes and vegetation structures.

Dry Forest PVG

The dry forest PVG composed 18 percent of the Basin during the current period, a decrease from 19 percent during the historical period. This decline was mostly attributable to agricultural and urban development. Fire severity in this PVG increased as fire frequency declined. A changed fire regime operated synergistically with traditional timber harvest practices to increase severity. Fire exclusion promoted an increase in stocking levels of shade-tolerant species such as Douglas-fir and grand fir. At the same time, traditional harvest practices targeted the removal of shade-intolerant species such as ponderosa pine. Consequently, the ratio of shade-tolerant to shade-intolerant species increased substantially. In addition, due to the combined effect of fire exclusion and succession, single-layered structures have largely converted into multi-layered structures that regress to mid-seral structures as a result of insect or disease mortality or selective harvest of the large, old trees. As a whole, mid-seral structures increased at the expense of both early- and late-seral structures. Within forest systems, the composition of the dry forest PVG had the lowest similarity to the native system (that is, HRV). This substantial departure was largely correlated with the proximity of the dry forest PVG to human settlements and its accessibility, which increased the probability of successful fire exclusion as well as the amount of timber harvest.

Moist Forest PVG

The moist forest PVG composed 18 percent of the Basin during the current period, and had only a slightly greater percent during the historical period. This minor decline was attributable to agricultural and urban development. Fire exclusion and traditional timber harvest practices have substantially altered the composition of the moist forest PVG. As in the dry forest PVG, fire exclusion and timber harvest practices promoted the dominance of shade-tolerant species, multiple canopy layers, and mid-seral structures. In addition, the introduction of white pine blister rust eliminated western white pine as a dominant component of the moist forest PVG.

Cold Forest PVG

The cold forest PVG composed 10 percent of the Basin. There was essentially no loss of this PVG from the historical to the current period. The vegetation transitions that occurred within the cold forest PVG were not as substantial as those in the dry forest and moist forest PVGs. The current composition of the cold forest PVG has greater similarity to the native system because the cold forest PVG has not had an extensive history of

timber management, fire suppression efforts have been less efficient, and successional change is slower. In addition, the productivity of the cold forest PVG is low, suggesting that the inherent rate of change would be lower than the dry forest and moist forest PVGs. Even so, the composition of shade-tolerant species has increased, as have tree densities, fuel loadings, and subsequently, fire severity. Fire exclusion and white pine blister rust have caused areal declines of communities dominated by whitebark pine.

Dry Grass PVG

The dry grass PVG composed 4 percent of the Basin during the current period, down from 9 percent during the historical period. The decline was attributable to agricultural and urban development. The current vegetation composition and succession/disturbance regimes of the dry grass PVG were the least similar to the native system of any of the PVGs within the Basin. The dominant bunchgrasses that existed historically have largely been replaced by crops, annual exotic grasses, native forbs, exotic forbs, and seeded exotic grasses. With the exception of agricultural lands, dry grasslands are the most susceptible to the invasion of exotic plants. Although fire intervals have lengthened due to fire suppression, in general, fire severity did not increase in this PVG. This is because fuels are typically removed by the grazing of domestic livestock.

Dry Shrub PVG

The dry shrub PVG composed 21 percent of the Basin during the current period, a decrease from 30 percent during the historical period. The decline was attributable to agricultural and urban development. Fire regimes in the dry shrub PVG have changed substantially, with the shortening of fire-return intervals in some areas, and the lengthening of fire-return intervals in other areas.

The shortened fire-return intervals were a consequence of the invasion of exotic annual grasses and a subsequent increase in the extent and connectivity of highly-flammable fuels. Fire severity also increased in these areas, and as a result, the upland shrubland physiognomic type transitioned to the exotic herbland physiognomic type, particularly on BLM- and FS-administered lands. Even more problematic, the altered fire regime perpetuates the dominance of exotic annual grasses, which then exacerbates the flux of the fire regime. Excessive livestock grazing pressure has lengthened fire-return intervals in some areas, because the activity can lead to the decline in herbaceous species' vigor and abundance. In this instance, the transitioning of the upland herbland to the shrubland physiognomic type often occurs.

Cool Shrub PVG

The cool shrub PVG composed 8 percent of the Basin during the current period, down from 9 percent during the historical period. This minor decline was attributable to agricultural and urban development. Fire exclusion was operative and resulted in a large transition of the upland herbland and upland shrubland physiognomic types to the upland woodland physiognomic type. The upland herbland physiognomic type was nearly eliminated between the historical and current periods. Excessive livestock grazing pressure was partly the cause of the lengthening of fire-return intervals. Although fire frequency declined in the cool shrub PVG, fire severity has risen with the increased prevalence of the upland woodland type and associated higher amounts of woody fuels.

Riparian Shrub PVG

The riparian shrub PVG was difficult to detect at the broad scale. Our data indicate a substantial decline, which was probably attributable to agricultural and urban development. Excessive livestock grazing pressure has been prevalent in this PVG and as a consequence, herbland physiognomic types have increased and shrubland physiognomic types have declined. Exotic plant species are common components of vegetation communities within the riparian shrub PVG.

Riparian Woodland PVG

The riparian woodland PVG was also difficult to detect at the broad scale. Our broad-scale data were inadequate to suggest a decline in this PVG from the historical to the current period, but we suspect this PVG did decline and that decline was attributable to agricultural and urban development. Flooding disturbances have been virtually eliminated from larger drainages in the riparian woodland PVG. Excessive livestock grazing pressure was prevalent in this PVG, particularly during the early historical period. The dominance of mid-seral structures has increased dramatically as a result of the changed disturbance regimes. Floods were an important process that promoted the regeneration of deciduous species, particularly black cottonwood. On the other hand, excessive livestock grazing pressure during the growing season has caused limited recruitment of many deciduous species. Consequently, mid-seral structures have increased due to the lack of recruitment of early-seral riparian woodlands, and the senescence of large, old trees in late-seral riparian woodlands.

Alpine PVG

The alpine PVG is another relatively rare type that composed 1 percent of the Basin during the current period. Our broad-scale data did not suggest a change in the areal extent of the alpine PVG from the historical to the current period. Succession/disturbance regimes have changed due to fire exclusion, but this does not appear to have substantially affected the biophysical processes. We suspect that finer-resolution data would indicate that there have been effects on soils and vegetation composition from excessive grazing pressure by domestic sheep and localized recreation impacts within alpine environments. These environments were found to be sensitive to climate change and air pollutants and thus provide potential for monitoring.

Road PVG

The road PVG composed nearly 2 percent of the Basin during the current period and was evenly distributed between BLM- and FS-administered lands and Other land ownerships. Approximately 39 percent of the road PVG occurred in subwatersheds that were highly susceptible to erosion and sediment transport to streams. Although designed to serve as a transportation network for humans, roads also function as conduits for exotic plant dispersal, water flow, and sediment transport.

Regional and Landscape Conditions of Ecological Reporting Units

Our findings are focused on (1) the historical to current period changes in vegetation and disturbances, and their interactions that were significantly different from those predicted for the biophysical templates, and (2) the susceptibility of rangeland health to management-induced disturbance stresses. These are integrated findings of the broad- and mid-scale (Hessburg and others 1996a) analyses of landscape conditions within each of the 13 ERUs of the Basin.

Our analyses of broad-scale data suggested that in some instances, the data were inadequate to characterize broad-scale trends in the Basin. In particular, trends in vegetation and disturbances within riparian areas, and trends in vegetation and disturbances attributable to exotic plants, were difficult to characterize at the broad scale. For riparian areas and exotic plants, then, finer-scale information was used to supplement the broad-scale data, permitting us to elucidate broad-scale trends.

Blue Mountains ERU

1. Forest landscapes were substantially fragmented. The distribution of patch sizes was not typical of the size distribution expected for the dominant fire regimes and biophysical templates.

2. Many landscapes that were historically dominated by early-seral ponderosa pine and western larch cover types, were dominated by grand fir/white fir and Douglas-fir cover types in the current period. Patches of early-seral, shade-intolerant species had been extensively fragmented, whereas those dominated by shade-tolerant conifers coalesced into larger, more contiguous areas.
3. Stand structural conditions and composition did not match those that would be expected for their predicted fire regimes. For example, current period forest stands were more contiguous and consisted largely of multi-storied canopies, dominated by fire-intolerant species.
4. Current period forest stands were commonly overstocked by small- to medium-sized, shade-tolerant trees that were more susceptible to fires, insects, and pathogens.
5. Based on mid-scale analysis of subsamples, woodlands increased in areal extent from the historical to the current period. Finer-scale information suggests that these woodlands (1) were dominated primarily by western juniper, (2) increased at the expense of herbland and shrubland terrestrial communities, and (3) increased because of excessive livestock grazing pressure and lengthening of fire-return intervals, which were initiated in the early historical period.
6. Forest cover types have encroached into other physiognomic types in the absence of fire and as a result of excessive livestock grazing pressure.
7. The areal extent of middle-aged multi-story structures having Douglas-fir, grand fir, and subalpine fir understories expanded substantially.
8. The areal extent of old-forest multi-story structures declined substantially in areas where long fire-return intervals typically would have maintained them.
9. The areal extent of old-forest single-story structures declined substantially within areas where short fire-return intervals typically would have maintained them.
10. The areal extent of grassland cover types (for example, fescue-bunchgrass and wheatgrass bunchgrass), and shrubland cover types (for example, big sagebrush, mountain big sagebrush) declined from the historical to the current period. This decline was partially attributable to the colonization of exotic plants including: cheatgrass, medusahead, ventenata, yellow starthistle, whitetop, and Scotch thistle. Yellow starthistle is particularly prevalent in the northern portion of the Blue Mountains ERU; a great areal extent (22%, across All land ownerships) of the Blue Mountains ERU is of high susceptibility to invasion by yellow starthistle.
11. Soils in the northern portion of this ERU (southeast Washington), primarily on Other lands, were particularly susceptible to erosion by water. Nearly half of the BLM/FS lands had soils that were susceptible to erosion by wind. Approximately 10 percent of BLM/FS lands had soils susceptible to shrinking or swelling from drying or wetting; these soils are particularly susceptible to invasion by medusahead, an exotic annual grass. At present, medusahead is invading and colonizing on these soils.
12. Dead tree structure is essential to the persistence of many native species. In many cases, the amount and arrangement of dead structure needed is unknown but could be determined experimentally.

Central Idaho Mountains ERU

1. Prior to Euro-American settlement, large areas were affected by mixed-severity fires. Consequently, stand-initiation forest and montane shrubland structures were more common landscape elements in historical forest settings than they were in current period forests that witnessed shifts in disturbance regimes.

2. Historically, many landscapes were dominated by seral ponderosa pine and Douglas-fir where fire regimes were conducive to their dominance. Many of those same areas were dominated by the grand fir/white fir cover type in the current period.
3. Current period forested landscapes have been extensively fragmented. Patch sizes were no longer typical of the dominant fire regimes within each biophysical template.
4. The areal extent of old-forest single-story structures declined substantially from the historical to the current period in areas where short fire-return intervals typically maintained those structures.
5. The whitebark pine/subalpine larch cover type declined substantially from the historical to the current period due to fire exclusion, mountain pine beetle infestation, and the epidemic spread of white pine blister rust.
6. Many current period forest stands were overstocked, dominated by shade-tolerant species, and had multiple canopy layers where they were once more open, single-layered stands, composed of fire-tolerant species.
7. Many riparian areas have been degraded by excessive livestock grazing pressure and were no longer functioning effectively in the current period.
8. Some upland areas, particularly on southern exposures, have been degraded by excessive livestock (especially sheep) grazing pressure.
9. The areal extent of grassland cover types (for example, fescue-bunchgrass and wheatgrass bunchgrass) declined from the historical to the current period. This decline was partially attributable to woody species encroachment by mountain big sagebrush and big sagebrush, and agricultural development. However, some of the decline was also attributable to the colonization of exotic plants, including: yellow starthistle, common crupina, spotted knapweed, and leafy spurge. Spotted knapweed is prevalent in the Central Idaho Mountains ERU; a great areal extent (22%, across All ownerships) of the Central Idaho Mountains ERU is of high susceptibility to invasion by spotted knapweed.
10. Dead tree structure is essential to the persistence of many native species. In many cases, the amount and arrangement of dead structure needed is unknown but could be determined experimentally.

Columbia Plateau ERU

1. Forest and shrubland landscapes have been extensively fragmented. Patch sizes were no longer consistent with the dominant fire regime within each biophysical template.
2. Ponderosa pine has encroached into other physiognomic types as a result of current period fire exclusion and excessive livestock grazing pressure.
3. The areal extent of grassland cover types (for example, fescue-bunchgrass and wheatgrass bunchgrass) and shrubland cover types (for example, big sagebrush and mountain big sagebrush) declined from the historical to the current period, primarily because of agricultural development. However, some decline was attributable to colonization by exotic plants, including medusahead, yellow starthistle, and diffuse knapweed. Medusahead is widespread in the southern portion of the Columbia Plateau ERU, where there is a prevalence of soils susceptible to shrinking or swelling from drying or wetting (an areal extent of approximately 6% of the Columbia Plateau ERU, primarily on Other lands). Yellow starthistle is particularly prevalent in the northeastern portion of the Columbia Plateau ERU and a great areal extent (27%, across All ownerships) of the Columbia Plateau ERU is of high susceptibility to invasion by yellow starthistle. Diffuse knapweed is particularly prevalent on the western and northern edges of the Columbia

Plateau ERU and about 13 percent of the areal extent of the Columbia Plateau ERU is of high susceptibility to invasion by diffuse knapweed.

4. Western juniper woodlands increased significantly in areal extent from the historical to the current period at the expense of the upland shrubland terrestrial community (more specifically, the mountain big sagebrush cover type). The increase in woodlands was caused by excessive livestock grazing pressure and the lengthening of fire-return intervals, which were initiated in the early historical period.
5. The areal extent of old-forest single-story ponderosa pine structures declined substantially in areas where short fire-return intervals typically maintained them.
6. Areas historically dominated by Douglas-fir, western hemlock, and grand fir have become more contiguous in current period environments, where the historic fire regime would have reduced their occurrence. Conversely, areas dominated by early-seral ponderosa pine and Douglas-fir have declined and have become extensively fragmented.
7. Many riparian areas have been degraded by excessive livestock grazing pressure and were no longer fully functional.
8. Although the extent of BLM/FS lands is minor in the Columbia Plateau ERU, nearly all of these lands have soils that are particularly susceptible to erosion by water, erosion by wind, or the combination of these. Across All ownerships, soils in the Columbia Plateau ERU showed the greatest areal extent of susceptibility to erosion by water.
9. Dead tree structures are essential to the persistence of many native species. In many cases, the amount and arrangement of dead structure needed is unknown but could be determined experimentally.
10. Rangeland health is of high or moderate susceptibility to management-induced disturbance stresses (that is, human-caused disturbance stresses, such as excessive livestock grazing pressure, invasion of exotic plants, and alteration of fire regimes) across a great areal extent (46%) of the Columbia Plateau ERU. The causes of this susceptibility are aridity, and the susceptibility of soils to erosion by water, wind, or the combination of these. Rangeland health on nearly all of the rangeland on BLM/FS lands is of high or moderate susceptibility to management-induced disturbance stresses.
11. Many rangeland potential vegetation types in this ERU, subsequent to prolonged periods of excessive livestock grazing pressure, were in degraded stable states. Succession and vegetation recovery, frequency and extent of disturbances, and the interaction of succession with disturbances, were unpredictable in their rate and extent, even with removal or reduction in livestock grazing pressure.
12. Excessive livestock grazing pressure initiated in the early historical period has been deleterious to microbiotic crust development and extent. Until science findings are more definitive regarding the ecological roles of microbiotic crusts and their response to disturbances, the importance of microbiotic crusts to rangeland health in the Columbia Plateau ERU remains speculative.

Lower Clark Fork ERU

1. Prior to Euro-American settlement, large areas of this ERU were once affected by mixed- and high-severity fires. Consequently, stand initiation and montane shrubland structures were once more common landscape elements in historical forest settings. Mixed-severity fires killed 20 to 70 percent of the overstory trees in disturbed areas. Disturbance areas tended to be large (hundreds to thousands of hectares).
2. Forest landscapes have been extensively fragmented. Patch sizes no longer coincide with the sizes typical of the dominant fire regimes within the biophysical templates.

3. The areal extent of forests dominated by early-seral species (for example ponderosa pine, Douglas-fir, western white pine, western larch, and whitebark pine) declined substantially from the historical to the current period, particularly in areas where historical fire regimes would have promoted their dominance. Conversely, areas of forests dominated by late-seral, shade-tolerant species (for example, grand fir/white fir-dominated forests) increased. Consequently, early-seral shade-intolerant dominated cover types have been fragmented, while patches of late-seral shade-tolerant dominated cover types have grown larger and more contiguous.
4. White pine blister rust reduced the current period distribution and dominance of western white pine and whitebark pine in settings that formerly supported them.
5. The areal extent of old-forest multi-story structures declined substantially from the historical to the current period in areas where long fire-return intervals typically would have maintained them.
6. The areal extent of old-forest single-story structures declined substantially in areas where short fire-return intervals typically would have maintained them.
7. The areal extent of middle-aged multi-story structures (that is, stem exclusion with closed canopy, young forest multi-story, and understory reinitiation) having grand fir and western hemlock/western redcedar understories increased substantially between the historical and current periods.
8. From the historical to the current period, fuel loading and crown-fire potential increased significantly, thereby increasing the potential for high rates of fire spread. The vertical and horizontal continuity of live and dead fuels also increased.
9. Some riparian areas have been degraded by excessive livestock grazing pressure and were no longer fully functional.
10. Although the broad-scale data failed to verify it, finer-resolution information suggests that exotic plants, particularly spotted knapweed, leafy spurge, and sulfur cinquefoil, have been causal in the decline in areal extent of the grassland cover types (for example, fescue-bunchgrass and wheatgrass bunchgrass) between the historical and the current periods. Spotted knapweed is particularly prevalent in the Lower Clark Fork ERU.
11. Dead tree structure is essential to the persistence of many native species. In many cases, the amount and arrangement of dead structure needed is unknown but could be determined experimentally.

Northern Cascades ERU

1. Forest environments have been extensively fragmented from the historical to the current period. Forest patch sizes no longer coincide with the size ranges typical of the dominant fire regimes within biophysical templates.
2. A relatively large proportion of the ERU has been administratively withdrawn from active vegetation management. Fire exclusion, in the withdrawn areas, has had a homogenizing effect on structure and composition.
3. Forest patches dominated by early-seral ponderosa pine, western larch, and whitebark pine declined substantially from the historical to the current period in areas where fire regimes would have promoted their dominance. Conversely, forest patches dominated by late-seral, shade-tolerant conifers such as Douglas-fir, grand fir, and Pacific silver fir have grown larger and more contiguous.
4. Areas in which Douglas-fir existed as a codominant or subdominant species within the grand fir and subalpine fir series have substantially declined from the historical to

the current period. In the historical period, a larger proportion of the subalpine fir series was dominated by Douglas-fir and western larch, whereas a larger proportion of the grand fir series was dominated by Douglas-fir and ponderosa pine. In the current period, Douglas-fir was conspicuously absent from areas that had incurred some sort of regeneration harvests. Similarly, in the Douglas-fir series, the existence of Douglas-fir as a subdominant species was less than would have been expected. This appears to be related to harvest practices, tree regeneration strategies, and exclusion of fires in these environments.

5. Development of the wildland/rural interface occurred within the lower montane forest types where historical fire regimes maintained non-forest or open, dry forest conditions. The fire regimes of these areas largely shifted from non-lethal underburns, to mixed or lethal crown fires. Fire protection could be increasingly difficult and costly.
6. To a large degree, current period forest structural conditions and composition no longer coincided with the predicted fire regimes. For example, forest patches consisting of multi-story canopies and dominated by fire-intolerant species were more contiguous than the predicted fire regimes would suggest.
7. The areal extent of middle-aged, multi-story forest structures having Douglas-fir, grand fir, and subalpine fir understories increased substantially from the historical to the current period.
8. The areal extent of current period old-forest multi-story structures was less than what would be expected in areas where long fire return intervals typically maintained them.
9. The areal extent of old-forest single-story structures in which ponderosa pine or western larch dominated the overstory has declined substantially within areas where frequent non-lethal fires typically would have maintained them.
10. Although the broad-scale data failed to verify it, finer-resolution information suggests that exotic plants, particularly diffuse knapweed, have been causal in the decline in the areal extent of grassland cover types (for example fescue-bunchgrass and wheatgrass bunchgrass) and shrubland-grassland cover types (for example, bitterbrush/bluebunch wheatgrass) from the historical to the current period. A large portion (18%, across All land ownerships) of the Northern Cascades ERU is of high susceptibility to invasion by diffuse knapweed.
11. Dead tree structures are essential to the persistence of many native species. In many cases, the amount and arrangement of dead structure needed is unknown but could be determined experimentally.

Northern Glaciated Mountains ERU

1. Old-forest structures were relatively rare prior to Euro-American settlement because much of the area of this ERU was under the influence of mixed- and high-severity fire regimes. Residual large tree cover (≤20% canopy cover) after fire was common. The large tree residual structure occurring singly or in large groups declined in many areas. More specifically, in the current period large western larch and ponderosa pine emergent structures (large trees above the dominant overstory) were much less abundant in areas where mixed- and high-severity fire regimes would have encouraged their development.
2. Prior to Euro-American settlement, large areas of this ERU were affected by mixed- and high-severity fires. Accordingly, stand initiation and montane shrubland structures were once more common landscape elements within forest settings than what occurred in the current period.
3. Forest landscapes have been substantially fragmented. The frequency distribution of patch sizes did not coincide with the size ranges typical of the dominant fire regimes

within the biophysical templates. For example, mixed-severity fires commonly killed 20 to 70 percent of the overstory trees in the disturbed area. Disturbance areas tended to be large (hundreds to thousands of hectares).

4. Non-forest landscapes have also been extensively fragmented. The frequency distribution of patch sizes did not coincide with the size ranges typical of the dominant fire regimes within the biophysical templates.
5. The areal extent of middle-aged multi-story (that is, stem exclusion with closed canopy and understory reinitiation) structures having grand fir, western hemlock/western redcedar, and subalpine fir understories increased well above the levels which would have been expected for the biophysical templates.
6. As a result of fire exclusion, the areal extent of the grand fir/white fir, Engelmann spruce/subalpine fir, and western hemlock cover types increased. This change was exacerbated by timber harvests that extracted seral Douglas-fir, western larch, and western white pine. The western white pine cover type also declined substantially as a result of epidemic white pine blister rust and mountain pine beetle infestations.
7. In the eastern portion of the ERU, the current period areal extent of the whitebark pine cover type declined substantially due to fire exclusion, mountain pine beetle infestation, and epidemic spread of white pine blister rust.
8. A large proportion of the current period forests consisted of overstocked, multi-story stands, dominated by shade-intolerant conifers.
9. The areal extent of grassland cover types (for example, fescue-bunchgrass and wheatgrass bunchgrass), shrubland-grassland cover types (for example, bitterbrush/bluebunch wheatgrass), and shrubland cover types (for example, big sagebrush) declined from the historical to the current period, primarily because of agricultural development. Although the broad-scale data failed to verify it, finer-resolution information suggests that some decline was also attributable to colonization by exotic plants, including: diffuse knapweed, spotted knapweed, sulfur cinquefoil, leafy spurge, and the hawkweeds (orange and yellow). Diffuse knapweed is particularly prevalent in the Northern Glaciated Mountains ERU; approximately 15 percent of the areal extent is of high susceptibility to invasion by diffuse knapweed.
10. Dead tree structure is essential to the persistence of many native species. In many cases, the amount and arrangement of dead structure needed is unknown but could be determined experimentally.

Northern Great Basin ERU

1. Non-forest landscapes have been extensively fragmented. The frequency distribution of patch sizes did not coincide with the size ranges typical of the biophysical templates. Patch sizes may be controlled by physical characteristics such as shallow soil or by a dominant fire regime.
2. The areal extent of shrubland cover types (for example, big sagebrush and mountain big sagebrush) declined from the historical to the current period. This was partially attributable to colonization by exotic plants such as Mediterranean sage.
3. Western juniper woodlands increased significantly in areal extent from the historical to the current period at the expense of the upland herbland and upland shrubland (specifically the mountain big sagebrush cover type) terrestrial communities. The increase in woodlands was caused by excessive livestock grazing pressure and lengthening of fire-return intervals, which were initiated in the early historical period.

4. Ponderosa pine woodlands and forests encroached into other physiognomic types due to excessive livestock grazing pressure and fire exclusion.
5. Many riparian areas have been degraded by excessive livestock grazing pressure and are no longer functioning at their full capacity.
6. Soils in the Northern Great Basin ERU were particularly susceptible to erosion by wind and shrinking or swelling from drying or wetting. Soils on about 70 percent of BLM/FS lands were susceptible to erosion by wind. Saline soils were prevalent on BLM/FS and Other lands, particularly in the southeastern and northeastern portions of the Northern Great Basin ERU.
7. Rangeland health is of high or moderate susceptibility to management-induced disturbance stresses across a great areal extent of the Northern Great Basin ERU (>40% of BLM/FS lands and > 40% of All land ownerships). The causes of this susceptibility are aridity, saline soils, soils susceptible to erosion by wind, and soils susceptible to shrinking or swelling from drying or wetting.
8. Many rangeland potential vegetation types in this ERU, subsequent to prolonged periods of excessive livestock grazing pressure, were in degraded stable states. Succession and vegetation recovery, frequency and extent of disturbances, and the interaction of succession with disturbances, were unpredictable in their rate and extent, even with removal or reduction in livestock grazing pressure.
9. Excessive livestock grazing pressure initiated in the early historical period has been deleterious to microbiotic crust development and extent. Until science findings are more definitive regarding the ecological roles of microbiotic crusts and their response to disturbances, the importance of microbiotic crusts to rangeland health in the Northern Great Basin ERU remains speculative.

Owyhee Uplands ERU

1. Non-forest landscapes have been extensively fragmented. The distribution of patch sizes no longer coincides with the size ranges typical of the biophysical templates. Patch sizes were controlled by the dominant fire regime or physical factors such as shallow soil.
2. Western juniper woodlands increased significantly in areal extent from the historical to the current period, primarily at the expense of the upland shrubland terrestrial community (specifically, the mountain big sagebrush cover type). The increase in woodlands was caused by excessive livestock grazing pressure and lengthening of fire-return intervals, initiated in the early historical period.
3. Invasion and dominance by the exotic annual grasses, cheatgrass, and/or medusahead, particularly within the big sagebrush cover type in the Snake River Plains, has shortened the fire-return interval and caused a decline in abundance of native flora, and thus biodiversity. A large portion (67%, across All ownerships) of the Owyhee Uplands ERU is of high susceptibility to invasion by cheatgrass. Medusahead invasion has been prevalent in the northwestern portion of the Owyhee Uplands ERU, where there is a prevalence of soils that are susceptible to shrinking or swelling from drying or wetting. Other exotic plants, such as yellow starthistle and rush skeletonweed, are partially causal in the decline of the grassland cover types (for example, fescue-bunchgrass, wheatgrass bunchgrass) detected from the historical to the current period.
4. Many riparian areas have been degraded by excessive livestock grazing pressure and are no longer functioning at their full capacity in the current period. Exotic plants, particularly Scotch thistle and perennial pepperweed, were prevalent in riparian areas and displacing native flora.

5. Soils in the Owyhee Uplands ERU were particularly susceptible to erosion by water, erosion by wind, and shrinking or swelling from drying or wetting. In addition, saline soils were prevalent. Soils on approximately 75 percent of BLM/FS lands were susceptible to erosion by wind. Although not prevalent within the Basin in any ERU, sodic soils were more prevalent within the Owyhee Uplands ERU than in any other ERU except the Upper Snake.
6. Rangeland health is of high or moderate susceptibility to management-induced disturbance stresses across a large portion of the Owyhee Uplands ERU (> 50% of BLM/FS lands, and > 50% of All land ownerships). The causes of this susceptibility are aridity, saline soils, soils susceptible to erosion by wind, soils susceptible to erosion by water, and soils susceptible to shrinking or swelling from drying or wetting.
7. Many rangeland potential vegetation types in this ERU, subsequent to prolonged periods of excessive livestock grazing pressure, were in degraded stable states. Succession and vegetation recovery, frequency and extent of disturbances, and the interaction of succession with disturbances, were unpredictable in their rate and extent, even with removal or reduction in livestock grazing pressure.
8. Excessive livestock grazing pressure initiated in the early historical period has been deleterious to microbiotic crust development and extent. Until science findings are more definitive regarding the ecological roles of microbiotic crusts and their response to disturbances, the importance of microbiotic crusts to rangeland health in the Owyhee Uplands ERU remains speculative.

Snake Headwaters ERU

1. The age distribution of many large cottonwood stands in the upper reaches of the Snake River has been skewed toward older stands which were rapidly deteriorating in the current period. Without periodic flood disturbances, juvenile cottonwood recruitment could not occur.
2. Fire exclusion encouraged the development of expansive areas of the lodgepole pine cover type which is susceptible to mountain pine beetle infestation. The size and age structures in the lodgepole pine cover type within the lodgepole pine series has been homogenized.
3. Fire exclusion led to a current period areal decline of the aspen and lodgepole pine cover types, and areal increase of the Engelmann spruce/subalpine fir cover type, particularly at lower elevations.
4. Current period areas dominated by multi-layered stands of Douglas-fir were more extensive than in the native system, as indicated by the modeling process. The susceptibility of these areas to dwarf mistletoe, western spruce budworm, and Douglas-fir beetle also increased significantly between the historical and current periods.
5. The current period areal extent of old-forest multi-story structures was below that expected in areas where long fire-return intervals would have typically maintained them.
6. The areal extent of old-forest single-story structures was below that expected in areas where short fire-return intervals would have typically maintained them.
7. Soils on about 10 percent of the land area of the Snake Headwaters ERU were particularly susceptible to erosion by water, primarily in the southwestern portion of the ERU, on Other lands.
8. The areal extent of grassland cover types (for example, fescue-bunchgrass and wheatgrass bunchgrass), and shrubland cover types (for example, big sagebrush and mountain big sagebrush) declined from the historical to the current period. Agricultural development was most causal in the decline of the big sagebrush cover type, whereas woody species encroachment (primarily by Douglas-fir) was mostly the cause of the decline in the mountain big sagebrush cover type. Some decline was also attributable to the colonization of exotic plants, including dyers woad, leafy spurge, and spotted knapweed.

9. Dead tree structures are essential to the persistence of many native species. In many cases, the amount and arrangement of dead structure needed is unknown but could be determined experimentally.

Southern Cascades ERU

1. Old-forest ponderosa pine structures were relatively common prior to Euro-American settlement because much of the area of this ERU was under the influence of low- and mixed-severity fire regimes. Residual large tree cover (≤20% canopy cover) occurring singly, or in large groups after fires was quite common historically, but declined in many areas between that period and the current period.
2. From the historical to the current period, the dominance of early-seral ponderosa pine, sugar pine (*Pinus lambertiana*), incense-cedar (*Calocedrus decurrens*), and Douglas-fir declined substantially in the white fir and red fir series where fire regimes would have promoted their dominance. Many current period forest landscapes were dominated by shade-tolerant conifers. Patches of shade-tolerant conifers have grown larger and more contiguous.
3. Areas of old-forest single-story and old-forest multi-story structures declined substantially where low- and mixed-severity fire regimes would have encouraged their development.
4. Fire exclusion promoted the development of expansive areas of the lodgepole pine cover type, which is susceptible to mountain pine beetle infestation. Size and age structures in the current period lodgepole pine cover type within the edaphic lodgepole pine series have become more simplified and homogeneous than they were historically.
5. Fuel loadings, the vertical and horizontal continuity of live and dead fuels, and subsequently crown fire potential increased substantially.
6. The proportion of forests that comprised overstocked, multi-story stands of shade-tolerant and fire-intolerant species increased substantially.
7. Some riparian areas were degraded by excessive livestock grazing pressure and were no longer functioning at their full capacity.
8. Soils were particularly susceptible to erosion by wind in the east-central portion of the Southern Cascades ERU in the vicinity of Bend and Redmond, Oregon, primarily on Other lands. Rangeland health of high or moderate susceptibility to management-induced disturbance stresses in the Southern Cascades ERU was restricted to the Bend-Redmond area.
9. Although the broad-scale data failed to verify it, finer-resolution information suggests that the decline in areal extent of grassland cover types (for example, fescue-bunchgrass and wheatgrass bunchgrass) and shrubland cover types (for example, big sagebrush) between the historical and the current period was partially attributable to colonization by exotic plants, for example diffuse knapweed. A large portion (23%, across All ownerships) of the Southern Cascades ERU is of high susceptibility to invasion by diffuse knapweed.
10. Dead tree structures are essential to the persistence of many native species. In many cases, the amount and arrangement of dead structure needed is unknown but could be determined experimentally.

Upper Clark Fork ERU

1. Herbland and forested landscapes have been extensively fragmented. The distribution of patch sizes no longer coincides with the size ranges typical of the dominant fire regimes within the biophysical templates.
2. The current period areal extent of forest stands dominated by early-seral ponderosa pine, western larch, Douglas-fir, and whitebark pine declined substantially as a result of fire

suppression and timber harvests, particularly in those environments where fire regimes would have encouraged their dominance. Forest patches dominated by shade-tolerant conifers increased in size and were more contiguous, whereas stands dominated by shade-intolerant species became fragmented.

3. The current period areal extent of old-forest multi-story structures declined substantially from areas where long fire-return intervals typically maintained them.
4. The areal extent of old-forest single-story structures declined substantially from areas where short fire-return intervals typically maintained them.
5. Fire exclusion promoted the current period development of large areas of the lodgepole pine cover type, which is susceptible to mountain pine beetle infestation. The homogeneity of size and age structures in the lodgepole pine cover type within the lodgepole pine and subalpine fir series increased.
6. Fire exclusion and timber harvesting activities increased the current period areal extent of the subalpine fir cover type by reducing the dominance of seral Douglas-fir and lodgepole pine.
7. The current period areal extent of the whitebark pine cover type declined substantially due to fire exclusion, mountain pine beetle infestation, and epidemic spread of white pine blister rust.
8. Areas dominated by relatively dense, multi-layered stands of Douglas-fir became more extensive in the current period. Their susceptibility to dwarf mistletoe, western spruce budworm, and Douglas-fir beetle also increased significantly.
9. Ponderosa pine cover encroached into other physiognomic types due to the absence of fire.
10. The areal extent of grassland (for example, fescue-bunchgrass, wheatgrass bunchgrass) cover types declined from the historical to the current period, primarily due to agricultural development and encroachment of woody species (for example, interior ponderosa pine and interior Douglas-fir cover types). Although the broad-scale data failed to detect much of the decline attributable to exotic plant invasion, finer-resolution information suggests that some decline was attributable to colonization by exotic plants, particularly spotted knapweed, leafy spurge, and sulfur cinquefoil. Spotted knapweed is particularly prevalent in the Upper Clark Fork ERU, and a large portion (39%, across All ownerships) of the Upper Clark Fork ERU is highly susceptible to invasion by spotted knapweed.
10. Some riparian areas have been degraded by excessive livestock grazing pressure and are no longer functioning at their full potential.
11. Development of the wildland/rural interface has been occurring within the lower montane forest types where historical fires maintained non-forest or widely open, dry forest conditions. The preponderance of crown fires versus underburning fires has increased in these areas. Fire protection could be increasingly difficult and costly.
12. Dead tree structures are essential to the persistence of many native species. In many cases, the amount and arrangement of dead structure needed is unknown but could be determined experimentally.

Upper Klamath ERU

1. Forests dominated by early-seral species declined substantially between the historical and current periods. The proportion of current period forest stands within the white fir series that were dominated by ponderosa pine; and within the red fir series that were dominated by Douglas-fir, incense cedar, and sugar pine, was less than expected in areas where fire regimes would have encouraged their dominance. Patches of shade-tolerant conifers have beome larger and more contiguous.

2. Blister rust led to the decrease in sugar pine distribution and dominance.
3. The current period areal extent of old-forest single-story structures declined from areas where short fire-return intervals typically maintained them.
4. Crown fire potential and rate of spread increased substantially from the historical to the current period as a result of the increased vertical and horizontal continuity of live and dead fuels.
5. The areal extent of overstocked, multi-story stands that contained shade-tolerant, fire-intolerant conifers increased substantially.
6. From the historical to the current period, ponderosa pine encroached into grassland and shrubland physiognomic types due to fire exclusion.
7. Western juniper woodlands increased significantly in areal extent from the historical to the current period, primarily at the expense of the upland shrubland terrestrial community (specifically, mountain big sagebrush and low sagebrush cover types). The increase in woodlands was caused by excessive livestock grazing pressure and lengthening of fire-return intervals, initiated in the early historical period.
8. Some riparian areas have been degraded by excessive livestock grazing pressure and are no longer functioning at their full potential.
9. About 30 percent of the areal extent of the Upper Klamath ERU, primarily in the southern portion, is characterized by saline soils, soils susceptible to erosion by wind, or soils susceptible to shrinking or swelling from drying or wetting.
10. Although broad-scale data failed to verify it, finer resolution information suggests that exotic plants, particularly medusahead, yellow starthistle, and Mediterranean sage, have been causal in the decline in areal extent of the grassland cover types (for example, fescue-bunchgrass) and shrubland cover types (for example, low sagebrush) between the historical and the current period.
11. Dead tree structures are essential to the persistence of many native species. In many cases, the amount and arrangement of dead structure needed is unknown but could be determined experimentally.

Upper Snake ERU

1. A large proportion of the native shrublands has been extensively fragmented, largely by agricultural developments.
2. The areal extent of shrubland (for example, big sagebrush, mountain big sagebrush) cover types declined substantially from the historical to the current period, primarily attributable to agricultural development. However, colonization by exotic plants, including dyers woad, cheatgrass, and leafy spurge, was also causal. Invasion and dominance by cheatgrass, particularly within the big sagebrush cover type in the western portion of the Upper Snake ERU, has shortened the fire-return interval and caused a decline in abundance of native flora, and thus biodiversity. A large portion (46%, across All ownerships) of the Upper Snake ERU is of high susceptibility to invasion by cheatgrass.
3. Many riparian areas have been degraded by excessive livestock grazing pressure and are no longer functioning at their full potential.
4. Soils in the Upper Snake ERU are particularly susceptible to erosion by water and erosion by wind. In addition, of all ERUs, the Upper Snake ERU has the greatest areal extent of saline soils (35% of the ERU, across All ownerships). Although not prevalent within the Basin in any ERU, sodic soils were more prevalent within the Upper Snake ERU than in any other ERU except the Owyhee Uplands.

5. Rangeland health is of high or moderate susceptibility to management-induced disturbance stresses across a large portion of the Upper Snake ERU (> 50% of BLM/FS lands, and nearly 50% of All land ownerships). The causes of this susceptibility are aridity, saline soils, soils susceptible to erosion by wind, and soils susceptible to erosion by water.
6. Many rangeland potential vegetation types in this ERU, subsequent to prolonged periods of excessive livestock grazing pressure, were in degraded stable states. Succession and vegetation recovery, frequency and extent of disturbances, and the interaction of succession with disturbances, were unpredictable in their rate and extent, even with removal or reduction in livestock grazing pressure.
7. Excessive livestock grazing pressure initiated in the early historical period has been deleterious to microbiotic crust development and extent. Until science findings are more definitive regarding the ecological roles of microbiotic crusts and their response to disturbances, the importance of microbiotic crusts to rangeland health in the Upper Snake ERU remains speculative.

Regional Cover Type Trends

Ecologically significant changes were detected for 66 and 34 percent of the cover types relative to cover type class and the Basin, respectively. Only 8 percent of the cover types occurred within their median 75-percent historical ranges during the current period. The western white pine and whitebark pine/subalpine larch cover types were virtually eliminated from the Basin.

In rangeland settings, agricultural development was primarily responsible for areal declines of the fescue-bunchgrass, wheatgrass bunchgrass, big sagebrush, and native forb cover types. On an areal extent basis, the invasion of exotic species occurred largely to the detriment of the big sagebrush cover type, and to a lesser extent, the wheatgrass bunchgrass, mountain big sagebrush, and fescue bunchgrass cover types.

Forest settings were dominated by transitions from shade-intolerant tree species to shade-tolerant tree species. For example, within the dry forest PVG, the areal decline of interior ponderosa pine was mostly attributable to increases in the grand fir/white fir, and interior Douglas-fir cover types. The dominant transitions within the moist forest PVG involved the conversions of the western larch cover type to the Douglas-fir, lodgepole pine, or grand fir/white fir cover types; and the western white pine cover type to the grand fir/white fir cover type. Colder forests were affected mostly by the conversion of the whitebark pine cover type to the Engelmann spruce/subalpine fir cover type.

Regional Trends of Terrestrial Communities

Terrestrial communities were identified by the amalgamation of cover types and structural stages in order to address changes of terrestrial habitats. The areal extents of most (83%) terrestrial communities occurred outside of their median 75-percent historical range. No terrestrial community within rangeland settings occurred within its median historical range during the current period. Agricultural development, fire exclusion, and the invasions by exotic species were chiefly responsible for these observed transitions. In forest settings, only the early-seral montane forest community occurred within its median historical range. The flux of forest communities was dominated by the transitions of early- and late-seral communities into mid-seral communities. Forest transitions were attributed to the synergistic influences of fire exclusion and timber harvest practices. To some extent, timber harvests and fire reduced the areal extent of late-seral communities, while fire exclusion limited the recruitment of early-seral communities. Forest changes were greatest in lower montane forest communities and least in subalpine forest communities.

Landscape Trends of Terrestrial Community Group Departure

A landscape analysis of 12 terrestrial community groups (an aggregation of terrestrial community types) was conducted to spatially refine and display the habitat changes that occurred across the Basin as a whole. The current areal extent of 12 terrestrial community groups was compared to median historical ranges at the subbasin level, when either historical or current areas composed at least 1 percent of the subbasin.

The Basin was dominated by subbasins in which 8 of 12 terrestrial community groups occurred well below their median historical ranges. Conversely, 4 of 12 community groups occurred well above their median historical ranges across most subbasins within the Basin. In other words, subbasins in which the terrestrial community groups occurred within their median historical range were the exception, rather than the rule. Of the 12 terrestrial community groups, the early-seral and late-seral lower montane forest communities differed the most from their historical conditions. Basin-wide, the montane forest and subalpine forest communities had more closely approximated historical conditions than did the lower montane forest communities.

Early-seral Lower Montane Forest

Nearly all subbasins that contained a substantial area of the early-seral lower montane forest, had current extents that were below its median historical range. The exception to this overall trend occurred in the Northern Cascades ERU where this community group occurred within or above its median historical range throughout most subbasins.

Mid-seral Lower Montane Forest

Most subbasins containing substantial areas of this community group had current extents that exceeded its median historical range. Notable exceptions of this trend occurred in the Upper Klamath, Southern Cascades, Northern Great Basin, Lower Clark Fork, Upper Clark Fork, and Northern Glaciated Mountains ERUs.

Late-seral Lower Montane Forest

Most subbasins contained areal extents of the late-seral lower montane forest community that were well below their median historical range. Notable exceptions included subbasins within the Upper Klamath and Northern Great Basin ERUs.

Early-seral Montane Forest

The Basin was nearly evenly split in the proportion of subbasins in which the early-seral montane forest community occurred below its median historical range versus the proportion of subbasins in which this community occurred within or above its median historical range; the latter subbasins tended to be concentrated within the Central Idaho Mountains, Northern Cascades, Southern Cascades, Northern Glaciated Mountains, Lower Clark Fork, and Snake Headwaters ERUs.

Mid-seral Montane Forest

Most subbasins (78%) contained areal extents of the mid-seral montane forest community within or above its historical range. Exceptions to this trend were distributed throughout of the Southern Cascades, Upper Klamath, and Central Idaho Mountains ERUs.

Late-seral Montane Forest

Sixty-three percent of the subbasins had areal extents of the late-seral montane forest community below their median historical range. However, most of the subbasins throughout Oregon, and many within the Central Idaho Mountains ERU had areas of this community that were well above their median historical range.

Early-seral Subalpine Forest

Most subbasins (76%) contained the early-seral subalpine forest community at a level within or exceeding its historical range. The exceptions to this trend were concentrated within the Northern Glaciated Mountains and Upper Clark Fork ERUs.

Mid-seral Subalpine Forest

Nearly one-half of the subbasins contained areal extents of this community that were below its median historical range. The subbasins in which there appeared to be a deficit of this community were largely concentrated in the Northern Cascades, Southern Cascades, Upper Klamath, Blue Mountains, and Central Idaho Mountains ERUs.

Late-seral Subalpine Forest

The majority (72%) of subbasins having substantial components of the late-seral subalpine forest community had areal extents below their median historical range. Notable exceptions included subbasins within the Upper Klamath and Central Idaho Mountain ERUs.

Upland Herbland

The majority (81%) of subbasins had a deficit of the upland herbland community relative to its median historical range. The exceptions to this trend occurred in two relatively disjunct areas - one in the Upper Klamath ERU, and the other in the Central Idaho Mountains ERU.

Upland Shrubland

The upland shrubland community occurred below its median historical range in most (61%) subbasins. Subbasins in which this community occurred within or above its median historical range were largely concentrated within the Northern Great Basin, Owyhee Uplands, and Central Idaho Mountains ERUs.

Upland Woodland

The proportion of subbasins containing substantial components of the upland woodland community was nearly evenly split between those subbasins that had areal extents exceeding their median historical range, and those in which the community occurred below its median historical range.

Forest and Rangeland Integrity

We characterized the ecological integrity of forests and rangelands at the subbasin level. Because ecological integrity could not be measured directly, relative integrity values were estimated from the departures of broad-scale indicator variables. Both direct and indirect indicator variables were used including PVGs, physiognomic types, changes of fire disturbance regimes, and road densities (fig. 3.30). Subbasin integrity ratings were based upon a relative scale and should not be thought of as absolute integrity values. Consequently, a high value simply indicated that the integrity value was among the highest detected.

Subbasins having the highest forest integrity values were largely unroaded, and composed of cold forest PVG or a mixture of moist and cold forest PVGs. Conversely, subbasins composed of a relatively large proportion of the dry forest PVG and that had been intensively roaded, typically had the lowest forest integrity. Forest integrity was thus, strongly associated with the efficacy of fire exclusion, the intensity of timber management, and the degree to which succession/disturbance regimes have changed within a subbasin. Most (59%) of the forested subbasins were characterized as having low forest integrity, whereas substantially fewer (23%) were characterized as having high forest integrity.

Most (69%) of the rangeland subbasins were characterized as having low rangeland integrity. In contrast, few (8%) rangeland subbasins had a high rangeland integrity. In general, the subbasins characterized with low rangeland integrity had high compositions of agricultural development or dry grass and dry shrub PVGs, which are indicative of their susceptibility to exotic plant infestations and their lack of recovery potential from excessive livestock grazing.

Regional and Landscape Vegetation Patterns

We evaluated landscape patterns of physiognomic types, and regional patterns of an aggregation of terrestrial community groups. As a whole, landscapes within the Basin became substantially more fragmented between historical and current periods. However, the coarse-grained fragmentation trends that occurred across the Basin were not consistently apparent among the broad-scale vegetation types, or the ERUs. For example, at the regional level, we detected an increase in fragmentation of the lower montane forest, subalpine forest, upland herbland, and upland shrubland terrestrial community groups. In contrast, montane forest and upland woodland community groups became more homogeneous and interconnected Basin-wide. Similarly, at the landscape level, vegetation patterns throughout approximately one-half of the ERUs became more fragmented, whereas patterns became more homogeneous across other ERUs. Not surprisingly, these opposing trends were not independent, since the areal extent and connectivity of one vegetation type had the potential increase as other types became increasingly fragmented.

In forest settings, the montane forest community group expanded, largely at the expense of the lower montane forest community group and, to a lesser extent, the subalpine forest community group. Similarly, in rangeland settings, the extent and connectivity of the upland woodland community group increased at the expense of the upland shrubland and upland herbland community groups. These transitions were largely an expression of fire exclusion and timber harvest activities. However, the most substantial fragmentation trend observed at both regional and landscape levels occurred as a result of agricultural development within shrubland and herbland physiognomies.

Trends and Ecology of Wildland Fire

The changes in vegetation composition and structure of forests and rangelands that occurred between historical and current periods have substantially increased the risks of wildland wildfires at both the landscape and regional levels. Although wildfire-suppression activities have been successful in reducing the areal extent of wildfires since the early- to mid-1900s, it now appears that the trends since the 1960s have started to change (table 3.202 and see table 3.187). That is, even though land managers have been allocating an increasing amount of resources to suppress wildfires, suppression efficacy seems to be declining. In fact, the current areal extent of wildfires is approaching those experienced in the early 1900s. Fuel loadings have steadily increased as a result of suppression efforts and the subsequent decline of fire frequencies (see map 3.23). As a result, fire severity has increased (see map 3.22), as have suppression costs and the associated hazards to life and property. The average costs of wildfire suppression, number of firefighter fatalities, and areal extent of high-intensity fires during the last 25 years have exceeded the corresponding levels that occurred between 1910 and 1970.

Further complicating matters, human populations within the wildland/urban interface have substantially increased within the last few decades. These areas of rapidly-growing human populations are commonly associated with high fire risks (see map 3.31).

Wildland fire management on BLM- and FS-administered lands will likely become more challenging in the future. Our projections indicated that an active management strategy could likely reduce the areal extent of wildfires on BLM- and FS-administered lands. The area burned by wildfires would likely be greatest under a passive management strategy for reserve landscape patterns, whereas the area burned under a consumptive demand approach would be intermediate. Costs and hazards to life and property would likely be directly associated with the amount of area burned under each management strategy.

Table 3.202—Fire regime severity and frequency classes within the Basin.

Frequency / Severity Class	Historical Period	Current Period	Change
	..... Percent		
Lethal extremely infrequent	2.2	1.5	-0.8
Lethal frequent	21.5	6.0	-15.6
Lethal infrequent	20.4	34.5	14.1
Lethal very frequent	0	14.2	14.2
Lethal very infrequent	3.2	8.1	4.9
Mixed frequent	6.2	3.8	-2.5
Mixed infrequent	9.3	16.8	7.5
Mixed very frequent	0.6	0	-0.6
Mixed very infrequent	1.3	0	-1.3
Non-lethal frequent	6.9	2.3	-4.6
Non-lethal infrequent	2.7	10.0	7.3
Non-lethal very frequent	24.3	1.4	-22.9
No Data	0.1	0.1	0
Rarely	1.3	1.5	0.2
Total	100.0	100.0	NA[1]

[1]NA = Not Applicable.

Trends of Mid-scale Conditions

A thorough comprehension of ecological relationships requires a look to larger scales to understand context, and to smaller scales to understand mechanisms (Allen and Hoekstra 1992). Our ability to perceive change is dependent upon the scale of observation, or in other words, the grain used in the assessment. Many finer-grained, subtle landscape changes could be overlooked by an assessment that only evaluated coarse-grained data. The mechanisms behind the observed coarse-grained changes may not be apparent. On the other hand, the context, role, and significance of landscape changes might be lost by restricting an analysis to finer-grained data. These premises apply to temporal as well as spatial data. Mid-scale vegetation trends within the Basin, and their linkage to potential insect and pathogen disturbances was thoroughly described by Hessburg and others (1996a). The association between changed mid-scale vegetation conditions and potential smoke production and fire behavior was assessed by Ottmar and others (1996). This section is based entirely on their work, except where comparisons were made with the broad-scale data.

Hessburg and others (1996a) characterized trends of mid-scale vegetation patterns, structure, and composition within the Basin through a two-stage random sampling procedure in which 337 subwatersheds were assessed from 43 subbasins. They evaluated the change that occurred between a recent historical period (1932-1966) and the

current period (1981-1993). Thus, the temporal period of the mid-scale analysis was shorter and more recent than the temporal period evaluated with the broad-scale assessment. Consequently, some of the changes that we detected with the broad-scale assessment had occurred prior to the period assessed with the mid-scale assessment. These discrepancies were particularly noteworthy with respect to the large extent of agricultural conversions and the subsequent declines of native herblands and shrublands.

The mid-scale assessment also characterized the vulnerability to 21 forest insect and pathogen disturbances, and assessed trends between the recent historical and current temporal periods. The forest insect and pathogen disturbances included: one defoliator, seven bark beetles, four dwarf mistletoe, six root diseases, two rusts, and one stem decay.

Change of vegetation and vulnerabilities to forest disturbances was estimated as the mean difference between recent historical and current periods within subwatersheds of an ERU. Ecologically significant trends were identified using: (1) the statistical significance of the mean differences; (2) a comparison of the change with respect to an estimate of the historical range of variation; and (3) a characterization of the dominant changes in absolute area that occurred within an ERU.

Mid-Scale Physiognomic Types

Forest cover increased in the Blue Mountains, Columbia Plateau, Southern Cascades, and Upper Snake ERUs, but declined in the Upper Klamath ERU. The connectivity of forests increased in the Central Idaho Mountains and Upper Snake ERUs, but declined significantly in the Upper Klamath ERU. Changes of extent and connectivity of forests were attributed to fire exclusion in most of the aforementioned ERUs, but timber harvest was largely responsible for the decline and fragmentation of forests within the Upper Klamath ERU.

Woodland area increased in the Blue Mountains, Columbia Plateau, Northern Cascades, Northern Great Basin, Owyhee Uplands, Snake Headwaters, and Upper Klamath ERUs. Hessburg and others (1996a) were not able to detect significant declines of woodlands within any ERU. They believed that woodlands increased at the expense of herblands and shrublands, due primarily to fire exclusion and excessive livestock grazing pressure.

Herbland area increased significantly in the Central Idaho Mountains, Northern Great Basin, Owyhee Uplands, Snake Headwaters, and Southern Cascades ERUs. The mid-scale assessment did not detect significant declines of herblands in any ERU. Hessburg and others (1995) believed that the observed increase in herblands was largely a result of expanding colline exotic grass and forb cover at the expense of shrublands.

Mid-Scale Cover Types

Shifts from early-seral forest species (such as, ponderosa pine, western larch, lodgepole pine, western white pine, and sugar pine) to late-seral forest species (such as, grand fir, white fir, subalpine fir, Engelmann spruce, western hemlock, and western redcedar) were prevalent in many ERUs, but particularly within the Northern Glaciated Mountains ERU. The loss of a specific shade-intolerant species varied geographically within the Basin. The areal extent of western larch declined in the Central Idaho Mountains, Columbia Plateau, and Northern Glaciated Mountains ERUs, whereas ponderosa pine declined in the Northern Cascades, Northern Glaciated Mountains, Upper Clark Fork, and Upper Klamath ERUs. The lodgepole pine cover type declined throughout seven ERUs. The western white pine cover type declined in the Northern Glaciated Mountains ERU due to timber harvest, white pine blister rust, and mountain pine beetle mortality. Similarly, the whitebark pine/subalpine larch cover type declined in the Central Idaho Mountains, Northern Glaciated Mountains, Snake Headwaters, and Upper Clark Fork ERUs, but increased in the Blue Mountains and Northern Cascades ERUs. The observed decline of whitebark pine was also attributed to blister rust and mountain pine beetle mortalities.

The increased areal extent of a particular shade-tolerant species also varied geographically within the Basin. The Douglas-fir cover type increased significantly in the Blue Mountains, Columbia Plateau, and Northern Cascades ERUs; the grand fir/white fir cover type increased in the Northern Cascades and Northern Glaciated Mountains ERUs; the Pacific silver fir cover type increased in the Northern Cascades ERU; the Engelmann spruce/subalpine fir cover type increased in the Northern Glaciated Mountains, Snake Headwaters, Southern Cascades, and Upper Clark Fork ERUs; and the western hemlock/western redcedar cover type increased in the Columbia Plateau and Northern Glaciated Mountains ERUs. The substantial increase of many shade-tolerant cover types was presumed to have been the result of fire exclusion and selective timber harvest of shade-intolerant species (Hessburg and others 1996a).

In regard to woodland cover types, the mid-scale assessment detected a significant increase in the areal extent of the juniper cover type within the Blue Mountains, Columbia Plateau, Northern Great Basin, Owyhee Uplands, Snake Headwaters, and Upper Klamath ERUs. Hessburg and others (1996a) believed that the increase of juniper was largely a result of fire exclusion and excessive livestock grazing pressure.

Significant reductions in shrubland cover types were consistently observed in virtually every ERU throughout the Basin. The areal decline of shrubland cover types was especially evident in the Columbia Plateau, Northern Great Basin, Owyhee Uplands, and Upper Snake ERUs (that is, those ERUs that were composed of predominantly rangeland physiognomies). However, significant declines were also observed in the Blue Mountains, Snake Headwaters, and Upper Klamath ERUs. The areal decline of shrubland cover types was associated with forest or woodland expansions in the Blue Mountains and Northern Great Basin ERUs, cropland expansion in the Northern Great Basin ERU, and conversion to non-native herblands in the Owyhee Uplands and Snake Headwaters ERUs.

In general, mid-scale herbland cover types increased throughout the Basin, largely at the expense of shrubland cover types. At first it would seem that the observed increase of mid-scale herbland cover types was not consistent with the overall demise of herbland cover types detected in the broad-scale assessment. This apparent discrepancy is largely attributed to the different temporal periods involved in the mid- and broad-scale assessments. The broad-scale analysis assessed trends that occurred between the mid-1850s and the late 1980s, whereas the mid-scale analysis reported on the changes that occurred between the recent historical (1930s-1960s) and current (1980s-1990s) periods. We believe that many of the large-scale changes that occurred within herbland cover types were due to the extensive agricultural conversions that occurred in the late 1800s and early 1900s. Thus, much of the change occurred prior to the temporal period covered by the mid-scale assessment. In addition, many of the recent changes of herbland cover types could only be detected by a finer-grained assessment. Hessburg and others (1996a) believed that the increase of mid-scale herbland cover types was largely due to the finer-scaled transitions that occurred between shrubland and herbland physiognomies. In addition, the mid-scale assessment did not differentiate between native and exotic herbland cover types (as did the broad-scale assessment). Thus, a substantial component of the areal increase of herbland cover types reported in the mid-scale assessment was due to the invasions of exotic grasses and forbs, which were particularly prevalent in the Blue Mountains, Columbia Plateau, Northern Cascades, Northern Great Basin, Owyhee Uplands, Snake Headwaters, and Upper Clark Fork ERUs.

Trends of Mid-Scale Forest and Rangeland Structural Classes

In general, the structure of forests in the current period were simpler than the presiding structures during the recent historical period. The areal extent of stand initiation structures (early-seral

structures) declined in four of nine ERUs dominated by forest settings (Central Idaho Mountains, Lower Clark Fork, Northern Glaciated Mountains, and Upper Clark Fork ERUs), despite relatively high levels of timber harvest. The areal extent of old forest single- and multi-layered structures (late-seral structures) declined in nearly all ERUs dominated by forest settings, especially in the Blue Mountains, Northern Cascades, Snake Headwaters, and Upper Klamath ERUs. Lastly, the areal extent of intermediate structures (mid-seral structures) increased in most of the ERUs dominated by forests. Thus, the forests of the current period were more homogeneous than those of the recent historical period. Timber harvest reduced the areal extent of old-forest structures, forest area containing remnant large trees, and the presence of medium to large trees in all forest structural classes. In contrast, fire exclusion promoted the transition of early to intermediate structural classes.

The area of open or closed shrub structures declined in every ERU in which the shrubland physiognomic type composed a substantial proportion. The most significant declines involved sagebrush, rabbitbrush, and bitterbrush, and were noted in the Blue Mountains, Columbia Plateau, Northern Great Basin, Owyhee Uplands, and Snake Headwaters ERUs. The decline of open or closed shrub structures was associated with forest and woodland expansions in the Blue Mountains and Northern Great Basin ERUs, cropland expansion in the Northern Great Basin ERU, and the expansion of exotic grasses and forbs in the Owyhee Uplands and Snake Headwaters ERUs.

Forest Vulnerability to Insect and Pathogen Disturbance

The change of potential insect and pathogen disturbances was directly correlated with the change in composition, structure, and connectivity of forest host species. Thus, changes in potential insect and pathogen disturbance were strongly tied to the transitions involving the ratio of shade-intolerant to shade-tolerant species, dominance of medium to large trees, increased crown cover, development of the understory, and development of multiple crown layers. Not surprisingly, the causal factors varied geographically by type and intensity of timber harvest, efficacy of fire exclusion, and subsequently, the resultant stand structures and composition.

Forest landscapes changed significantly with respect to their vulnerability to major insect and pathogen disturbances. Changes of landscape vulnerability occurred in response to management practices that either increased or decreased the susceptibility of landscapes within some subbasins and some ERUs. However, at the regional ERU level, vulnerability changes were commonly insignificant or masked due to a high variation among sampled subwatersheds. The high variability of insect and pathogen vulnerability was a function of the large geographic extents of the ERUs, and subsequent variability of biophysical conditions (especially climatic and disturbance regimes) and vegetation communities. As a result, the dynamics of forest insect and pathogen vulnerability is better assessed at the subwatershed scale, while considering the context of change among similar types of subwatersheds, stratified by appropriate ecological subregions.

As a consequence of mid-scale changes of vegetation structure and composition, the vulnerability of landscapes to western spruce budworm, fir engraver, Douglas-fir beetle, Douglas-fir and lodgepole pine dwarf mistletoe, and most major root diseases increased across the Basin as a whole between recent historical and current periods. In contrast, landscape vulnerability to western pine beetle, and ponderosa pine and western larch dwarf mistletoe disturbance decreased. In addition, the vulnerability of whitebark pine to white pine blister rust has increased, especially within Idaho and Montana portions of the Basin.

Potential Smoke Production and Fire Behavior

Ottmar and others (1996) used the mid-scale assessment of vegetation conditions conducted by Hessburg and others (1996a) to evaluate temporal and spatial changes in fuel loading, potential smoke production, potential fire behavior, and crown fire potential. Fuel-loading estimates were assigned to patches of recent historical and current vegetation identified by potential vegetation type, cover type, and structural stage. Potential smoke production, fireline intensity, crown fire potential, rate of spread, and flame length were then simulated from mid-scale vegetation composition, structure, and pattern of sampled subwatersheds for recent historical and current time periods.

For the Basin as a whole, fuel loading increased significantly ($P \leq 0.2$), resulting in significant increases in potential wildfire fuel consumption, wildfire smoke production, fireline intensity, crown fire potential, rate of spread, and flame length. In addition, for the current period, Ottmar and others (1996) projected that potential smoke production of wildfires would be more than twice the smoke production resulting from prescribed fires.

At the ERU scale, fuel loading increased significantly in 6 of 13 ERUs ($P \leq 0.2$). The increased fuel loading seemed positively correlated to the conversion of open ponderosa pine and western larch stands to dense stands dominated by mixed coniferous species. In contrast, decreased fuel loading was positively correlated with timber harvest and fire disturbances. Due to increased fuel loading, subsequent increases of fuel consumption and potential smoke production were observed in 8 of 13 ERUs. As with the Basin as a whole, potential wildfire smoke production projected for the current period was two to four times greater than potential prescribed fire smoke production for all ERUs.

Trends in General Landscape Patterns

Landscape patterns at a subbasin level were associated with type of landscape mosaic, landform, PVG composition, vegetation composition and structure, succession/disturbance regime, and historical land use. We correlated landforms (for example, ridges, slopes, terraces, and channel zones) with their associated attributes for the different landscape mosaics (that is, forests, rangelands, and forest-rangelands). The resultant strata were highly correlated to biophysical potential, succession/disturbance regimes, and consequently, land-management potentials and activities. Because of these relationships, we detected predictable patterns of vegetation composition and structure.

We compared current landscape patterns with those expected from native processes, and to those expected to result in traditional commodity or reserve management strategies. The traditional commodity patterns were associated with traditional forestry and livestock grazing practices, including fire suppression and the introduction of exotic plants and pathogens. As expected, the traditional commodity patterns radically changed succession/disturbance regimes and resultant vegetation compositions and structures typical of the native systems. A traditional reserve pattern was associated with management scenarios more common in wilderness and semi-primitive areas. The reserve-management strategy also had substantially changed succession/disturbance regimes and associated vegetation conditions, although not to the degree of traditional commodity-management strategies. Under both of these patterns, disturbance intervals were extended, while disturbance severity increased. The effects of disturbance were more acute or more chronic than those associated with native systems.

We assessed the similarity of historical and current vegetation conditions at the regional and landscape levels. The similarity of the composition of broad-scale physiognomic types within the Basin as a whole and within BLM/FS lands was

evaluated at the regional level. Landscape similarities were assessed at the subbasin scale and were stratified by landform, management class, and PVG. Broad-scale physiognomic types, fine-scale vegetation attributes, and succession/disturbance regimes were used to evaluate similarities at the landscape level. Current landscape conditions were also evaluated with respect to patterns expected from traditional commodity- and reserve-management strategies.

The regional-level similarity of the historical and current conditions of vegetation for the Basin as a whole was low (29%), but much higher than the landscape-level similarities for the Basin (2%). Landscape patterns for BLM/FS within the Basin were similar to those expected under a traditional commodity-management pattern (64%) or a reserve pattern (29%), while only 7 percent of the Basin had patterns that fit the native regime.

The regional and landscape similarity indices pertaining to BLM- and FS-administered lands were higher than the indices for the Basin as a whole. However, the distribution of landscape patterns that were similar to the native system, or to patterns expected under a traditional commodity or reserve pattern, was essentially identical to that observed for the Basin as a whole. Forest-dominated landscapes on BLM- and FS-administered lands more closely approximated historical conditions than did rangeland-dominated landscapes. Furthermore, a greater proportion of the lands classified as forest landscapes had vegetation conditions similar to traditional reserve patterns than rangeland-dominated landscapes. Nearly all of the BLM- and FS-administered lands classified as rangeland landscapes had vegetation conditions similar to that expected from a traditional commodity pattern. Vegetation patterns of forests were more similar to the traditional reserve pattern because they contained a greater proportion of wilderness and unroaded areas. On the other hand, a higher proportion of rangeland landscapes were affected by traditional grazing practices and exotic plant infestations relative to the proportion of forest landscapes affected by traditional forestry practices.

Nearly all of BLM- and FS-administered lands within the six geographic areas defined by the subbasin group were dominated by landscape patterns similar to those expected from traditional commodity activities. The exceptions included the Central Rocky Mountains and Northern Cascade Mountains subbasin groups, which were dominated by reserve patterns. Approximately 80 percent of the BLM- and FS-administered lands that had landscape patterns similar to the native system were located within the Central Rocky Mountains subbasin group.

The projected effects of traditional consumptive demand and passive management scenarios compared with active (ecological) management for regional similarity indices varied substantially by land ownership strata. The regional similarity projections on BLM- and FS-administered lands increased regardless of scenario, largely as a result of the projected increase in area burned by wildfires. However, the projections of the active ecological-management strategy had the highest similarity to the native system, followed in rank by the passive management strategy, and lastly by the consumptive demand strategy.

Proper Functioning Landscape Systems

Proper functioning landscapes are those landscapes whose processes are in dynamic equilibrium (including the production of human values), such that the rates and routes of key processes are resilient and have predictable responses to disturbances. Humans have the opportunity to strategically work with changing landscape conditions to benefit from a predictable and reliable flow of values (both commodity and amenity). The assessment of proper functioning landscape systems (PFS) is a process which strategically links the "driving variables" of the key ecological systems to each other and predicts responses of these variables at hierarchical landscape scales.

PFS assessment provides a framework, much like a house plan, for strategic spatial and temporal allocation of management activities to conserve, restore, or produce desired system states. Of the traditional management scenarios, consumptive demand strategies resulted in commodity landscape patterns, whereas passive management produced reserve landscape patterns; neither resulted in trends toward a dynamic equilibrium that would achieve the multiple goals of ecosystem management within limited landscape spatial and temporal templates. The goals for ecosystem management include the simultaneous 1)recovery and conservation of viable native species populations; 2) restoration of ecosystem integrity and health; and 3) sustainability of human use and values (Grumbine 1992; Kaufmann and other 1994; Haynes and others 1996). In contrast, the active ecological management scenario resulted in trends toward equilibrium interactions of native (HRV) species, elements, functions, and processes, and thus conservation of the integrity and health of ecosystems. Consequently the active management strategy has a higher probability of achieving the multiple goals of ecosystem management.

As a comparison, consider building a house with no plan except for the individual vision of the carpenter, plumber, and electrician. What is the probability that such a scheme would result in a house that was functional, let alone desirable? Such a scheme is comparable to the independent model that resulted in traditional commodity or reserve landscape patterns. Having a house plan provides a way to compare different outcomes so a choice can be made, as well as a model that can be used by the carpenter, plumber, and electrician to produce the chosen outcome. In a similar fashion, proper functioning landscapes can be used as a model to ensure desirable landscape patterns. Traditional commodity management has produced a wide variety of fragmented landscapes that are simplified compared with native patterns, whereas traditional reserve (protection) management has produced a variety of more contiguous, simplified landscapes. Native patterns were dominated by succession/disturbance regimes that operated in concert with the energy relationships of the landscape pattern. Both traditional commodity and reserve management have either lengthened or shortened regimes, or caused retrogressive regimes that have increased the cumulative severity or chronicity of disturbance effects. In addition, the spatial array of regimes does not currently line up with the biophysical conditions and energy relationships of most landscapes.

The challenge of shifting trends so that landscapes function properly is that most landscapes do not currently reflect native regimes. In fact, across the Basin we estimated that only 2 percent of All ownerships were similar to native landscape patterns and only 5 percent of BLM/FS lands resembled native patterns. If native landscape patterns were more common, a change toward PFS could be achieved simply by conserving the systems through mimicking disturbances with human production activities and reaping the benefits of both commodities and amenities.

However, since most landscapes (subbasins) are currently far from functioning properly, a substantial change in trend may not be possible for a long time. This is particularly true with traditional commodity landscape patterns, where slow growing elements, such as large, old trees or bunchgrasses, have been "lost". On the other hand, restoration of succession/disturbance regimes and restoration of "lost" elements, functions, or processes can produce substantial benefits from traditional commodity patterns (such as small diameter logs and firewood or forage). Because most of these "lost" elements are still present to some extent in the traditional reserve landscape patterns, reversing historical trends is not beyond the realm of possibilities. However, because of the need to conserve habitats for recovery of native populations at risk (for example, threatened or endangered species), conservation of scenic values, or protection to maintain air and water quality, the amount of restoration and production activities in landscapes having traditional commodity or reserve patterns may be hampered, thus slowing the transition rates to proper functioning landscapes.

We used a spatial scale of subbasin landscapes to summarize projected effects assuming the traditional independent limits model for the consumptive demand and passive management scenarios, and the ecological model for the active management scenario. We then used the PFS process outlined in the Methods section to assess outcomes for selected variables that integrate the ecological relationships on the landscape template. Because this process was a summary of results of variables already reported, there is not a PFS component in the Results sections.

We assessed the effects of the management scenarios on PFS only for BLM/FS lands. Humans have developed their own system that interacts with the other systems; consequently, we added humans to our PFS assessment. Management has little influence on the energy system, except as it effects the other systems, so we dropped energy from our PFS assessment. Thus, our assessment was based on 20 variables (table 3.203) that are indicators of one or more of the key PFS systems (human resource values, hydrologic, carbon-nutrient, food web, and evolution).

None of the scenarios changed range landscape patterns in a trend toward PFS in the first decade (table 3.204). The lack of reponse was because range landscape patterns respond very slowly to changes in management. In the long term (50- to 100-year period) the active management scenario had a high rate of transition, while the passive scenario has a low rate of transition and the consumptive demand scenario resulted in no detectable change.

Forest landscapes respond faster to changes in management than range landscapes because of their more productive environments. Although forested landscapes did not respond positively in the first decade as a result of the consumptive demand and passive scenarios, the active scenario produced a moderate transition. Furthermore, the active management scenario produced a high transition rate toward PFS in the long term. In contrast, the long-term trend of the consumptive demand scenario continued to decline, whereas the passive scenario resulted in a low rate of transition. Passive management had a low transition rate in the long term because of the initial disequilibrium relationships between succession and disturbance, and a lag period needed for the system to reach equilibrium.

The forest-range landscape mosaics were similar to the range landscapes in that they did not change toward PFS within the first decade. Their response differed from those of either forest or range landscapes in the long term because of mosaic interactions. The consumptive demand scenario continued the departure away from PFS. Similarly, the passive management scenario did not produce a net transition toward PFS because of the states of disequilibrium associated with fire, fuels, exotic plants, and succession that did not return to equilibrium in the long-term. However, active management produced a positive trend toward PFS in the long-term.

The dry grass and dry shrub PVGs had low similarity to the native (HRV) regime for the Basin, as well as for both the EEIS and UCRB areas (tables 3.205 and 3.206), due primarily to fire exclusion, excessive grazing, invasion of exotic annual grasses and the subsequent increase in fire frequency, invasion of exotic forbs, and soil erosion. Increased similarity to the native succession/disturbance regime did not result in trends to PFS across most of these environments due to the risk of exacerbating the current problems with exotic annual grasses and forbs, and soil erosion. The PFS succession/disturbance regime would have shifted to longer cycle regimes or increased similarity to the native regime if areas with high components of annual grass could be restored to a predominance of perennial grasses and shrubs. The consumptive demand scenario resulted in little change in similarity and associated succession/disturbance regime composition, while the passive scenario increased similarity. Active management also resulted in a slight increase in similarity to the native regime.

Table 3.203—Basin ranking of management scenarios for their ability to achieve proper functioning landscape systems (PFS).[1]

Variable	Scenario					
	Consumptive Demand		Active Management		Passive Management	
	Decade	Long-term	Decade	Long-term	Decade	Long-term
Rangeland Landscape Patterns	N[2]	N	N	H	N	L
Forest Landscape Patterns	N	N	M	H	N	L
Forest-Rangeland Landscape Patterns	N	N	N	H	N	N
Dry Shrub and Dry Grass PVGs PFS Succession/Disturbance Regime	N	N	M	H	L	M
Cool Shrub PVG PFS Succession/Disturbance Regime	N	N	M	H	M	M
Woodland PVG PFS Succession/Disturbance Regime	N	N	L	H	L	M
Rangeland Riparian PVG PFS Succession/Disturbance Regime	N	L	M	H	M	H
Dry Forest PVG PFS Succession/Disturbance Regime	N	N	M	H	M	M
Moist Forest PVG PFS Succession/Disturbance Regime	N	N	M	H	L	L
Cold Forest PVG PFS Succession/Disturbance Regime	N	N	M	H	L	L
Alpine PVG PFS Succession/Disturbance Regime	L	L	M	M	L	M
Reduction in Forest Soil Disturbance	N	N	M	M	L	L
Reduction in Rangeland Soil Disturbance	N	N	M	M	L	L
Forest Exotic Plant Risk Reduction	N	N	H	H	M	M
Rangeland Exotic Plant Risk Reduction	N	N	H	H	M	M
Coarse-filter Terrestrial Habitats	N	N	M	M	L	M
Coarse-filter Riparian Habitats	N	N	H	H	M	M
Fire Risk Reduction in Wildland interface	L	L	H	H	L	M
Human Commodity Values	H	M	M	H	L	L
Human Amenity Values	L	L	M	H	M	H
Summary	N	N	M	H	L	M

[1]Proper functioning landscape systems (PFS) - those landscapes whose processes are in equilibrium, such that the rates and routes of key processes and disturbances are resilient and have predictable responses to disturbance, while producing human values. The ecological systems that interact in dynamic equilibrium include the: human system; hydrologic and land system; carbon-nutrient system; food web system, evolutionary system, and role of toxins in the system.

[2]N = No trend to PFS; L = Low trend to PFS; M = Moderate trend to PFS; H = High trend to PFS.

Table 3.204—Trends in response to management scenarios for landscape patterns for BLM/FS lands in the Basin.

	Scenario					
Pattern Type[1]	Consumptive Demand Decade[2]	Consumptive Demand Long-term[3]	Active Decade	Active Long-term	Passive Decade	Passive Long-term
Forest - PFS	NC	-	++	+++	NC	+
Forest - Traditional Commodity	+	++	NC	-	NC	-
Forest - Traditional Reserve	NC	-	-	--	+	++
Rangeland - PFS	NC	NC	NC	+++	NC	+
Rangeland - Traditional Commodity	NC	NC	NC	---	NC	-
Rangeland - Traditional Reserve	NC	NC	NC	NC	NC	NC
Forest - Rangeland PFS	NC	-	NC	+++	NC	NC
Forest - Rangeland Traditional Commodity	NC	+	NC	--	NC	-
Forest - Rangeland Traditional Reserve	NC	-	NC	-	NC	+

[1] Type of landscape pattern; PFS = proper functioning landscape systems.

[2] First decade estimate of trend (NC = No change, - - = Decline, + = Increase).

[3] Long-term (50 to 100 years) estimate of trend of landscape patterns.

This is consistent with PFS in these PVGs for careful maintenance and restoration to succession/disturbance regimes that are different from native conditions because of exotic species and altered biophysical conditions.

In the first decade, active management resulted in a moderate trend toward the PFS succession/disturbance regime due to the strong emphasis on perennial grass and shrub restoration with control of exotic plants (table 3.203). In contrast, there was no trend toward PFS for the consumptive demand scenario and only a low rate of transition to PFS for the passive scenario in the first decade. In the long term, active management with high restoration emphasis resulted in a high transition toward PFS. An important difference between the long-term and short-term responses is that in the long-term the passive scenario reached a moderate transition level to PFS as system interactions trend to equilibrium in response to exclusion of grazing, low to moderate levels of exotic plant control, and limited protection from wildfire.

The cool shrub PVG had low similarity to the native (HRV) composition for the Basin, as well as for both the EEIS and UCRB areas (tables 3.205 and 3.206), due primarily to fire exclusion, excessive grazing, and invasion of exotic forbs and grasses. Increased similarity to the native succession/disturbance regime to achieve properly functioning systems would be desirable for unaltered landscapes in this environment. The consumptive demand scenario provided virtually no change in

Table 3.205—Succession disturbance regime percent similarity to historical for the Basin land ownership groups by potential vegetation group (PVG).

Land Ownership Group	PVG[2]	Current Period	Scenario[1]		
			CD	AM	PM
		Percent			
BLM/FS	All PVGs	7	7	37	10
	Alpine	4	4	66	6
	Cold Forest	8	8	59	13
	Cool Shrub	6	6	66	9
	Dry Forest	6	8	34	10
	Dry Grass	5	5	0	8
	Dry Shrub	5	5	0	8
	Moist Forest	9	9	59	12
	Woodland	1	1	45	2
Other	All PVGs	0	0	0	0
	Alpine	0	0	0	0
	Cold Forest	2	2	2	2
	Cool Shrub	0	0	0	0
	Dry Forest	0	0	0	0
	Dry Grass	0	0	0	0
	Dry Shrub	0	0	0	0
	Moist Forest	1	1	1	1
	Woodland	0	0	0	0
All	All PVGs	3	3	15	4
	Alpine	2	2	25	2
	Cold Forest	6	6	37	9
	Cool Shrub	2	2	17	3
	Dry Forest	3	3	13	4
	Dry Grass	1	1	0	1
	Dry Shrub	1	1	0	2
	Moist Forest	5	5	28	7
	Woodland	0	0	10	1

[1]Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management.
[2]Rangeland riparian data not available to scale.

Table 3. 206—Succession/disturbance regimes percent similarity to historical for management region by potential vegetation groups (PVGs).

Management Region	Land Ownership Group	PVG[2]	Current Period	Scenario[1]		
				CD	AM	PM
			Percent			
EEIS	BLM/FS	All PVGs	6	6	27	10
		Alpine	2	2	66	3
		Cold Forest	8	8	60	15
		Cool Shrub	5	5	67	8
		Dry Forest	3	3	27	5
		Dry Grass	11	11	0	18
		Dry Shrub	6	6	0	10
		Moist Forest	9	8	60	14
		Woodland	2	2	34	4
	Other	All PVGs	0	0	0	0
		Alpine	0	0	0	0
		Cold Forest	2	2	2	2
		Cool Shrub	0	0	0	0
		Dry Forest	0	0	0	0
		Dry Grass	0	0	0	0
		Dry Shrub	0	0	0	0
		Moist Forest	1	1	1	1
		Woodland	0	0	0	0
UCRB	BLM/FS	All PVGs	7	8	43	10
		Alpine	5	5	67	8
		Cold Forest	8	9	59	12
		Cool Shrub	6	7	65	8
		Dry Forest	10	13	42	15
		Dry Grass	3	3	0	4
		Dry Shrub	4	4	0	5
		Moist Forest	8	9	59	11
		Woodland	1	1	52	2
	Other	All PVGs	1	1	1	1
		Alpine	0	0	0	0
		Cold Forest	2	3	3	3
		Cool Shrub	0	0	0	0
		Dry Forest	0	0	0	0
		Dry Grass	0	0	0	0
		Dry Shrub	0	0	0	0
		Moist Forest	1	1	1	1
		Woodland	0	0	0	0

[1]Scenarios: CD = Consumptive Demand Management; AM=Active Management; PM=Passive Management.

[2]Rangeland riparian data not available to scale.

similarity and associated succession/disturbance regime composition, while the passive scenario increased similarity. Active management resulted in a substantial increase in similarity in response to restoration of fire, exotic plant control, and changes in grazing systems.

In the first decade, both active and passive management resulted in a moderate trend toward the PFS succession/disturbance regime due to relatively rapid response of cool shrublands to treatments such as improved grazing management or weed control in comparison to the dry shrub and grass PVG (table 3.203). In contrast, there was no trend toward PFS for the consumptive demand scenario in the first decade. In the long term, active management resulted in a high transition to PFS due to a high emphasis on restoration, including grazing management. The passive management scenario reached a moderate trend toward PFS and the consumptive demand scenario produced no trend toward PFS in the long term.

The woodland PVG had low similarity to the native (HRV) composition for the Basin, as well as for both the EEIS and UCRB areas (tables 3.205 and 3.206), due to fire exclusion, excessive livestock grazing, invasion of exotic annual grasses and forbs, and soil erosion. The consumptive demand scenario resulted in no change to similarity and associated succession/disturbance regime composition while the passive scenario increased similarity only slightly. The active management scenario resulted in a strong increase in similarity on BLM/FS lands in response to restoration, changes in grazing systems, and exotic plant control.

The active and passive management scenarios produced a minor trend toward the PFS succession/disturbance regime in the first decade, while the consumptive demand scenario produced no trend to PFS (table 3.203). The active management scenario produced a high trend toward PFS for the woodland PVG, while the passive management scenario produced a moderate trend, and the consumptive demand scenario showed no trend to PFS in the long term.

We were unable to assess similarity of succession/disturbance regimes on the rangeland riparian PVG because of a lack of continuous mid-scale riparian data (rangeland riparian area is not accounted for adequately in broad-scale data). However, based on the mid-scale changes in riparian (Hessburg and others 1996a), valley bottom data (see Biophysical Environments, Chapter 2 of this document), and a report on riparian communities by Manning and Engelking (1995), we concluded that there was very low similarity to the native (HRV) regime in the current period. The long-term trend results from modeling using the VDDT models (Byler and others 1996; Hann and others 1997) also support this conclusion. Estimates for trends to PFS from the different scenarios were based on the management prescriptions assigned to the scenarios (table 3.203). In the first decade, the strong emphasis on riparian restoration in active management produced a moderate trend toward PFS. A moderate transition to PFS was also predicted for passive management in the first decade as a result of the removal of grazing pressure. The consumptive demand scenario was predicted to show transition to PFS in the first decade. In the long term, the consumptive demand scenario resulted in a low level of transition to PFS; and both the active and passive management scenarios resulted in a high trend toward the PFS succession/disturbance regime.

The dry forest PVG had low similarity to the native (HRV) composition for the Basin and for the EEIS and UCRB areas (tables 3.205 and 3.206), due primarily to fire exclusion, past harvest practices, and excessive road densities. Increased similarity to the native succession/disturbance regime for some portions of this PVG resulted in trends to properly functioning systems in this environment. However, in many of the wildland/urban or rural subdivision interface areas, increased similarity to native succession/disturbance regimes would not be desirable. The consumptive demand scenario resulted in little increase in the similarity to the native system and associated succession/disturbance regime composition on BLM/FS lands. The passive management

scenario slightly increased the amount of similarity, while the active management scenario showed a stronger increase in similarity.

In the dry forest PVG native succession/disturbance regime, a mixture of non-lethal, mixed, and lethal wildfires produced mosaics of open to somewhat closed forests dominated by ponderosa pine or Douglas-fir. For the dry forest PVG to trend toward PFS, these disturbance process would need to be restored or simulated. In the first decade, the consumptive demand scenario resulted in no trend to PFS (table 3.203). The passive management and active management scenarios produced a moderate trend to PFS in the first decade, while the active management scenario showed a quicker shift toward PFS because of its emphasis on restoration. In the long term, the active management scenario produced a high trend toward PFS because it emphasized thinning dense stands, promoting early-seral species (shade-intolerant) and large trees, and encouraged use of prescribed fire. The passive management scenario produced a moderate trend toward PFS, and the consumptive demand scenario resulted in no trend to PFS in the long term.

The moist forest PVG had low similarity to the native (HRV) composition for the Basin as well as for both the EEIS and UCRB areas (tables 3.205 and 3.206) due to fire exclusion, past timber harvest activities, high road densities, and decline of western white pine due to blister rust. Increased similarity to the native succession/disturbance regime would result in trends to properly functioning systems. The consumptive demand scenario resulted in little change to similarity and associated succession/disturbance regime composition. The passive management scenario resulted in a small increase in similarity while the active management scenario resulted in a stronger increase.

The moist forest PVG includes the most productive land in the assessment area. In the absence of disturbance, biomass accumulates very rapidly. Achieving PFS would mean an increase in the amount of late-seral forest and single-story forest, at the expense of mid-seral and multi-story forest, as well as promoting ponderosa pine, western larch and western white pine. The active management scenario resulted in a moderate trend to PFS in the short term (table 3.203). In the long term, the active management scenario was rated as having a high transition to PFS because of its restorative emphasis. The passive management scenario produced a moderate trend toward PFS in both the short and long terms due to the absence of active management in reserves. The consumptive demand scenario produced no trend toward PFS in either the first decade or the long term.

The cold forest PVG had low similarity to the native (HRV) composition for the Basin, as well as for both the EEIS and UCRB areas (tables 3.205 and 3.206), due primarily to fire exclusion and decline of whitebark pine as a result of blister rust. Increased similarity for substantial portions of this PVG resulted in trends to properly functioning systems. The consumptive demand scenario resulted in no change in similarity to the native system. The passive management scenario resulted in a small increase in similarity to the native system, while the active management scenario resulted in a larger increase in similarity to the native system.

Unlike the dry and moist forests, much of the cold forest had less frequent disturbance and slower succession rates; therefore, conditions are still within the HRV. However, traditional fire suppression practices have resulted in simplification of landscape patterns and whitebark pine is declining rapidly from effects of blister rust and fire exclusion. The active management scenario had a high probability of transition to PFS in the long term because of its emphasis on restoration (table 3.203). The passive management scenario resulted in a low transition to PFS in both the first decade and the long term because of disequilibrium between successional conditions and disturbance processes. The consumptive demand scenario for the cold forest succession/disturbance regime resulted in no trend toward PFS in either the first decade or the long term.

Although the alpine PVG is important ecologically, it is a sensitive ecosystem which has low productivity and succession is slow. None of the scenarios resulted in increased similarity to the native regime (tables 3.205 and 3.206). Because of the slow rates of response to restoration, none of the scenarios produced a high trend toward PFS in either the first decade or the long term (table 3.203). The consumptive demand scenario rated low in trend toward PFS in both the first decade and the long term. The passive management scenario rated low in the first decade and moderate in the long term. The active management scenario produced a moderate trend in both the first decade and long term due to higher levels of restoration of roads and other site-specific watershed conditions.

Scenarios that would increase the amount and intensity of soil disturbance would be more likely to harm soil stability, function, and productivity. Soil disturbance can come from a number of sources including, timber harvest, thinning, wildfire, prescribed fire, roads, recreation, livestock grazing, and wildlife grazing. The consumptive demand scenario had the most additional soil disturbance in the long and short term with no trend toward PFS (table 3.203). The passive management scenario resulted in low probability of reducing soil disturbance. The active management scenario resulted in a moderate trend to PFS in both the first decade and the long term, because of higher levels of restoration activities.

The active management scenario emphasis on soil protection through improved vegetation and grazing management, and the resultant residual cover produced a moderate trend toward reduction in rangeland soil disturbance in the first decade and in the long term. The passive management scenario produced a low trend in the first decade because of its lack of a restoration emphasis that would reduce exotic plant invasion or effects of severe wildlife.

In forest and rangeland systems, the active management scenario, with its high emphasis on exotic plant control, produced a high trend toward exotic plant risk reduction in both the first decade and in the long term. The passive management scenario, with less emphasis on activity levels to reduce exotic plant spread, produced a moderate trend toward risk reduction in both the first decade and in the long term. The consumptive demand scenario had no trend in exotic plant risk reduction in either the first decade or the long term.

The active management scenario, which assumes active restoration of terrestrial habitats, produced moderate trends toward improving landscape level terrestrial habitats in the first decade (table 3.203). The passive management scenario, which has a lower emphasis on restoration activities, produced a slight trend toward improvement (PFS) in the first decade. In the long term, both the active and passive management scenarios produced moderate trends toward improvement. None of the scenarios produced high trends. The connectivity of the populations of terrestrial species were altered by land uses and land ownership patterns that have fragmented the habitats of many terrestrial species and no longer allows these fragmented populations to interbreed. Such isolation of populations as a result of habitat fragmentation has put these species at risk. Little can be done on BLM/FS lands alone, relative to broad-scale conditions, to improve (PFS) over moderate levels.

The active management scenario with a high restoration emphasis produced a high trend toward improvement of landscape level riparian habitats in both the first decade and the long term (table 3.203). The passive management scenario produced a moderate trend in these two periods, because of lack of restoration. The consumptive demand scenario resulted in no trend toward improvement of coarse-filter riparian habitats in both the first decade and the long term.

Risk reduction to human life and property from wildfire in the wildland interface with urban and rural land uses was a key variable for PFS. The wildfire risk analysis used for the PFS assessment is discussed in the discussion of results. There were only low levels of risk reduction in response to the consumptive demand scenario, both in the short

and long term (table 3.203). This scenario focuses on commodity elements and increases fragmentation of landscape mosaics. It does not focus on fuel conditions in the interface areas or representation of PFS disturbance regimes. As a result, the risk in the long term actually increased. In direct contrast, the active management scenario focuses on fuel conditions in the interface areas as well as representation of disturbance regimes that reduce vulnerability to wildfire. Active management PFS risk reduction responded with high levels of transition in both the short and long term. The passive management scenario responded with short- and long-term contrasts. In the short term the current risk conditions increased because reduction in active wildfire suppression efforts is coupled with continued increase in contiguous high-risk fuel conditions. However, as wildfires reduced fuels the long-term risk declined and the transition to PFS increased to a moderate rate.

PFS response for human commodity values presents an interesting paradox. Because of a focus on high investment of energy in the extraction of specific elements as commodities, the short-term transition was high for the consumptive demand scenario (table 3.203). However, because of rapid transition to disequilibrium of landscape relationships, the availability of these elements declined and transition dropped to a moderate rate in the long term. Unfortunately, the energy investment required to sustain even moderate levels of commodity production in the long term continued to escalate in association with increased levels of disequilibrium in landscape conditions. The passive management scenario did little to respond to human needs for commodity-type elements. In contrast to the other scenarios, the active management scenario produced a moderate rate in the short term, primarily as an offshoot of restoration activities, and transitioned to a high rate in the long term as PFS equilibrium conditions were approximated and a flow of commodities was produced with only low to moderate levels of system subsidy.

The production of human amenity values in PFS was an almost direct opposite to the production of commodity values (table 3.203). Consumptive demand scenarios responded with low transition rates and actually result in the long term decline of amenity values. The passive management scenario sustained high levels of amenity values for the short term, but as disturbances became more severe and extensive in the long term, landscape elements important for amenities (such as big trees, bunchgrass, and clean water) were "lost." In contrast, very similar to the commodity-value response, active management only produced a moderate flow of amenity values in the short term. This is because many restoration activities can detract from amenity values (prescribed fire, extensive thinning, and road closures, for example). However, a high rate of transition was produced in the long term as more landscapes became native in appearance and human amenity values were produced from these landscapes with only low to moderate levels of subsidy.

Transition to an aggregate PFS, measured in this assessment by the 20 variables described above, was much like putting money in the bank. At the landscape level all variables contributed to the bank account by interacting to reduce disequilibrium, and thereby improving trends to dynamic equilibrium. This resulted in ecological cause-and-effect relations between the human, hydrologic, carbon-nutrient, food web, and evolutionary system that maintain the complexity of native as well as desired non-native elements, functions, and processes. Any one of the variables had little influence on the bank account when considered independently, but great influence when considered in the context of ecological cause-and-effect with all other variables. In other words, the interest rate on the account was exponentially higher when all variables were contributing. In contrast, if one variable was dysfunctional it caused an exponential decrease in the interest rate. The opportunity to simultaneously achieve the goals of ecosystem management, with the lowest subsidy investment, appeared to be highest with management scenarios that resulted in transition to landscape patterns

that are consistent with their biophysical succession/ disturbance regimes, and that have associated reduction in soil disturbance and exotic species invasion, and emphasize conservation of coarse-filter terrestrial and riparian habitats, reduction in fire risk in the wildland interface, and a flow of human commodity and amenity values.

A parable is a glass of water. When the glass is upright you can tip the glass, swirl the water, drink the water, and refill the glass. The glass is the landscape template; the water includes the ecological relationships; you as a human can drink the water; the glass is connected to the flow of water that comes from the mountains, that comes from the rain or snow, that comes from the storms carrying water evaporated from the oceans by the sun's energy. You as a human invest energy to fill the glass, hold the glass upright, swirl the water, and in return can drink the water. This is a properly functioning system in dynamic equilibrium. In contrast, if you tip the glass too far and the water runs out of the glass (landscape template), the water splatters in a relatively unpredictable fashion. As long as the glass is tipped or upside down you cannot fill it with water or drink the water. This is the traditional management model and disequilibrium. In the short term this model can produce a desired value (1 drink of water), but in the long-term the model does not sustain the flow of the value. The key is to hold the glass upright, know how much you can swirl and still not spill, and understand the connection in order to refill the glass. This is management with the ecological model to achieve trends toward dynamic equilibrium. These landscapes are properly functioning systems.

Landscape Health

Patterns of system dynamics and associated ecological functions and processes were quite similar for forests and rangelands. We concluded that the definition for forest health and rangeland health for this assessment should be the same:

> *Conditions under which the integrity of the soil and ecological processes are sustained resulting in systems that maintain their diversity, resiliency, and productivity with associated sustainable resource values.*

Forest and rangeland patterns were inherently connected at broad-, and mid-scales across the Basin. We concluded that forest and rangeland health should be considered in a landscape health context. We defined landscape health as:

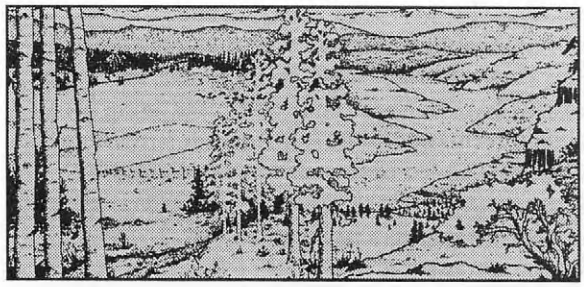
> *the "best fit" of the dynamic interactions of human land use, biodiversity, and ecosystem health that is in balance with he limitations of the biophysical system and inherent disturbance processes.*

The assessment of landscape health was based on the concept of proper functioning systems. Proper functioning systems occurred where ecological interactions were in a dynamic balance, such that the ecological systems (hydrologic and land, carbon-nutrient, food web, and evolution) had resilient and relatively predictable responses to disturbance, while sustaining human resource values (both amenity and commodity). We found only a small amount of BLM/FS lands in the Basin (5%) that fit the definition of healthy landscapes. However, a relatively large amount of BLM/FS lands in the Basin (approximately 60%) have high potential for restoration within the coming decades.

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CONCLUSION

Broad-scale assessments that use continuous data may provide important context across large geographic areas, but by default, lack the necessary resolution to address fine-scale elements and processes or the persistence of biota that rely upon fine-scale attributes. Rarer elements are more readily detected using finer-grained techniques (Turner and others 1989). Thus, coarse-grained analyses commonly underestimate elements occurring in small- to medium-sized patches. However, continuous, fine-grained data are more costly to obtain and analyze. Alternatively, fine-grained data can be efficiently collected and analyzed by sampling a broad geographic area. Even so, a feasible sampling design may also miss elements that have a low representation within the sampled area.

Inherent to any ecosystem analysis is the need to summarize data about elements and processes of different scales to an explicit spatial and temporal unit. Thus, the spatial and temporal scale in which regional and landscape data is quantified directly influences the inferences derived from that data. Unless explicitly addressed, data variability is commonly overlooked in simplistic summaries. Thus, data summaries and inferences made at different nested scales may not immediately seem comparable. For our analyses, we chose to summarize trends at the Basin, Ecological Reporting Unit (ERU), and subbasin group scales. In addition, several analyses were further stratified by geographic area (that is, EIS management areas) and land ownership group (that is, BLM/FS, Other, and All lands). We do not imply that the observed trends are consistent within any further disaggregation or nested strata, but rather, we fully acknowledge and indeed expect some level of variability throughout the area assessed. For example, compositional changes within ERUs did not always reflect the observed trends for the Basin as a whole. Furthermore, the ability to detect change varies by temporal and spatial scales. Trends may not have been detected at the Basin level, but were readily apparent within various strata of the Basin. Similarly, broad-scale trends from the historical to the current period may not be the same as trends from the recent historical to the current period used in the mid-scale assessment conducted by Hessburg and others (1996a) and Ottmar and others (1996). That is, substantive changes may be either "washed out" or refined as information is pooled or disaggregated among various stratifications of space and time. Consequently, we used a multi-scaled approach to identify and better understand the context of regional and landscape patterns and processes, as well as the mechanisms that drive those patterns and processes. The context of patterns and processes are better addressed using broader scales, whereas the mechanisms that drive these patterns and processes are better addressed at finer scales.

Because of the coarse resolution (1 km^2) of our broad-scale assessment, many issues have not been fully addressed. Assessments conducted at a finer resolution (such as the mid-scale assessment conducted by Hessburg and others 1996a and Ottmar and others 1996) would provide a more complete understanding. For example, the trends of riparian vegetation types that most commonly occur as

small patches or narrow stringers, or the distribution of microhabitats important to the persistence of various biota (such as snags, logs, fens, and scree slopes) have not been fully addressed using broad-scale information only. Information pertaining to these fine-scaled elements is better defined by more intensive data sources, and then aggregated or extrapolated to a broader context. However, by using statistical correlates of these fine-scale attributes with the broad-scale data we were able to infer trends for these elements at the broad scale.

We found that characterization of landscape spatial and temporal patterns, in relation to integrated succession and disturbance regimes, provides more analytical power for multiple scale assessment than stratification of biophysical environments. Traditional landscape analysis methods reduce variation in landscape patterns and processes by stratifying environments based on potential vegetation, soils, landform and climate. However, to assess proper functioning landscapes we needed a classification system which addressed the complexity of human, hydrologic, carbon-nutrient, food-web, and evolutionary system interactions, yet did not overwhelm us with excessive stratifications. The classification of types of landscape patterns of successsion/ disturbance regimes provides an analytical platform that simplifies these complex interactions and does not multiply stratifications by variation in the biophysical environment. This approach does not reduce the importance of hierarchical biophysical data, however, because we use such data to predict the type of landscape pattern of succession/disturbance regimes. The combination of biophysical environment classifications and types of disturbance-specific regimes produces excessive stratifications. In addition, the wide variety of biophysical environments and associated landscape interactions often compensates to produce the same landscape pattern outcome. We found that dynamic system interactions are better assessed by direct classification of landscape patterns of succession/disturbance regimes. In addition, we found that these integrated succession/disturbance regimes were much more sensitive in detecting differences at multiple scales than disturbance-specific disturbance regimes (for example, fire regimes).

A critical problem that surfaced during our analyses was the paucity of data that could be used for a broad-scale assessment. An abundance of fine- and mid-scaled data was available. Unfortunately, these data were collected to address mid- and fine-scale issues. Thus, the inventory design would not allow pooling of data within larger geographic areas. Furthermore, the data collected were not consistent across the Basin. Each agency, and nearly every administrative unit within an agency, had different sampling designs, collected different data, and stored the data in different formats. Perhaps that was to be expected as there have not been similar assessments conducted with a geographic extent the size of the Basin. Consequently, many existing data were not of the quality or consistency needed for interpretation or for extrapolation to multiple scales. In addition, there has been little emphasis on integrated sampling designs that address the ecology of complete systems. Instead, the majority of data were collected to investigate subsets of systems such as plant ecology, forest ecology, rangeland ecology, wildlife ecology, aquatic ecology, and fire ecology. It is imperative that data be collected under an appropriate design and in a consistent manner, if it is to be useful for broad-scale assessments or the monitoring of broad, multi-scaled, land-management objectives.

At the onset of our ecological assessment of the Basin, we hypothesized that landscapes were in dynamic ecological equilibrium prior to the extensive effects of human-caused (anthropogenic) disturbance that occurred after Euro-American settlement of the Basin. This appears to be the case. We also hypothesized that this dynamic equilibrium would be disrupted where the key ecological processes (that is, energy flows, carbon-nutrient cycles, ecological food webs, and hydrologic cycles) have been substantively altered. This has also proven to be the case. Furthermore, disequilibrium seemed strongly correlated with the history and magnitude of human influences. For example, system states in valley and plains landforms were more frequently out of equilibrium than systems in mountain landforms due largely to agricultural and urban developments, as well as excessive livestock grazing

practices. In forest settings, there seemed to be a gradient of disequilibrium ranging from the cold forest PVG to the dry forest PVG. Dry forest systems were more frequently out of equilibrium because of their common adjacency to human settlements and the associated disruption of their succession/disturbance regimes.

The predictability and resiliency of systems to disturbance have decreased substantially where biophysical templates and their associated succession/ disturbance regimes have radically changed. Systems strongly influenced by humans within the Basin have undergone radical changes in state, and more importantly, those changes have occurred at unprecedented rates relative to the rates of native systems. Consequently, the equilibrium relationships of ecological processes have become dysfunctional, resulting in disequilibrium. Furthermore, as human populations within the Basin continue to expand, the disequilibrium and simplification of these systems increase. Thus, relative to native systems, future systems will likely remain in disequilibrium (Allen and Hoekstra 1992). The variability and mean state of a system depend upon whether equilibrium is the most common state of that system, or whether it occurs rarely (Huston 1992). As the variability of future systems increases, their predictability will likely decline. We again emphasize that equilibrium refers to predictable response of dynamic, rather than static, conditions.

We concur with the new land-management paradigm suggested by Allen and Hoekstra (1992). That is, land management aimed at maintaining ecological integrity and human values must be mindful of this disequilibrium and offer a viable context for the systems being managed. In other words, management identifies the functions and processes of native systems that have been removed through anthropogenic processes, determines the scale to which they have been altered, and artificially subsidizes the function or restores the process at the appropriate scale of space and time. In this way, the contributions of energy to the functioning of the managed system can be maximized, while artificial energy subsidies (for example, species reintroductions, fire suppression, pesticide application, range seeding, tree planting, and precommerical thinning)can be minimized. Alternatively, if a managed system lacks processes or functions provided in the native context, the internal workings of a management unit may become dysfunctional. Working in opposition to system processes results in the accumulation or depletion of energy in ways that result in disruption of expected and desired responses. This is representative of the traditional management model. In contrast, the ecological model emphasizes working with the system's processes to achieve expected, desired, and sustainable responses.

Barrett and others (1993) introduced the concept of "proper functioning condition" for riparian systems. This same concept can be expanded and applied to systems at a landscape scale. As outlined above, landscape managers could identify the elements, functions, and processes of native systems that have been removed or altered through anthropogenic activities. The context within which these functions and processes operate is provided by understanding larger scale relationships, and involves those elements that constrain the functions and processes at lower levels. Identifying the function that the elements and processes provided in native systems enables managers to better project change associated with activities. For example, as a consequence of historic succession/ disturbance regimes, landscapes comprise a shifting mosaic of habitat conditions, which ensures the dispersal of terrestrial species, and supports metapopulations of species. Anthropogenic activities such as agricultural development, fire exclusion, and traditional forestry and grazing practices have dramatically changed these patterns. Restoring or conserving functions and processes within landscapes to maintain a shifting mosaic of habitats which represents native conditions to the extent possible would maintain a proper functioning landscape. However, because of human-induced limitations on current wildland landscapes, processes of prescribed fire, watershed, timber, forest, range, access management, and wildfire

suppression are used to supply the appropriate space and time context for current conditions. In addition, the dynamics of the meta-populations could be subsidized to stabilize rare or at-risk species.

Unfortunately, there is a significant deficiency of information pertaining to the habitat relationships and population response to habitat change for most species residing in the Basin. There is little likelihood that this information void will be filled for the majority of the biota within the next decade. Thus, the coarse-filter approach of assessing landscape dynamics provides a useful means for projecting population responses. The coarse-filter approach is a multi-scaled option for managing proper functioning systems. The appeal of the coarse-filter approach is its simplicity. For example, an area could be assumed to be functioning properly if its elements, functions and processes (for example, succession/disturbance regimes, vegetation composition, structure, and pattern) were managed to represent relationships similar to the native regime. Furthermore, it could be assumed that most native biota would have a high probability of persistence if missing functions at larger scales are adequately subsidized or restored. In areas where biophysical templates have undergone substantial change, strategies for maintenance and production of human values and restoration may require substantial subsidies in order to achieve equilibrium, and successful representation or mimicking of native processes is unlikely.

An important consideration of the coarse-filter approach, however, is that the variability of native systems is often the most critical aspect of proper functioning systems and biota persistence. That is, if proper functioning systems are a management objective, a static level (for example, mean, median, or modal values) of equilibrium conditions would not be the goal. In addition, element or function subsidies may be required in those areas of the Basin in which land-ownership patterns or species-specific conservation strategies do not allow the full spatial or temporal expression of those elements, functions, and processes necessary for system equilibrium. For example, the full expression of the native patterns may not be compatible with small and often isolated habitat patches that serve as refugia or source areas for populations that are near the threshold of extirpation.

We evaluated regional and landscape departures of individual habitats (for example physiognomic types, cover types, and terrestrial communities) from the HRV. However, the fitness and population of most animal species are not closely correlated to the areal extent of a single kind of habitat type. Instead, most species rely upon the availability and spatial juxtaposition of several to many habitats. A multi-habitat approach for estimating departures from the native landscape patterns and succession/disturbance regimes (such as our similarity analyses) is more appropriate for these species. In addition, the fitness of many, if not most, species are strongly correlated to fine-scale habitat attributes. These attributes are correlated to changes in landscape patterns and succession/disturbance regimes, broad-scale biophysical environments, and disturbance histories.

Over the past 150 years, humans have altered virtually all biophysical environments within the Basin to some degree. Regardless of the geographic scale at which data was summarized, the Basin is currently dominated by areas in which succession/disturbance processes and landscape conditions are outside the HRV. For example, when we evaluated the composition of succession/disturbance regimes and vegetation conditions at the broad subbasin landscape scale, only 2 percent of the Basin had conditions similar to the HRV. In addition, 92 percent of the cover types and 83 percent of the terrestrial communities occurred outside of their median historical ranges for the Basin as a whole. Even on BLM- and FS-administered lands, the opportunity to manage within the HRV is limited to about 24 percent of the area. Given the level of departure, it is no surprise that forest and rangeland health, threatened and endangered species, and air and water quality, are major issues confronting resource managers and society as a whole. However, all of these wildland systems appear to

have high resiliency when managed in the proper functioning system context (that is, the use of managment energy to represent native processes, and restore or subsidize "lost" elements and functions while producing human commodities and values). Of particular importance in this context, management for proper functioning systems reduces risk to rare native elements (such as threatened and endangered species), clean air, and clean water, by strategically scheduling management activities through time and between landscapes at different scales.

The health of the Basin's landscapes can be better understood within a global context. Compared to other areas of the earth, the Basin is relatively pristine from an ecological perspective. When viewed globally, the degradation of ecological integrity is strongly associated with the duration of major agricultural and industrial developmental periods of human society, that is, the duration and intensity of human use of the land.

Very broadly, humans interact with the environment through their technologies in a number of ways. Although human culture is not driven by technology, cultural application of technology can be grouped into general categories to illustrate points in our discussion. These categories might include hunting and gathering, migratory and non-migratory herding/gardening, rural non-mechanized agriculture, rural agriculture and industry, and urban industry and industrial agriculture (Fagan 1989, Naveh and Lieberman 1994). Each of these applications of technology is characterized by a certain duration, intensity, and extent of effects on the environment.

As hunter/gatherers, low human-population densities had little effect on the key ecological processes. However, on a relatively limited spatial scale, they were an integral part of the ecological food webs. Hunter/gatherers also influenced fire regimes, and consequently carbon cycles, although again the spatial extent of such changes was probably limited. Generally, indigenous Basin societies (primarily hunter/gatherers) had comparatively low population densities and consequently little effect on primary ecological processes.

Animal and plant husbandry practices initiated extensive alteration of biophysical environments by the annual cultivation of monocultures, the development of irrigation technologies, and excessive livestock grazing practices that changed hydrologic and carbon-nutrient cycles. In many instances, these practices may have been linked to soil erosion, which influences food-web and carbon-nutrient cycles and hydrologic processes. When herding was migratory, these effects were transitory and ameliorated by the relatively frequent migration of humans and their animals to more productive areas. Non-migratory herding and gardening practices, however, might often be characterized by excessive livestock grazing and its effects upon hydrologic and carbon-nutrient cycles. In addition, ecological food webs were altered by intensive practices, as well as by continued excessive hunting and grazing practices.

The rural non-mechanized agricultural period was characterized by the development of rural communities, transportation systems, intensive agricultural technologies, and more extensive grazing effects. The magnitude and extent of human-induced change increased dramatically during this period. However, more importantly, the rate of change was too fast to allow natural systems to recover their equilibrium and maintain ecological integrity. This is similar to what occurred in the Basin in the late 19th and early 20th centuries. Thus, widespread disequilibrium began to emerge during this period as a result of the disruption of hydrologic and carbon-nutrient cycles and ecological food webs. Biophysical environments changed substantially as soils and nutrients were "lost" and as humans began to overload the system with pollutants.

During the two industrial periods, global human population increased exponentially, as did the use of natural resources and the output of wastes and toxins. Consequently, the magnitude, extent, and rates of change to ecological processes again increased dramatically.

The Basin is relatively unique when compared to the rest of the world in that its exposure to a number of these technological land uses, including non-migratory and migratory herding and gardening and non-mechanized agriculture, was relatively short. In contrast, these periods lasted centuries in many other portions of the world, such as Eurasia and Africa. In this context, the Basin is just beginning to experience the ecological ramifications that result from extensive anthropogenic activities; in relative terms, its health and ecological integrity are far better than many portions of the world. And, therefore, it may still be possible, in the Basin, to reverse the trend toward ecological disequilibrium. The proper functioning landscape system provides a way to conceptualize the transition toward stabilization of equilibrium processes and representation of native systems.

In our landscape analysis of the Basin, we were asked to address the following four general questions.

(1) Within the Basin, what are the status and trends of landscape processes and functions? What are the causal agents responsible for these trends?

The key ecological processes, and consequently the compositions, structures, and functions of landscape elements have been radically altered relative to the native systems. Current system states appear to be dysfunctional, and no longer occur in dynamic equilibrium. Existing systems are less resilient to disturbance, and their responses to disturbance are less predictable. If established as a goal and managed with an ecological management approach it may be possible to reverse, or at least stabilize, the losses in system resiliency and predictability with substantially fewer artificial subsidies.

(2) In what capacity will current and future landscape disturbance regimes affect landscape patterns and biophysical potentials? In response to landscape management strategies, what are the probable trends of disturbance regimes for the future?

Regional and landscape conditions, and their associated succession/disturbance regimes have changed substantially since Euro-American settlement of the Basin. The biophysical potential of several systems cannot be restored to their native conditions with current technology. Furthermore, without considerable subsidies, traditional commodity and reserve landscape patterns will likely continue to decline in their biophysical potentials and predictability of response. In contrast, proper functioning landscape patterns will likely require fewer subsidies and produce a more sustainable and predictable biophysical system.

(3) What are the historical and probable future trends of landscape elements important to amenity and commodity resource flows? How will these trends differ under various landscape management strategies?

The succession/disturbance regimes that provide the spatial and temporal framework for the flow of commodities and amenities have become increasingly chaotic, and subsequently, less predictable. Continued management for traditional commodity and reserve landscape patterns will require ever increasing levels of management-provided subsidies including wildfire suppression; control of exotic plants, and insect and pathogen outbreaks; timber salvage; and rangeland and watershed mitigation. A management strategy for more reserve landscape patterns results in exacerbating the disequilibrium. Adoption of traditional commodity and reserve landscape patterns perpetuates the lack of resiliency to produce predictable commodity and amenity resource flows. The subsidies required by an active ecological management strategy that results in proper functioning landscape patterns would be substantially less, and the predictability of commodity and resource flows would be substantially greater.

(4) What are the probable trends of functions and processes for various landscape management futures? What will be the opportunities, tradeoffs, and consequences of these management futures with respect to biogeochemical processes, nutrient and carbon cycling, and long-term productivity?

Anthropogenic activities have substantially altered most biogeochemical processes. As a consequence, the ecological relationships of many native systems have been altered. The perpetuation of traditional commodity or reserve landscape patterns will likely result in increased potentials for altered succession/disturbance regimes and consequent loss of productive capability. In contrast, an active ecological management approach for proper functioning landscapes will stabilize biogeochemical processes and maintain or restore productivity.

One can legitimately ask if we could have answered these questions without this landscape assessment. Our answer is both yes and no: yes, we could have answered the questions that focused on the parts of the landscape system; and no, we could not have answered the complex multiple questions because we did not understand the ecological relationships and options for outcomes at multiple scales. In particular, we found that traditional reserve (that is, protection) patterns result in the same long-term outcome as traditional commodity patterns (that is, one of disequilibrium and simplification of landscape functions). Logic tells us these two patterns should be contrasting paradigms, yet their outcomes are similar. The loss of a landscape function — whether it is caused by selective removal of commodities, selective removal of a species through loss of populations or habitat, or selective removal of fire — creates disequilibrium and eventually people lose what they desired most from the system (for example, big trees), lose what they sought to protect (for example, native species), or are overcome by what they fought to suppress (for example, fires).

Traditional management strategies, which emphasize the management of landscape elements as though they were independent from each other as well as the spatial and temporal biophysical template, have disrupted ecological processes and functions throughout the Basin. As a result, the ecological states of most systems are currently in disequilibrium. That is, populations of many species having complex adaptations to native environments seem to be in decline, system responses to disturbances are becoming less predictable, and productivity of many systems seems to be declining, while risks to the production of human needs and values are increasing.

By modeling different future scenarios across the wide array of biophysical templates and current conditions we found two distinct potential outcomes. Scenarios with tendency to the traditional independent-limits management model result in loss of both resiliency and reliability in achieving three general groups of ecosystem management goals (Grumbine 1994; Kaufmann and others 1994; Haynes and others 1996). These goals are the simultaneous achievement of: (1) sustainability of native biodiversity and recovery of viable populations of species at risk; (2) sustainability of ecological integrity and health; and (3) production of human commodity and amenity values within the limits of the first two; all within the limits of landscape biophysical templates. We found that loss of resiliency and the inability to reliably achieve the simultaneous goals of ecosystem management is a direct result of disequilibrium between interacting ecological effects.

Landscapes trending toward disequilibrium tend to be dominated by human processes that control causes and effects for the selected variables of commodity production or value protection in ways very different from equilibrium dynamics. Effects of traditional harvest and roads such as high fuel accumulations from fire suppression in environments adapted to frequent fire, bare soil and surface water drainage from roads in environments adapted to full soil cover and subsoil water drainage, and lack of large emergent live or dead trees (snags) and associated cavity nesting and perching habitats, are examples of just such trends toward disequilibrium. In response, ecological causes and effects that differ from equilibrium dynamics reverberate throughout the key systems (hydrologic, carbon-nutrient, food web, and evolutionary). The departure from the expected promotes and effects of the equilibrium dynamics regime causes simplification of native species and

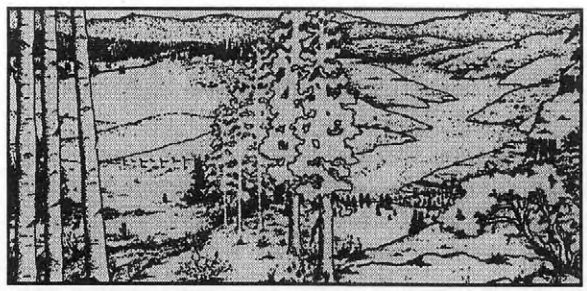
biophysical templates because of the many native species and biophysical templates that are not adapted to the changed regime. In concert with these interactions, and also adding to the causal effects of simplication, are the dispersal of toxic substances from various human activities resulting in decline in air and water quality. As a cumulative consequence, generalist and human-disturbance adapted biota dominate, along with poorly developed biophysical templates of low productivity (for instance shallow, poorly developed soils that result from erosion or straightened, intermittent stream channels resulting from bank degradation and flow regime disruption).

We conclude that traditional types of management that are based on independent limits may sustain human values within a limited array of biota and biophysical templates. This management model does not, however, have a tendency to sustain human values in dynamic equilibrium with high species diversity and biophysical capacity. In contrast, types of management based on ecological relationships and contextual opportunity and risk can represent, through human activities, the ecological cause and effects of equilibrium dynamics and provide the "best fit" to sustain the diversity of native and non-native biota, biophysical capacity, and human needs and values. This is exceedingly apparent in BLM/FS public wildland environments where the goals of ecosystem management are desired and resources for mitigation, subsidy, and recovery of system functions are at a premium. The ecological model can also be beneficially applied in urban, rural, and agricultural environments to sustain biophysical capacity and human values. (Allen and Hoekstra 1992, Naveh and Lieberman 1994).

Ecosystems have an astounding ability to recover, or to at least function in some modified capacity. If disruptions of key processes are removed or adjusted to represent native cause-and-effect relationships, the ecological states will eventually return to equilibrium. If not, systems will continue to operate but they will be in a perpetual state of disequilibrium in which the predictability of disturbance responses and the capacity to produce the values and needs of society is problematic. Our analyses of dynamic landscapes indicate that society can choose outcomes for landscape patterns within the Basin. The potential for working with Basin systems based on an equilibrium model still exists. Society's investment in an ecological model for strategic landscape conservation, production, restoration, and subsidies (to achieve proper functioning systems), can maintain some predictability and thus, the capacity of the systems to provide for human needs and values.

Fortunately, like ecosystems, people also have astounding resilience. As people broaden their understanding of ecological relationships, human dependence on the land, and options for the future, it is highly likely that they will be responsive.

As we conclude on this positive note, it is important to emphasize that the current landscape patterns are already producing disequilibrium effects. At the Basin scale we predicted that only 2 percent of the current condition has properly functioning landscape patterns (similar to the native pattern) with tendency to produce the effects of dynamic equilibrium. The other 98 percent resides in the traditional commodity or reserve patterns with tendency towards increased disequilibrium and associated effects of loss of resiliency, productivity, and increased severity or chronicity of disturbance.



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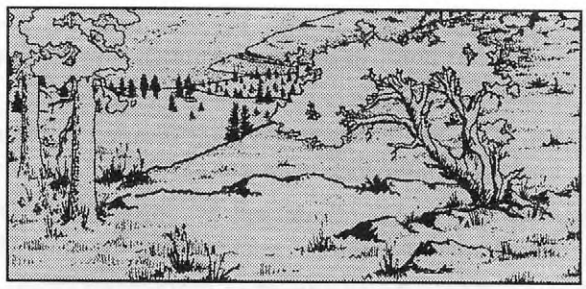
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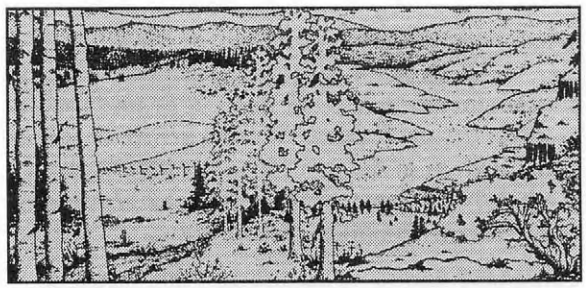
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GLOSSARY[1]

Aquatic integrity - a mosaic of well connected, high-quality water and habitats that support a diverse assemblage of native and desired non-native species, the full expression of potential life histories and taxonomic lineages, and the taxonomic and genetic diversity necessary for long-term persistence and adaptation in a variable environment.

Biogeochemical - the flow and interactions of biological and chemical processes in relation to organisms and their environments.

Biogeographic - the spatial distribution patterns of organisms in relation to changes through time (paleoecological, historical, current, and future).

Biological diversity - also commonly called biodiversity - the diversity of living things (species) and of life patterns and processes (ecosystem structures and functions). Includes genetic diversity, ecosystem diversity, landscape and regional diversity, and biosphere diversity (Grumbine 1992).

[1] The following sources were used to define the terms presented in this glossary: (1) Authors of the chapter; (2) Society for Range Management. 1989. A glossary of terms used in range management, 3rd ed. Denver, CO: Glossary Revision Special Committee, Publications Committee, Society for Range Management; (3) Lincoln, R.J.; Boxshall, G.A.; Clark, P.F. 1982. A dictionary of ecology, evolution and systematics. Cambridge: Cambridge Press. 298 p. (4) Raven, P.H.; Evert, R.F.; Eichhorn, S.E. 1986. Biology of plants. New York: Worth Publishers, Inc. 775 p. (5) American Geological Institute. 1962. Dictionary of geologic terms. Garden City, NY: Dolphin Books. (6) Literature referenced in this chapter.

Biophysical processes - (biophysics) the application of physics to the study of living organisms and systems.

Biophysical template - landscape patterns of composition and structure, with associated environmental gradients, and processes of change.

Changed biophysical template - biophysical systems that have the biotic or physical potentials of the historical range of variability (HRV), but have a different composition, structure, or disturbance regime than present during HRV.

Altered biophysical template - biophysical systems that do not have the biotic or physical potentials of the historical range of variability (HRV).

Bureau of Land Management and Forest Service (BLM/FS) land - public lands managed by the U.S. Department of Interior, Bureau of Land Management and the U.S. Department of Agriculture, Forest Service.

Columbia River Basin Succession Model (CRBSUM) subbasin clusters - a group of subbasins into five clusters that have somewhat similar urban/wildland interface conditions, ecological integrity, and management implications.

Composition - the amount of different elements or individuals within a whole. For landscapes or regions, this typically relates to the amount of certain kinds of vegetation, species populations, or land uses. For biotic communities, this typically relates to the amount of different types of biota or kinds of environments.

Cover type - a vegetation classification depicting a genera, species, group of species, or life form of tree, shrub, grass, or sedge, or a dominant physical feature (for example water or rock) or land use (for example urban or road). When a genera or species name is given to the cover type at a broad scale it is typically representative of a complex of species and genera with similar characteristics.

CRBSUM Action - a disturbance that results in the change of conditions on a pixel in a simulation year.

CRBSUM Phase - a finite length of time in which a management scenario applies.

CRBSUM Disturbance probability - a model probability of change that affects the condition of a successional class by altering the cover type, structural stage, or successional stage.

CRBSUM Scenario - the collective set of assumptions for management and other disturbances that describe a type of management.

Decreaser species - plant species of the potential vegetation that will decrease in relative amount when management-induced disturbance stresses (such as excessive livestock grazing pressure or alteration of fire frequency and severity) operate during drought and when management-induced disturbance stresses operate during and immediately after drought. The term is used particularly for plant species on rangelands.

Dewatering/dewater - the removal of water from a stream/river network, typically for irrigation, industrial, or human use. This removal commonly changes a network that developed by concentrating flows from stream/river branches to main-stems to main-stems branching to canals, which reduces the flow in the main-stems.

Disturbance - an effect of a planned human management activity, or unplanned native or exotic agent or event, that changes the state of a landscape element, landscape pattern, or regional composition.

Disturbance severity - the impact of the disturbance on the community as a whole.

Disturbance severity classes:

Lethal - disturbance that causes mortality to most of the upper layer or layers of vegetation and changes the structure.

Non-lethal - disturbance does not cause mortality to a substantial portion of the upper layer, removes susceptible individuals from all layers, and maintains the structure.

Mixed - disturbance causes a fine-scale mosaic of lethal and non-lethal effects that result in clump/gap mosaics of changed and maintained or unaffected structure.

Disturbance regime - the pattern of intervals between disturbance and severity of disturbance. For landscapes, this can be for a given disturbance, such as fire, or for a complex of disturbances.

Dominant - an organism exerting considerable influence upon a community by its size, abundance, or coverage.

Codominant - Codominance: the condition of having two equally dominant species in a plant community.

Subdominant - a species subordinate to the *dominant species of a community.*

Ecological element - the individual constituent of the whole. For example: vegetation patch, stream reach, road, city site, or large snag.

Ecological function - the activity or role performed by an organism or element in relation to other organisms, elements, or the environment. The ecological activity for which a given element, function, or process evolved. For example, snags function as habitats for some species, linked environments function as migration routes, predators function in the food chain, or fire functions to cycle nutrients in systems with slow decay rates.

Ecological integrity - the maintenance of native and desired non-native species and associated processes.

Ecological process - a series of actions, changes, or functions that produce a resulting condition for biota, elements, or the environment. For example succession, decay, photosynthesis, food chain, fire, drought, or flood.

Ecological Reporting Unit (ERU) - a large grouping of subwatersheds into thirteen areas within the ICB that have similar ecoregion and hydrologic characteristics.

Ecological Disequilibria/disequilibrium - a system that has unequal relationships of inputs and outputs that result in erratic (and unpredictable) successional patterns and associated responses to disturbance.

Ecological resiliency - ability of system biota and their environments to renew the cycle of functions and processes following disturbance. At a landscape scale the focus is on connections of the hydrologic and land system, carbon-nutrient system, food web, and evolutionary systems and their aggregate tendency towards equilibrium or disequilibrium in response to disturbance. Equilibrium systems have a dynamic balance of changing conditions that are somewhat predictable because of relatively consistent cause and effect responses that are limited by the capabilities of the biophysical system and inherent disturbance processes. Disequilibrium systems have relatively unpredictable changing conditions because of inconsistent cause and effect responses that are not limited by the capabilities of the biophysical system, because of inputs or extractions of energy or materials from outside the system.

Ecological predictability - causal agents of disturbance (such as fire, erosion, floods, grazing, harvest, predation, insects, and pathogens) produce "expected" effects that are consistent with the limitations of the biophysical system and inherent disturbance regimes (based on native, historical range of variability, or altered regime, as appropriate).

Ecological simplification - loss of inherent patterns of elements (such as native species, large trees, bunchgrasses, soil, or channel stability), mosaics (such as vegetation patch patterns, migration routes, or connected stream pools and runs), and succession/disturbance regimes (such as frequent non-lethal fire to infrequent lethal fire or high sinuosity streams to low sinuosity). These patterns evolved through time in association with development of biophysical capability and inherent disturbance to produce the "best fit" of elements, mosaics, and succession/disturbance regimes given the limitations of the biophysical system. Simplification results in loss of resiliency and associated predictability (or reliabilty) of system response. When landscape patterns are not consistent with the inherent biophysical limitations and disturbance processes the force of biophysical energy will eventually cause acute or chronic disturbances that result in reduced biophysical capabilities that are consistent with the changed disturbance regime. For example when fire exclusion results in high woody fuel levels and low herbaceous ground cover, that are inconsistent with the productivity of the soil, temperature, and precipitation regimes there will eventually be acute severe fire events or chronic erosion resulting in loss of nutrients and soil that will reduce productivity to a level consistent with the long interval fire regime.

Ecology - the relationship of species, including humans, and their environment.

Ecosystem management - 1. management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes necessary to sustain ecosystem composition, structure, and function (Haynes and others 1996). 2. Any land management system that seeks to protect viable populations of all native species, perpetuate natural-disturbance regimes on the regional scale, adopt a planning timeline of centuries, and allow human use at levels that do not result in long-term ecological degradation (Grumbine 1992).

Ecotone - a zone of integradation or interfingering, narrow or broad, between contiguous types of communities or environments.

Ecotypic variation - the variation within a species that is adapted to the variety of different habitats across the range of the species.

Encroachment - conditions where the succession/ disturbance regime have been changed to allow transition to dominance by species or structures that are not adapted to the biophysical succession/ disturbance regime.

Equilibria/equilibrium - a system that has cyclic successional patterns or multiple stable states, and associated response in disturbances.

Excessive livestock grazing pressure - Grazing pressure that results in a decline in physiological vigor of plants, typically observed as a decline in reproductive output (for example, seeds, rhizomes) and aboveground (for example, tiller production of grasses) and below ground (for example, root growth) growth. This decline in physiological vigor results in decreased ability of the plant to compete for resources and results in alteration of plant species composition in plant communities. The connotation of this phrase is negative. Note: the term "overgrazing" only appears in this document when it originated from literature cited in this document. For consistency, we attempted to use "excessive livestock grazing pressure" in this document to refer to what others typically call "overgrazing," or "heavy grazing".

Exotic plants; exotics; exotic - biota from a different geographic area or environment that would not have migrated to the affected geographic area, without the assistance of modern humans. These biota are typically transported by modern humans to a different geographic area that has suitable physical environments for survival and spread. They are transported at a much more rapid rate than would occur through expansion of the ranges of native biota. They are typically transported by humans without their native parasites or competitive biota, such that they become much more vigorous, and consequently are often more competitive than the native biota in the new area. These biota have typically adapted to the types of disturbances caused by humans.

Fire regime - the combination of severity of disturbance and frequency.

Fire frequency - the average of and variation in intervals between fire events.

Forestland health - conditions under which the integrity of the soil and ecological processes are sustained resulting in systems that maintain their diversity, resiliency, and productivity with associated sustainable human resource values.

Function - an activity for which a given element is designed. For landscapes, examples include human habitats, wildlife habitats, or corridors.

Future - a modeling scenario meant to describe a future outcome for land management.

Geomorphic - of, or pertaining to, the figure of the earth or the form of its surface; resembling the earth.

Grazing system - A specialization of grazing management that defines the periods of grazing and non-grazing. Source: Society for Range Management (1989).

Greater Yellowstone Ecosystem (GYE) - BLM- and FS-administered lands in the subbasins of the Greater Yellowstone area.

Heavy grazing - A comparative term which indicates that the stocking rate of a pasture is relatively greater than that of other pastures. Often erroneously used to mean overuse. Source: Society for Range Management (1989). Note: The phrase "heavy grazing" was only used in this document when used by other authors cited in this document. For consistency, we attempted to use "excessive livestock grazing pressure" in this document to refer to what others typically called "overgrazing", or "heavy grazing".

Historic - the approximate 1,000-year time period prior to Euro-American settlement (substantial effects in the Basin assumed to have begun by the mid 1800s).

Early Historic - the post-Euro-American settlement period, specificallly the 1800s.

Recent Historic - the post-Euro-American settlement period, specificallly the 1900s. The approximate time period since 1920, when we have records of vegetation mapping from aerial photography. Data from this time period and the current are commonly used to correlate recent historic human management regimes with the pattern and composition changes in vegetation and succession/disturbance regimes.

Historic range of variability (HRV) - the variability of regional or landscape composition, structure, and disturbances, during a period of time of several cycles of the common disturbance intervals, and similar environmental gradients. The historic 1000 year time period, or a subset of that period, is commonly used as the "window" for HRV. The objective is to understand the cycles and relationships of communities with biophysical conditions of climate, geomorphology, and species adaptations of a historic time period, that is somewhat similar to our current time period. This period is generally assumed to be the most appropriate benchmark period for describing the dynamics of the biophysical template and succession/disturbance regimes. This benchmark provides an understanding of dynamics in somewhat similar climate and geologic periods prior to the mechanical and technological affects of current human settlement. The affects of aboriginal man (Native Americans) are considered part of that variability. Periods with different climate, geomorphic processes, and species evolution are compared with HRV to understand the context for the historic and current conditions. Future changes in climate, geomorphology, and associated species relationships are compared with HRV and earlier periods to help provide a context for future conditions.

Hydrologic integrity - a network of streams, along with their unique ground water ecosystems, within the broader landscape where the upland, floodplain, and riparian areas have resilient vegetation, where the capture, storage, and release of water limits the effects of sedimentation and erosion, and where infiltration, percolation, and nutrient cycling provide for diverse and productive aquatic and terrestrial environments.

Hydrologic unit codes (HUCs) - a coding system with 2 numbers assigned to each level. The broadest level is the region, 2nd is the subregion, 3rd is the Basin, 4th is the subbasin, 5th is the watershed, and 6th is the subwatershed. Each level is delineated based on hydrologic boundaries.

Increaser - Plant species that will increase in relative amount when management induced disturbance stresses (such as excessive livestock grazing pressure or alteration of fire frequency and severity) operate and when management-induced disturbance stresses operate during and immediately after drought. The term is used particularly for plant species on rangelands.

Land ownership classes - a classification of federal, state, and other-agency administered public lands, private lands, and tribal lands. For the Basin, these classes are incorporated into the management classes.

Landscape integrity - a pattern of hierarchically interconnected land and water processes, structure, and change that maintain aquatic, terrestrial, and hydrologic integrity.

Landscape Characterization Area (LCA) - an extended area surrounding the Basin to the ecoregion section boundaries.

Landscape health - the "best fit" of the dynamic interactions of human land use, biodiversity, and ecosystem health that are in balance with the limitations of the biophysical system and inherent disturbance processes. The assessment of landscape health is based on the concept of proper functioning systems at a landscape scale. Proper functioning systems occur where ecological interactions are in a dynamic balance, such that the ecological systems (hydrologic and land, carbon-nutrient, food web, and evolution) have resilient and relatively predictable responses to disturbance, while sustaining human resource values (both amenity and commodity).

Landscape - a spatially heterogenous area with repeating patterns of elements and associated disturbance regimes, with similar climate and geomorphology.

Landscape ecology - the relationships of structure, function, and change in a heterogeneous land area composed of interacting ecosystems. Structure, function, and change refer to the patterns and processes of terrestrial, aquatic, hydrologic, social, and economic systems across space and through time.

Land unit - a combination of the potential vegetation type (PVT) a succession class that defines a unit of land for modeling change.

Management disturbances - intentional, planned human disturbance that changes the structure and composition of a landscape element, landscape pattern, or regional composition. Examples include: timber harvest, thinning, range improvements, livestock grazing, prescribed fire planned ignition, prescribed fire unplanned ignition, fire suppression, or road building and maintenance.

Management regions - a geographic area of class of ownership and type of management; EEIS, UCRB, and GYE.

Management region - the collective delineation of land that are modeled with similar assumptions relative to management objectives.

Management classes - a class of land ownership and type of management.

Management - the collective set of assumptions that affect the outcomes and interactions of disturbance and change.

Mosaic - the contiguous spatial arrangement of elements within an area. For regions this is typically the upland vegetation patches, large urban areas, large bodies of water, and large areas of barren ground or rock. However, regional mosaics can also be land ownership, habitat patches, land use patches, or other elements. For landscapes, this is typically the spatial arrangement of upland vegetation patches, riparian vegetation strips, roads, urban areas, water, barren ground, or rock. However, landscape mosaics can also be land ownership, habitat patches, land use patches, or other elements.

Native - plants or animals that are indigenous to a given place; synonymous with the HVR system or regime, the pre-Euro-American settlement system.

Native - biota that have their origin in the geographic area. These biota have adapted through evolutionary time with associated biota, their environment, and native disturbances.

Overgrazing - Continued heavy grazing that exceeds the recovery capacity of the plant community and creates a deteriorated range. Source: Society for Range Management (1989). Note: The term overgrazing was only used in this document when used by other authors cited in this document. For consistency, we attempted to use "excessive livestock grazing pressure" in this document to refer to what others typically called "overgrazing", or "heavy grazing".

Paleoecological - relationships between biota and their environments through geologic time.

Pattern - the composite of elements of a landscape in a characteristic spatial and temporal design. For landscapes, this is typically the characteristic pattern of topography, vegetation patches, disturbances, land use, and change through time.

Pedogenic - development and dynamics of soil formation.

Physiognomic type - also referred to as physiognomic community or vegetation type - a group of cover types in the same seral stage that have similar response to disturbance and succession processes.

Potential vegetation type (PVT)- A potential vegetation type is a kind of physical and biological environment, that produces a kind of vegetation, such as the dry Douglas-fir (*Pseudotsuga menziesii*) type. Potential vegetation types are identified by indicator species of similar environmental

conditions. For example, Douglas-fir (*Pseudotsuga menziesii*) indicates a cooler and moister environment than ponderosa pine (*Pinus ponderosa*). Because of growth, mortality, and disturbance of the vegetation, many other kinds of vegetation will occur on this type through time. In many cases the indicator species will not be present, due to disturbance. Douglas-fir is simply an indicator, and name, for the kind of physical and biological environment stratification that is used for prediction of response.

Potential vegetation group (PVG) - a group of potential vegetation types that have similar environmental conditions and are dominated by similar types of plants (for example the dry shrub PVG). They are often grouped by similar types of life forms.

Process - a series of actions, changes, or functions that produce a result. For landscapes, examples include vegetation succession, decay, photosynthesis, food chain relationships, and disturbance processes, such as fire, drought, or wind.

Quaternary - time period that includes the Pleistocene glacial and interglacial periods, and recent period since glacial recession.

Rangeland health - conditions under which the integrity of the soil and ecological processes are sustained in systems that maintain their diversity, resiliency, and productivity with associated sustainable human resource values.

Region - the broadest scale of landscape ecology composed of a coarse-grained pattern of connected landscapes, with contrasting boundaries, that have a similar macroclimate and sphere of human activity and interest.

Retrogression - the return along the successional path to an earlier successional community or an altered simpler state.

Scalar - a quantity, as mass, length, time, or temperature, completely specified by a number on an appropriate scale.

Seral stage - a stage of succession.

Early-seral - communities that occur early in the successional path and generally have less complex structural development than later successional communities.

Mid-seral - communities that occu in the middle of the successional path.

Late-seral - communities that occurr in the later stage of the successional path with mature, generally larger individuals.

Simulation - to project or estimate the future or historic conditions or outcomes of various attributes.

Sodicity - the concentration of exchangeable sodium in soil. It can be measured by the sodium adsorption ration (SAR), which is the proportion of sodium relative to other cations.

Structural stage - a stage of development of a vegetation community that is classified on the dominant processes of growth, development, competition, and mortality.

Structure - the manner which parts are arranged to form a whole. For landscapes, this typically relates to the spatial arrangements of elements. For example, the spatial arrangement of patches of vegetation. For biotic communities, this typically relates to the spatial arrangements of individual biota in relation to their environment, including both live and dead components.

Subbasin - the fourth delineation within the hydrologic unit code system. Provides a delineation generally of a river, or group of rivers, that flow into a basin.

Subbasin groups - a specific grouping, for landscape assessment reports, of subbasins into 6 geographic areas that generally represent groups of ERUs.

Subwatershed - the sixth delineation within the hydrologic unit code system. Provides a delineation of a group of streams, that flow into a watershed.

Succession - the development of biotic communities following disturbances that produce an earlier successional community.

Successional path - the sequence of successional communities. This may follow one path or multiple paths depending on competition, mortality of individuals, and non-lethal disturbances. There may be one endpoint or multiple endpoints depending on the degree of change in climate and soil properties.

Terrestrial community type - also referred to as terrestrial vegetation type - a group of cover types in the same seral stage that have similar characteristics for interpretation of terrestrial habitat values.

Terrestrial integrity - a mosaic of plant and animal communities, consisting of well connected, high-quality habitats that support a diverse assemblage of native and desired non-native species, the full expression of potential life histories and taxonomic lineages, and the taxonomic and genetic diversity necessary for long-term persistence and adaptation in a variable environment.

Unit - a set of similar elements. The land unit is an area of land that is homogeneous (at the scale of mapping) relative to the features being mapped (typically relating to soil, climate, landform, and/or existing or potential vegetation). This mapping is typically based on a classification of the attributes. For landscapes, examples include vegetation type, community type, habitat type, soil type, topographic type, landform, elevation zone, climate, or species group. These elements do not need to be contiguous spatially or temporally. The elements often occur in disjunct locations across the landscape, region, or through time.

Unplanned disturbance - unplanned native or exotic disturbance that changes the structure and composition of a landscape element, landscape pattern, or regional composition. Examples include: wildfire, windthrow, exotic plant invasion, exotic insect or disease mortality, native insect or disease mortality, freezing mortality, drought mortality, native or exotic wildlife herbivory, erosion, avalanche, volcanics, or mudflow.

Volcanics or volcanism - made of minerals derived from volcanos The term usually ordinarily includes all natural processes resulting in the formation of volcanoes, volcanic rocks, lava flows, etc.

Watershed - the fifth delineation within the hydrologic unit code system. Provides a delineation of a river or group of streams, that flow into a subbasin.

Continue

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APPENDIX 3-A

Aggregation of Native (HRV[1]) and Current Potential Vegetation Types (PVTs) Into Potential Vegetation Groups (PVGs).

Potential Vegetation Group	Native and Current Potential Vegetation Type
Agricultural	Dry Crop / Pasture Land[2]
	Irrigated Crop Land[2]
Alpine	Alpine Shrub-Herbaceous
Cold Forest	Mountain Hemlock East Cascades[5]
	Mountain Hemlock Inland[5]
	Mountain Hemlock / Red Fir[5]
	Spruce-Fir Dry with Aspen
	Spruce-Fir Dry without Aspen
	Spruce-Fir (LPP > WBP[3])
	Spruce-Fir (WBP > LPP[4])
	Whitebark Pine / Subalpine Larch North
	Whitebark Pine / Subalpine Larch South
Cool Shrub	Mountain Big Sagebrush-Mesic-East
	Mountain Big Sagebrush-Mesic-East with Conifer
	Mountain Big Sagebrush-Mesic-West
	Mountain Big Sagebrush Mesic West with Juniper
	Mountain Shrub
Dry Forest	Dry Douglas-fir with Ponderosa Pine
	Dry Douglas-fir without Ponderosa Pine
	Dry Grand Fir / White Fir
	Interior Ponderosa Pine
	Lodgepole Pine-Oregon
	Lodgepole Pine-Yellowstone
	Pacific Ponderosa Pine / Sierra Nevada Mixed-Conifer
Dry Grass	Fescue Grassland
	Fescue Grassland with Conifer
	Wheatgrass Grassland

Potential Vegetation Group	Native and Current Potential Vegetation Type
Dry Shrub	Antelope Bitterbrush
	Big Sagebrush
	Big Sagebrush-Cool
	Big Sagebrush-Warm
	Low Sagebrush-Mesic
	Low Sagebrush-Mesic with Juniper
	Low Sagebrush-Xeric
	Low Sagebrush-Xeric with Juniper
	Salt Desert Shrub
	Threetip Sagebrush
Moist Forest	Cedar / Hemlock East Cascades
	Cedar / Hemlock Inland
	Grand Fir / White Fir East Cascades
	Grand Fir / White Fir Inland
	Moist Douglas-fir
	Pacific Silver Fir
	Spruce-Fir Wet
Riparian Herb	Riparian Graminoid
	Riparian Sedge
Riparian Shrub	Mountain Riparian Low Shrub
	Saltbrush Riparian
	Willow / Sedge
Riparian Woodland	Aspen
	Cottonwood Riverine
Rock	Barren
Urban	Urban[2]
Water	Water[2]
Woodland	Juniper
	Limber Pine
	Mountain Mahogany
	Mountain Mahogany with Big Sagebrush
	White Oak

[1]Native and HRV are synonymous terms, defined in this chapter as the pre-Euro-American settlement regime.

[2]Indicates a PVT that did not exist in the native regime.

[3] Lodgepole pine more abundant than Whitebark pine.

[4] Whitebark pine more abundant than Lodgepole pine.

[5]Shifted from moist forest to cold forest in 2nd version of assessment PVGs.

APPENDIX 3-B

Aggregation of broad-scale terrestrial communities, cover types, and structural stages.

Terrestrial Community	Cover Type	Structural Stage[1]
Agricultural	Cropland / Hay / Pasture	Closed Herbland[2]
		Agricultural
Alpine	Alpine Tundra	Closed Low Shrub
		Open Low Shrub
Early-seral Lower Montane Forest	Interior Ponderosa Pine	Stand Initiation Forest
	Pacific Ponderosa Pine	Stand Initiation Forest
Early-seral Montane Forest	Shrub or Herb / Tree Regen	Closed Herbland
		Open Low Shrub
		Closed Mid Shrub
		Open Tall Shrub
	Pacific Silver Fir / Mountain Hemlock	Stand Initiation Forest
	Grand Fir / White Fir	Stand Initiation Forest
	Red Fir	Stand Initiation Forest
	Interior Douglas-fir	Stand Initiation Forest
	Western Larch	Stand Initiation Forest
	Western White Pine	Stand Initiation Forest
	Lodgepole Pine	Stand Initiation Forest
	Western Redcedar / Western Hemlock	Stand Initiation Forest
	Sierra Nevada Mixed-Conifer	Stand Initiation Forest
Early-seral Subalpine Forest	Whitebark Pine / Subalpine Larch	Stand Initiation Forest
	Mountain Hemlock	Stand Initiation Forest
	Engelmann Spruce / Subalpine Fir	Stand Initiation Forest
	Whitebark Pine	Stand Initiation Forest
Exotic Herbland	Exotic Forbs / Annual Grass	Open Herbland
		Closed Herbland
Late-seral Lower Montane Multi-layer Forest	Interior Ponderosa Pine	Old Multi-strata Forest
	Pacific Ponderosa Pine	Old Multi-strata Forest
Late-seral Lower Montane Single-layer Forest	Interior Ponderosa Pine	Old Single-strata Forest
	Pacific Ponderosa Pine	Old Single-strata Forest

Terrestrial Community	Cover Type	Structural Stage[1]
Late-seral Montane Multi-layer Forest	Grand Fir / White Fir	Old Multi-strata Forest
	Interior Douglas-fir	Old Multi-strata Forest
	Western Larch	Old Multi-strata Forest
	Lodgepole Pine	Old Multi-strata Forest
	Western Redcedar / Western Hemlock	Old Multi-strata Forest
	Sierra Nevada Mixed-Conifer	Old Multi-strata Forest
	Pacific Silver Fir / Mountain Hemlock	Old Multi-strata Forest
	Red Fir	Old Multi-strata Forest
Late-seral Montane Single-layer Forest	Grand Fir / White Fir	Old Single-strata Forest
	Interior Douglas-fir	Old Single-strata Forest
	Western Larch	Old Single-strata Forest
	Western Larch	Old Single-strata Forest
	Lodgepole Pine	Old Single-strata Forest
	Western Redcedar / Western Hemlock	Old Single-strata Forest
	Sierra Nevada Mixed-Conifer	Old Single-strata Forest
Late-seral Subalpine Multi-layer Forest	Mountain Hemlock	Old Multi-strata Forest
	Whitebark Pine	Old Multi-strata Forest
	Whitebark Pine / Subalpine Larch	Old Multi-strata Forest
	Engelmann Spruce / Subalpine Fir	Old Multi-strata Forest
Late-seral Subalpine Single-layer Forest	Mountain Hemlock	Old Single-strata Forest
	Whitebark Pine	*Old Single-strata Forest*
Mid-seral Lower Montane Forest	Interior Ponderosa Pine	Stem Exclusion Open Canopy Forest
		Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Pacific Ponderosa Pine	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
Mid-seral Montane Forest	Pacific Silver Fir / Mountain Hemlock	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
	Grand Fir / White Fir	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
	Red Fir	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest

Terrestrial Community	Cover Type	Structural Stage[1]
	Interior Douglas-fir	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
	Western Larch	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
	Western White Pine	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
	Lodgepole Pine	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
	Western Redcedar / Western Hemlock	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
	Sierra Nevada Mixed-Conifer	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
Mid-seral Subalpine Forest	Whitebark Pine / Subalpine Larch	Stem Exclusion Open Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
	Mountain Hemlock	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
	Engelmann Spruce / Subalpine Fir	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
	Whitebark Pine	Stem Exclusion Closed Canopy Forest
		Understory Reintiation Forest
		Young Multi-strata Forest
Riparian Herbland	Herbaceous Wetlands	Open Herbland
		Closed Herbland
Riparian Shrubland	Shrub Wetlands	Closed Low Shrub
		Open Low Shrub
		Open Mid Shrub
		Closed Mid Shrub
		Closed Tall Shrub
Riparian Woodland	Aspen	Stand Initiation Forest
		Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest

Terrestrial Community	Cover Type	Structural Stage[1]
	Cottonwood / Willow	Stand Initiation Forest
		Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
		Old Multi-strata Forest
Rock/Barren	Barren	Rock
Upland Herbland	Wheatgrass Bunchgrass	Open Herbland
		Closed Herbland
	Native Forb	Open Herbland
		Closed Herbland
	Fescue Bunchgrass	Open Herbland
		Closed Herbland
Upland Shrubland	Antelope Bitterbrush / Bluebunch Wheatgrass	Closed Low Shrub
	Bluebunch Wheatgrass	
	Mountain Mahogany	Closed Low Shrub
		Open Mid Shrub
	Mountain Big Sagebrush	Closed Low Shrub
		Open Mid Shrub
		Closed Mid Shrub
	Low Sagebrush	Closed Low Shrub
		Open Low Shrub
	Salt Desert Shrub	Closed Low Shrub
		Open Low Shrub
		Open Mid Shrub
	Chokecherry / Serviceberry / Rose	Closed Low Shrub
		Open Low Shrub
		Open Mid Shrub
		Open Tall Shrub
	Big Sagebrush	Closed Herbland
		Closed Low Shrub
		Open Low Shrub
		Open Mid Shrub
		Closed Mid Shrub
Upland Woodland	Juniper Woodlands	Stand Initiation Woodland
		Understory Reintiation Woodland
		Young Multi-strata Woodland
		Old Multi-strata Woodland
		Old Single-strata Woodland.

Terrestrial Community	Cover Type	Structural Stage[1]
	Mixed-Conifer Woodlands	Stand Initiation Woodland
		Stem Exclusion Woodland
		Understory Reinitiation Woodland
		Young Multi-strata Woodland
		Old Multi-strata Woodland
	Juniper / Sagebrush	Stand Initiation Woodland
		Understory Reinitiation Woodland
		Young Multi-strata Woodland
		Old Single-strata Woodland
	Limber Pine	Stand Initiation Forest
		Stem Exclusion Open Canopy Forest
		Understory Reintiation Forest
		Old Multi-strata Forest
	Oregon White Oak	Stand Initiation Woodland
		Understory Reinitiation Woodland
		Young Multi-strata Woodland
		Old Multi-strata Woodland
		Old Single-strata Woodland
Urban	Urban	Urban
Water	Water	Water

[1]See appendix 3-G for description of structural stages.

[2]The crosswalk between structure, cover type, and terrestrial community is simplified in this appendix. For more detailed crosswalk see metadata, on file with: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar, Walla Walla, WA 99362.

APPENDIX 3–C

Cross tabulation of broad-scale physiognomic types, cover types, and structural stages.

Physiognomic Type with Shade-Tolerance Modifer	Cover Type	Structural Stage[1]
Agricultural	Cropland / Hay / Pasture	Agricultural
		Closed Herbland
Alpine	Alpine Tundra	Closed Low Shrub
		Open Low Shrub
Early-seral Shade-intolerant Forest	Interior Ponderosa Pine	Stand Initiation Forest
	Lodgepole Pine	Stand Initiation Forest
	Pacific Ponderosa Pine	Stand Initiation Forest
	Shrub or Herb / Tree Regen	Closed Herbland
		Closed Mid Shrub
		Open Low Shrub
		Open Tall Shrub
	Western Larch	Stand Initiation Forest
	Western White Pine	Stand Initiation Forest
	Whitebark Pine / Subalpine Larch	Stand Initiation Forest
	Whitebark Pine	Stand Initiation Forest
Early-seral Shade-tolerant Forest	Engelmann Spruce / Subalpine Fir	Stand Initiation Forest
	Grand Fir / White Fir	Stand Initiation Forest
	Interior Douglas-fir	Stand Initiation Forest
	Mountain Hemlock	Stand Initiation Forest
	Pacific Silver Fir / Mountain Hemlock	Stand Initiation Forest
	Red Fir	Stand Initiation Forest
	Sierra Nevada Mixed-Conifer	Stand Initiation Forest
	Western Redcedar / Western Hemlock	Stand Initiation Forest
Exotic Herbland	Exotic Forbs / Annual Grass	Closed Herbland
		Open Herbland
Late-seral Shade-intolerant Multi-layer Forest	Interior Ponderosa Pine	Old Multi-strata Forest
	Lodgepole Pine	Old Multi-strata Forest
	Pacific Ponderosa Pine	Old Multi-strata Forest
	Western Larch	Old Multi-strata Forest
	Western White Pine	Old Multi-strata Forest
	Whitebark Pine / Subalpine Larch	Old Multi-strata Forest
	Whitebark Pine	Old Multi-strata Forest

Physiognomic Type with Shade-Tolerance Modifer	Cover Type	Structural Stage[1]
Late-seral Shade-intolerant Single-layer Forest	Interior Ponderosa Pine	Old Single-strata Forest
	Lodgepole Pine	Old Single-strata Forest
	Pacific Ponderosa Pine	Old Single-strata Forest
	Western Larch	Old Single-strata Forest
	Western White Pine	Old Single-strata Forest
	Whitebark Pine	Old Single-strata Forest
Late-seral Shade-tolerant Multi-layer Forest	Engelmann Spruce / Subalpine Fir	Old Multi-strata Forest
	Grand Fir / White Fir	Old Multi-strata Forest
	Interior Douglas-fir	Old Multi-strata Forest
	Mountain Hemlock	Old Multi-strata Forest
	Pacific Silver Fir / Mountain Hemlock	Old Multi-strata Forest
	Red Fir	Old Multi-strata Forest
	Sierra Nevada Mixed-Conifer	Old Multi-strata Forest
	Western Redcedar / Western Hemlock	Old Multi-strata Forest
Late-seral Shade-tolerant Single-layer Forest	Grand Fir / White Fir	Old Single-strata Forest
	Interior Douglas Fir	Old Single-strata Forest
	Mountain Hemlock	Old Single-strata Forest
	Sierra Nevada Mixed-Conifer	Old Single-strata Forest
	Western Redcedar / Western Hemlock	Old Single-strata Forest
Mid-seral Shade-intolerant Forest	Interior Ponderosa Pine	Stem Exclusion Closed Canopy Forest
		Stem Exclusion Open Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Lodgepole Pine	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Pacific Ponderosa Pine	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Western Larch	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Western White Pine	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Whitebark Pine / Subalpine Larch	Stem Exclusion Open Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Whitebark Pine	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest

Physiognomic Type with Shade-Tolerance Modifer	Cover Type	Structural Stage[1]
Mid-seral Shade-tolerant Forest	Engelmann Spruce / Subalpine Fir	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Grand Fir / White Fir	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Interior Douglas-fir	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Mountain Hemlock	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Pacific Silver Fir / Mountain Hemlock	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Red Fir	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Sierra Nevada Mixed-Conifer	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Western Redcedar / Western Hemlock	Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
Riparian Herbland	Herbaceous Wetlands	Closed Herbland
		Open Herbland
Riparian Shrubland	Shrub Wetlands	Closed Low Shrub
		Closed Mid Shrub
		Closed Tall Shrub
		Open Low Shrub
		Open Mid Shrub
Riparian Woodland	Aspen	Stand Initiation Forest
		Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest
	Cottonwood / Willow	Old Multi-strata Forest
		Stand Initiation Forest
		Stem Exclusion Closed Canopy Forest
		Understory Reinitiation Forest
		Young Multi-strata Forest

Physiognomic Type with Shade-Tolerance Modifer	Cover Type	Structural Stage[1]
Rock / Barren	Barren	Rock
Upland Herbland	Wheatgrass Bunchgrass	Closed Herbland
		Open Herbland
	Fescue-Bunchgrass	Closed Herbland
		Open Herbland
	Native Forb	Closed Herbland
		Open Herbland
Upland Shrubland	Antelope Bitterbrush / Bluebunch Wheatgrass Big Sagebrush	Closed Low Shrub
		Closed Low Shrub
		Closed Mid Shrub
		Open Low Shrub
		Open Mid Shrub
	Chokecherry / Serviceberry / Rose	Closed Low Shrub
		Open Low Shrub
		Open Mid Shrub
		Open Tall Shrub
	Low Sagebrush	Closed Low Shrub
		Open Low Shrub
	Mountain Big Sagebrush	Closed Low Shrub
		Closed Mid Shrub
		Open Mid Shrub
	Mountain Mahogany	Closed Low Shrub
		Open Mid Shrub
	Salt Desert Shrub	Closed Low Shrub
		Open Low Shrub
		Open Mid Shrub
Upland Woodland	Juniper / Sagebrush	Old Single-strata Woodland
		Stand Initiation Woodland
		Understory Reinitiation Woodland
		Young Multi-strata Woodland
	Juniper Woodlands	Old Multi-strata Woodland
		Old Single-strata Woodland
		Stand Initiation Woodland
		Understory Reinitiation Woodland
		Young Multi-strata Woodland
	Limber Pine	*Old Multi-strata Forest*
		Stand Initiation Forest
		Stem Exclusion Open Canopy Forest
		Understory Reinitiation Forest

Physiognomic Type with Shade-Tolerance Modifer	Cover Type	Structural Stage[1]
	Mixed-Conifer Woodlands	Old Multi-strata Woodland
		Stand Initiation Woodland
		Stem Exclusion Woodland
		Understory Reinitiation Woodland
		Young Multi-strata Woodland
	Oregon White Oak	Old Multi-strata Woodland
		Old Single-strata Woodland
		Stand Initiation Woodland
		Understory Reinitiation Woodland
		Young Multi-strata Woodland
Urban	Urban	Urban
Water	Water	Water

[1] The crosswalk between structure, cover type, and physiognomic type is simplified in this appendix. For more detailed crosswalk see metadata, on file with: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar, Walla Walla, WA 99362..

APPENDIX 3-D

Physiognomic type is a plant community of vegetation sharing characteristics, features, or appearance. Four progressions of data reduction with respect to physiognomic types are outlined in this appendix; from left to right, the data groupings reduce from most simplistic to most complex. Each of these physiognomic type groupings were used in our analysis of the Basin and are applied in differing circumstances throughout the Landscape Dynamics chapter. Structural stage is also included in the table in order to provide pertinent information and clarification for the reader.

Table 3D-1—Physiognomic type reduction and corresponding structural stage.

Physiognomic Group	Physiognomic Type Group	Physiognomic Type	Physiognomic Type with Shade-Tolerance Modifier	Structural Stage
Agriculture	Agriculture	Agricultural	Agricultural	Agricultural
				Closed Herbland
NU[1]	Herbland	Alpine	Alpine	Closed Low Shrub
				Open Low Shrub
Forest/Woodland Early-seral	Early-seral Forest	Early-seral Forest	Early-seral Shade-intolerant Forest	Closed Herbland
				Closed Mid Shrub
				Open Low Shrub
				Open Tall Shrub
				Stand Initiation Forest
Forest/Woodland Early-seral	Early-seral Forest	Early-seral Forest	Early-seral Shade-tolerant Forest	Stand Initiation Forest
	Exotics	Exotic Herbland	Exotic Herbland	Closed Herbland
				Open Herbland
Forest/Woodland Late-seral Multi-layer	Late-seral Multi-layer Forest	Late-seral Multi-layer Forest	Late-seral Shade-intolerant Forest Multi-layer	Old Multi-strata Forest
Forest/Woodland Late-seral Single-layer	Late-seral Single-layer Forest	Late-seral Single-layer Forest	Late-seral Shade-intolerant Single-layer Forest	Old Single-strata Forest
Forest/Woodland Late-seral Multi-layer	Late-seral Multi-layer Forest	Late-seral Multi-layer Forest	Late-seral Shade-tolerant Multi-layer Forest	Old Multi-strata Forest
Forest/Woodland Late-seral Single-layer	Late-seral Single-layer Forest	Late-seral Single-layer Forest	Late-seral Shade-tolerant Single-layer Forest	Old Single-strata Forest
Forest/Woodland Mid-seral	Mid-seral Shade-intolerant Forest	Mid-seral Forest	Mid-seral Shade-intolerant Forest	Stem Exclusion Closed Canopy Forest
				Stem Exclusion Open Canopy Forest
				Understory Reinitiation Forest
				Young Multi-strata Forest

Physiognomic Group	Physiognomic Type Group	Physiognomic Type	Physiognomic Type with Shade-Tolerance Modifier	Structural Stage
Forest/Woodland Mid-seral	Mid-seral Shade-tolerant Forest	Mid-seral Forest	Mid-seral Shade-tolerant Forest	Stem Exclusion Closed Canopy Forest
				Understory Reinitiation Forest
				Young Multi-strata Forest
Herbland	Herbland	Riparian Herbland	Riparian Herbland	Closed Herbland
				Open Herbland
Low Shrub	Shrubland	Riparian Shrubland	Riparian Shrubland	Closed Low Shrub
Mid Shrub				Closed Mid Shrub
Tall shrub				Closed Tall Shrub
				Open Low Shrub
				Open Mid Shrub
				Open Tall Shrub
Forest/Woodland Early-seral	Woodland	Early-seral Riparian Woodland	Riparian Woodland	Stand Initiation Forest
Forest/Woodland Late-seral		Late-seral Riparian Woodland		Understory Reinitiation Forest
				Old Multi-strata Forest
Forest/Woodland Mid-seral	Woodland	Mid-seral Riparian Woodland		Young Multi-strata Forest
				Stem Exclusion Closed Canopy Forest
Rock	Rock	Rock / Barren	Rock / Barren	Rock
Herbland	Herbland	Upland Herbland	Upland Herbland	Closed Herbland
Low Shurb	Shrubland	Upland Shrubland	Upland Shrubland	Closed Low Shrub
Mid Shrub				Closed Mid Shrub
Tall Shrub				Closed Tall Shrub
				Open Low Shrub
				Open Mid Shrub
				Open Tall Shrub
Forest/Woodland Early-seral	Woodland	Early-seral Woodland	Upland Woodland	Stand Initiation Forest
				Stand Initiation Woodland
Forest/Woodland Late-seral		Late-seral Woodland		Old Multi-strata Forest
				Old Multi-strata Woodland
				Old Single-strata Woodland
				Understory Reinitiation Forest
				Understory Reinitiation Woodland
Forest/Woodland Mid-seral		Mid-seral Woodland		Young Multi-strata Woodland
				Stem Exclusion Open Canopy Forest
				Stem Exclusion Woodland
Urban	Urban	Urban	Urban	Urban
Water	Water	Water	Water	Water

[1]NU = Not Used, there was no change from the historical to the current period so category was not used in this data set.

APPENDIX 3-E

Broad-scale cover types

Cover Type	Description
Alpine Tundra	*Phyllodoce* spp. (low shrubs)
Aspen	*Populus tremuloides*
Barren	Rock / Barrenlands
Big Sagebrush	*Artemisia tridentata wyomingensis* *Artemisia tridentata tridentata / Elymus cinereus* *Artemisia tripartita / Agropyron cristatum* *Artemisia tripartita* / Exotic Herbs *Artemisia tridentata tridentata / Agropyron* spp. *Artemisia tridentata tridentata / Bromus tectorum* *Artemisia* spp. / *Bromus tectorum* *Artemisia tripartita*
Bitterbrush / Bluebunch Wheatgrass	*Purshia tridentata / Bromus tectorum* *Purshia tridentata / Agropyron spicatum*
Chokecherry / Serviceberry / Rose	*Prunus virginiana / Amelanchier alnifolia / Rosa* spp.
Cottonwood / Willow	*Populus trichocarpa / Salix* spp. *Populus* spp. / *Cornus* spp. *Populus* spp. / *Poa pratensis*
Cropland / Hay / Pasture	Dryland Crop Dryland Pasture / Hayland Irrigated Crop Irrigated Pasture / Hayland
Engelmann Spruce / Subalpine Fir	*Picea engelmannii / Abies lasiocarpa*
Exotic Forbs / Annual Grass	Exotic Forbs Exotic Grass (*Bromus tectorum / Taeniatherum caput-medusae / Poa secunda*) *Elymus caput-mCA/* POSE)²*edusae/Poa secunda*) Exotic Herbaceous Exotic Herbs Exotic Perennial Grass

Cover Type	Description
Fescue-Bunchgrass	*Festuca idahoensis* / *Agropyron* spp.
	Low Productivity Perennial Grass
	Perennial Native Bunchgrass
	Perennial Native Herbaceous
	Seeded Native Grass (*Agropyron spicatum* / *Festuca idahoensis*)
	Seeded Native Grass (*Poa secunda* / *Agropyron spicatum*)
	Small Perennial Grass
Grand Fir / White Fir	*Abies grandis* / *Abies concolor*
Herbaceous Wetlands	*Carex nebraskensis*
	Carex rostrata / *Carex aquatilis*
	Grass / *Carex* spp.
	Elymus spp.
Interior Douglas-fir	*Pseudotsuga menziesii* var. *glauca*
	Pseudotsuga menziesii / *Abies grandis* / Exotic Herbs
	Pseudotsuga menziesii / *Abies grandis* / *Populus* spp. / Shrub
Interior Ponderosa Pine	*Pinus ponderosa* var. *scopulorum*
	Pinus spp. / *Populus* spp. / Exotic Herbs
	Pinus spp. / *Populus* spp. / Shrub
Juniper / Sagebrush	*Juniperus* spp. / *Artemisia arbuscula* / *Festuca idahoensis* / Forb
	Juniperus spp. / *Artemisia* spp. / *Agropyron* spp.
Juniper Woodlands	*Juniperus* spp. / Exotic Herbs
	Juniperus spp. / *Artemisia arbuscula* / Shortgrass
	Juniperus spp. Forest / Exotic Herbs
	Juniperus spp. Woodlands
	Juniperus spp. / Native Bunchgrass
	Juniperus spp. / *Poa secunda*
Limber Pine	*Pinus flexilis*
Lodgepole Pine	*Pinus contorta*
Low Sagebrush	*Artemisia arbuscula* / Native Forbs
	Artemisia arbuscula / *Bromus tectorum*
	Artemisia arbuscula / Native Bunchgrass
	Artemisia spp. / *Poa secunda*

Cover Type	Description
Mixed-Conifer Woodlands	Conifer / Exotic Herbs
	Conifer Encroachment / Exotic Grass
	Conifer Encroachment / *Artemisia* spp. / Perennial Grass
	Conifer / Perennial Grass
Mountain Big Sagebrush	*Artemisia tridentata vaseyana* / Perennial Grass
	Artemisia tridentata vaseyana / Exotic Herbs
	Artemisia tridentata vaseyana / Perennial Herbs
Mountain Hemlock	*Tsuga mertensiana*
Mountain Mahogany	*Cercocarpus* spp.
Native Forb	*Deschampsia* spp. / *Calamagrostis* spp.
	Exotic Moist Herbs
	Exotic Riparian Herbs
	Native Forbs
	Pioneer Forbs
Oregon White Oak	*Quercus alba* / Exotic Herbs
	Quercus alba / Shrub
Pacific Ponderosa Pine	*Pinus ponderosa* var. *ponderosa*
Pacific Silver Fir / Mountain Hemlock	*Abies amabilis* / *Tsuga mertensiana*
Red Fir	*Abies magnifica* var. *shastensis*
Salt Desert Shrub	*Sarcobatus vermiculatus*
	Sarcobatus vermiculatus / *Distichlis stricta*
	Salt Desert Shrub[1]
Shrub or Herb / Tree Regen	General Shrub
	Grass / Forb
	Mid Shrub West Cascades
	Mountain Shrub - No other
	Mountain Shrub / *Ceanothus* spp.
	Shrub / Regen
Shrub Wetlands	*Cornus* spp. / *Crataegus* spp.
	Gravel Bar
	Salix spp. low / *Carex* spp.
	Salix spp. low / Grass
	Salix spp. / *Calamagrostis* spp.
	Salix spp. / *Carex* spp. / *Castor canadensis*
	Salix spp. / *Poa pratensis*
	Sarcobatus vermiculatus

Cover Type	Description
Sierra Nevada Mixed-Conifer	Sierra Nevada Mixed-Conifer
Urban	Urban Land
Water	Water
Western Larch	*Larix occidentalis*
Western Redcedar / Western Hemlock	*Thuja plicata / Tsuga heterophylla*
Western White Pine	*Pinus monticola*
Wheatgrass Bunchgrass	*Agropyron cristatum*
	Agropyron cristatum / Bromus tectorum
	Agropyron spicatum
	Agropyron spp. / *Poa secunda*
	Aristida longiseta
	Bromus tectorum
	Elymus cinereus
	Elymus cinereus / Agropyron
	Elymus cinereus / Bromus tectorum
	Exotic Annual Grass
	Fire Maintained Grass (*Poa secunda / Agropyron spicatum*) secunda/AgroSP)[1]pyron
	Native Perennial Grass
	Perennial Herbs
	Poa secunda / Festuca octoflora
	Poa pratensis
	Poa secunda
	Poa secunda / Perennial Forbs
	Seeded Exotic *Agropyron* spp.
	Sitanion hystrix
Whitebark Pine / Subalpine Larch	*Pinus albicaulis / Larix lyallii*
	Pinus albicaulis / Larix lyallii / Abies lasiocarpa
Whitebark Pine	*Pinus albicaulis*

[1] Four representative plants in the Salt Desert Shrub type found within the Basin are *Eurotia lanata* (winterfat), *Atriplex confertifolia* (shadscale), *Elymus cinereus* (Great Basin wildrye), and *Grayia spinosa* (spiny hopsage).

APPENDIX 3-F

Historical potential vegetation types, associated cover types, and structural stages.

Potential Vegetation Type	Cover Type	Structural Stage[1]
Historical Wheatgrass Grassland	Wheatgrass Bunchgrass	CHERB
	Native Forbs	OHERB
Historical Antelope Bitterbrush	Wheatgrass Bunchgrass	CHERB
		OHERB
	Bitterbrush / Bluebunch Wheatgrass	CLSHR
Historical Big Sagebrush	Wheatgrass Bunchgrass	CHERB
		OHERB
	Big Sagebrush	CLSHR
Historical Low Sagebrush - Mesic	Wheatgrass Bunchgrass	CHERB
		OHERB
	Low Sagebrush	CLSHR
		OLSHR
Historical Low Sagebrush - Mesic with Juniper	*Wheatgrass Bunchgrass*	CHERB
		OHERB
	Juniper / Sagebrush	OSS_W
		SI_W
		UR_W
		YMS_W
	Low Sagebrush	CLSHR
		OLSHR
Historical Low Sagebrush - Xeric	Wheatgrass Bunchgrass	OHERB
	Low Sagebrush	CLSHR
		OLSHR
Historical Low Sagebrush - Xeric with Juniper	Wheatgrass Bunchgrass	OHERB
	Juniper Woodlands	OMS_W
		SI_W
		YMS_W
	Low Sagebrush	CLSHR
		OLSHR
Historical Big Sagebrush - Warm	Wheatgrass Bunchgrass	CHERB
	Big Sagebrush	OLSHR
	Low Sagebrush	OLSHR

Potential Vegetation Type	Cover Type	Structural Stage[1]
Historical Big Sagebrush - Cool	Wheatgrass Bunchgrass	CHERB
	Big Sagebrush	OLSHR
	Low Sagebrush	OLSHR
Historical Cottonwood Riverine	Cottonwood / Willow	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		YMS_F
	Interior Ponderosa Pine	OMS_F
		OSS_F
		UR_F
	Shrub Wetlands	CMSHR
		OMSHR
Historical Fescue Grassland	Fescue-Bunchgrass	CHERB
		OHERB
	Native Forbs	CHERB
Historical Mountain Big Sagebrush - Mesic / East	Wheatgrass Bunchgrass	OHERB
	Fescue-Bunchgrass	OHERB
	Mountain Big Sagebrush	CMSHR
Historical Mountain Big Sagebrush - Mesic / East with Juniper	Wheatgrass Bunchgrass	OHERB
	Fescue-Bunchgrass	OHERB
	Mixed Conifer Woodlands	SI_W
		UR_W
	Mountain Big Sagebrush	CMSHR
Historical Mountain Big Sagebrush - Mesic / West	Wheatgrass Bunchgrass	OHERB
	Fescue-Bunchgrass	CHERB
	Mountain Big Sagebrush	CMSHR
		OMSHR
Historical Mountain Big Sagebrush - Mesic / West with Juniper	Wheatgrass Bunchgrass	OHERB
	Fescue-Bunchgrass	CHERB
	Juniper / Sagebrush	OSS_W
		SI_W
		UR_W
		YMS_W
	Mountain Big Sagebrush	CMSHR
		OMSHR
Historical Salt Desert Shrub	Wheatgrass Bunchgrass	OHERB
	Salt Desert Shrub	CLSHR

Potential Vegetation Type	Cover Type	Structural Stage[1]
Historical Threetipp Sagebrush	Wheatgrass Bunchgrass	OHERB
	Big Sagebrush	CHERB
		CLSHR
Historical Willow / Sedge	Herbaceous Wetlands	OHERB
	Shrub Wetlands	CTSHR
Historical Aspen	Aspen	SEC_F
		SI_F
		UR_F
		YMS_F
	Fescue-Bunchgrass	CHERB
	Shrub or Herb / Tree Regen[2]	CMSHR
Historical Mountain Mahogany	Wheatgrass Bunchgrass	OHERB
	Fescue-Bunchgrass	OHERB
	Mountain Mahogany	CLSHR
		OMSHR
Historical Mountain Mahogany with Big Sagebrush	Wheatgrass Bunchgrass	OHERB
	Fescue-Bunchgrass	OHERB
	Mountain Big Sagebrush	CLSHR
	Mountain Mahogany	CLSHR
		OMSHR
Historical Mountain Shrub	Chokecherry / Serviceberry / Rose	CLSHR
		OLSHR
		OMSHR
		OTSHR
	Fescue-Bunchgrass	CHERB
Historical Riparian Graminoid -	Native Forbs	CHERB
Historical Saltbrush Riparian	Herbaceous Wetlands	CHERB
	Salt Desert Shrub	OMSHR
	Shrub Wetlands	OLSHR
Historical Riparian Sedge	Herbaceous Wetlands	CHERB
Historical Mountain Riparian Low Shrub	Herbaceous Wetlands	CHERB
	Shrub Wetlands	CLSHR
Historical Fescue Grassland with Conifer	Fescue-Bunchgrass	CHERB
	Mixed-Conifer Woodlands	OMS_W
		SE_W
		SI_W
		YMS_W

Potential Vegetation Type	Cover Type	Structural Stage[1]
Historical Juniper	Fescue-Bunchgrass	CHERB
		OHERB
	Juniper Woodlands	OMS_W
		OSS_W
		SI_W
		UR_W
		YMS_W
Historical Alpine Shrub - Herbaceous	Alpine Tundra	CLSHR
		OLSHR
Cedar / Hemlock - Eastern Cascades	Grand Fir / White Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	SEC_F
		SI_F
		UR_F
	Shrub or Herb / Tree Regen	OLSHR
	Western Larch	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Western Redcedar / Western Hemlock	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Western White Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F

Potential Vegetation Type	Cover Type	Structural Stage[1]
Cedar / Hemlock - Inland	Grand Fir / White Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	SEC_F
		SI_F
		UR_F
	Shrub or Herb / Tree Regen	OLSHR
	Western Larch	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Western Redcedar / Western Hemlock	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Western White Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
Dry Douglas-fir / without Ponderosa Pine	Interior Douglas-fir	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Mountain Big Sagebrush	CMSHR
	Shrub or Herb / Tree Regen	CHERB
		CMSHR
		OLSHR

Potential Vegetation Type	Cover Type	Structural Stage[1]
Dry Douglas-fir / with Ponderosa Pine	Fescue-Bunchgrass	OHERB
	Interior Douglas-fir	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Ponderosa Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	CHERB
		CMSHR
Dry Grand Fir / White Fir	Grand Fir / White Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Ponderosa Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	CMSHR
Limber Pine	Limber Pine	OMS_F
		SEO_F
		SI_F
		UR_F
	Shrub or Herb / Tree Regen	CMSHR
Lodgepole Pine - Yellowstone	Lodgepole Pine	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	CMSHR

Potential Vegetation Type	Cover Type	Structural Stage[1]
Lodgepole Pine - Oregon	Lodgepole Pine	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	CMSHR
Moist Douglas-fir	Interior Douglas-fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
Interior Ponderosa Pine		OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	CMSHR
	Western Larch	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
Grand Fir / White Fir - Eastern Cascades	Grand Fir / White Fir	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Ponderosa Pine	OMS_F

Potential Vegetation Type	Cover Type	Structural Stage[1]
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	OLSHR
	Western Larch	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Western White Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
Grand Fir / White Fir - Inland	Grand Fir / White Fir	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Ponderosa Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	SEC_F
		SI_F
		UR_F
		YMS_F

Potential Vegetation Type	Cover Type	Structural Stage[1]
	Shrub or Herb / Tree Regen	OLSHR
	Western Larch	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Western White Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
Mountain Hemlock - Eastern Cascades	Engelmann Spruce / Subalpine Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	SEC_F
		SI_F
		UR_F
		YMS_F
	Mountain Hemlock	OMS_F
		SEC_F
		SI_F
		UR_F
		MS_F
	Shrub or Herb / Tree Regen	OTSHR
	Western Larch	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Western White Pine	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F

Potential Vegetation Type	Cover Type	Structural Stage[1]
Mountain Hemlock - Inland	Engelmann Spruce / Subalpine Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	SEC_F
		SI_F
		UR_F
		YMS_F
	Mountain Hemlock	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	OTSHR
	Western Larch	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Western White Pine	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
Interior Ponderosa Pine	Exotic Forbs / Annual Grass	CHERB
	Fescue - Bunchgrass	CHERB
	Interior Ponderosa Pine	OMS_F
		OSS_F
		SEO_F
		SI_F
		UR_F
		YMS_F
	Mountain Big Sagebrush	OMSHR
	Shrub or Herb / Tree Regen	OLSHR

Potential Vegetation Type	Cover Type	Structural Stage[1]
Pacific Ponderosa Pine / Mixed-Conifer	Pacific Ponderosa Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	OLSHR
	Sierra Nevada Mixed-Conifer	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
Mountain Hemlock / Shasta Fir	Grand Fir / White Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	SEC_F
		SI_F
		UR_F
		YMS_F
	Mountain Hemlock	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Red Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	OTSHR
	Western White Pine	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F

Potential Vegetation Type	Cover Type	Structural Stage[1]
Pacific Silver Fir	Engelmann Spruce / Subalpine Fir	SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Mountain Hemlock	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
	Pacific Silver Fir / Mountain Hemlock	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	OLSHR
	Western Larch	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Western Redcedar / Western Hemlock	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
Spruce / Fir - Dry with Aspen	Aspen	SEC_F
		SI_F
		UR_F
	Engelmann Spruce / Subalpine Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		OSS_F
		SEC_F

Potential Vegetation Type	Cover Type	Structural Stage[1]
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	CMSHR
Spruce / Fir - Dry without Aspen	Aspen	SEC_F
		SI_F
		UR_F
	Engelmann Spruce / Subalpine Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	CMSHR
Spruce / Fir - Wet	Engelmann Spruce / Subalpine Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Interior Douglas-fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F

Potential Vegetation Type	Cover Type	Structural Stage[1]
	Shrub or Herb / Tree Regen	OLSHR
	Western Larch	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Western White Pine	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
Spruce / Fir (WBP>LPP[3])	Engelmann Spruce / Subalpine Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	CMSHR
	Whitebark Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
Spruce / Fir (LPP>WBP[4])	Engelmann Spruce / Subalpine Fir	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Lodgepole Pine	OMS_F
		OSS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Shrub or Herb / Tree Regen	CMSHR
	Whitebark Pine	OMS_F
		OSS_F
		SEC_F

Potential Vegetation Type	Cover Type	Structural Stage[1]
		SI_F
		UR_F
		YMS_F
Whitebark Pine / Subalpine Larch - North	Shrub or Herb / Tree Regen	CMSHR
	Whitebark Pine / Subalpine Larch	OMS_F
		SEO_F
		SI_F
		UR_F
		YMS_F
	Whitebark Pine	OSS_F
Whitebark Pine /Subalpine Larch - South	Shrub or Herb / Tree Regen	CMSHR
	Whitebark Pine / Subalpine Larch	OMS_F
		SEO_F
		SI_F
		UR_F
		YMS_F
	Whitebark Pine	OSS_F
White Oak	Wheatgrass Bunchgrass	OHERB
	Oregon White Oak	OMS_W
		OSS_W
		SI_W
		UR_W
		YMS_W
	Shrub or Herb / Tree Regen	CMSHR
Wheatgrass Grassland	Wheatgrass Bunchgrass	CHERB
	Exotic Forbs / Annual Grass	CHERB
		OHERB
	Fescue-Bunchgrass	CHERB
	Native Forbs	OHERB
Antelope Bitterbrush	Wheatgrass Bunchgrass	CHERB
		OHERB
	Antelope Bitterbrush / Bluebunch Wheatgrass	CLSHR
Big Sagebrush Grassland	Wheatgrass Bunchgrass	CHERB
		OHERB
	Big Sagebrush	CLSHR
Low Sagebrush - Mesic	Wheatgrass Bunchgrass	CHERB
		OHERB
	Exotic Forbs / Annual Grass	OHERB
	Fescue - Bunchgrass	OHERB
	Low Sagebrush	CLSHR
		OLSHR

Potential Vegetation Type	Cover Type	Structural Stage[1]
Low Sagebrush - Mesic with Juniper	Wheatgrass Bunchgrass	CHERB
		OHERB
	Exotic Forbs / Annual Grass	OHERB
	Fescue - Bunchgrass	OHERB
	Juniper / Sagebrush	OSS_W
		SI_W
		UR_W
	Juniper Woodlands	OMS_W
		UR_W
	Low Sagebrush	CLSHR
		OLSHR
Low Sagebrush - Xeric	Wheatgrass Bunchgrass	OHERB
	Low Sagebrush	CLSHR
		OLSHR
Low Sagebrush - Xeric with Juniper	Wheatgrass Bunchgrass	OHERB
	Juniper Woodlands	OMS_W
		SI_W
		YMS_W
	Low Sagebrush	CLSHR
		OLSHR
Big Sagebrush - Warm	Wheatgrass Bunchgrass	CHERB
		OHERB
	Big Sagebrush	OLSHR
	Exotic Forbs / Annual Grass	CHERB
	Fescue - Bunchgrass	CHERB
	Low Sagebrush	OLSHR
Big Sagebrush - Cool	Wheatgrass Bunchgrass	CHERB
		OHERB
	Big Sagebrush	OLSHR
	Exotic Forbs / Annual Grass	CHERB
	Fescue - Bunchgrass	CHERB
	Low Sagebrush	OLSHR
Cottonwood Riverine	Cottonwood / Willow	OMS_F
		SEC_F
		SI_F
		UR_F
		YMS_F
	Exotic Forbs / Annual Grass	CHERB
	Interior Douglas-fir	OMS_F
		YMS_F
	Interior Ponderosa Pine	OMS_F

Potential Vegetation Type	Cover Type	Structural Stage[1]
		OSS_F
		UR_F
	Shrub Wetlands	CMSHR
		OMSHR
Fescue Grassland	Wheatgrass Bunchgrass	OHERB
	Cropland / Hay / Pasture	CHERB
	Exotic Forbs / Annual Grass	OHERB
	Fescue - Bunchgrass	CHERB
		OHERB
	Native Forbs	CHERB
Mountain Big Sagebrush - Mesic / East	Wheatgrass Bunchgrass	OHERB
	Exotic Forbs / Annual Grass	OHERB
	Fescue-Bunchgrass	OHERB
	Mountain Big Sagebrush	CMSHR
		OMSHR
Mountain Big Sagebrush - Mesic / East with Conifer	Wheatgrass Bunchgrass	OHERB
	Exotic Forbs / Annual Grass	OHERB
	Fescue - Bunchgrass	OHERB
	Mixed-Conifer Woodlands	SI_W
		UR_W
	Mountain Big Sagebrush	CMSHR
		OMSHR
Mountain Big Sagebrush - Mesic / West	Wheatgrass Bunchgrass	CHERB
		OHERB
	Big Sagebrush	CMSHR
		OMSHR
	Exotic Forbs / Annual Grass	OHERB
	Fescue - Bunchgrass	CHERB
		OHERB
	Mountain Big Sagebrush	CMSHR
		OMSHR
Mountain Big Sagebrush - Mesic / West with Juniper	Wheatgrass Bunchgrass	CHERB
		OHERB
	Big Sagebrush	CMSHR
		OMSHR
	Exotic Forbs / Annual Grass	OHERB
	Fescue - Bunchgrass	CHERB
		OHERB
	Juniper / Sagebrush	OSS_W
		SI_W
		UR_W

Potential Vegetation Type	Cover Type	Structural Stage[1]
	Juniper Woodlands	OMS_W
		YMS_W
	Mountain Big Sagebrush	CMSHR
		OMSHR
Salt Desert Shrub	Wheatgrass Bunchgrass	CHERB
		OHERB
	Salt Desert Shrub	CLSHR
		OLSHR
Three Tipp Sagebrush	Wheatgrass Bunchgrass	OHERB
	Big Sagebrush	CHERB
		CLSHR
		OLSHR
	Exotic Forbs / Annual Grass	*OHERB*
Willow / Sedge	Exotic Forbs / Annual Grass	OHERB
	Herbaceous Wetlands	OHERB
	Shrub Wetlands	CTSHR
Aspen	Aspen	SEC_F
		SI_F
		UR_F
		YMS_F
	Exotic Forbs / Annual Grass	CHERB
	Fescue - Bunchgrass	CHERB
	Shrub or Herb / Tree Regen	CMSHR
Mountain Mahogany	Wheatgrass Bunchgrass	OHERB
	Fescue - Bunchgrass	OHERB
	Mountain Mahogany	CLSHR
		OMSHR
Mountain Mahogany with Big Sagebrush	Wheatgrass Bunchgrass	OHERB
	Fescue - Bunchgrass	OHERB
	Mountain Big Sagebrush	CLSHR
	Mountain Mahogany	CLSHR
		OMSHR
Mountain Shrub	Chokecherry / Serviceberry / Rose	CLSHR
		OLSHR
		OMSHR
		OTSHR
	Fescue - Bunchgrass	CHERB
Riparian Graminoid	Native Forbs	CHERB

Potential Vegetation Type	Cover Type	Structural Stage[1]
Saltbrush Riparian	Herbaceous Wetlands	CHERB
	Salt Desert Shrub	OMSHR
	Shrub Wetlands	OLSHR
Riparian Sedge	Herbaceous Wetlands	CHERB
Mountain Riparian Low Shrub	Wheatgrass Bunchgrass	CHERB
	Herbaceous Wetlands	CHERB
	Shrub Wetlands	CLSHR
Fescue Grassland with Conifer	Exotic Forbs / Annual Grass	OHERB
	Fescue - Bunchgrass	CHERB
	Mixed Conifer Woodlands	OMS_W
		SE_W
		SI_W
		YMS_W
Juniper	Exotic Forbs / Annual Grass	OHERB
	Fescue - Bunchgrass	CHERB
		OHERB
	Juniper Woodlands	OMS_W
		OSS_W
		SI_W
		UR_W
		YMS_W
Alpine Shrub - Herbaceous	Alpine Tundra	CLSHR
		OLSHR
Irrigated Crop Land	Cropland / Hay / Pasture	CHERB
		CROP
	Fescue - Bunchgrass	CHERB
		OHERB
	Urban	URBAN
Dry Crop / Pasture Land	Cropland / Hay / Pasture	CHERB
		CROP
	Fescue - Bunchgrass	CHERB
	Urban	URBAN
Urban	Urban	URBAN
Water	Water	WATER
Barren	Barren	ROCK

[1]See appendix 3-G for description of structural stages:

Structural Stage	Abbreviation
Stand Initiation Forest	SI_F
Stem Exclusion Open Canopy Forest	SEO_F
Stem Exclusion Closed Canopy Forest	SEC_F
Understory Reinitiation Forest	UR_F
Young Multi-strata Forest	YMS_F
Old Multi-strata Forest	OMS_F
Old Single-strata Forest	OSS_F
Stand Initiation Woodland	SI_W
Stem Exclusion Woodland	SE_W
Understory Reinitiation Woodland	UR_W
Young Multi-strata Woodland	YMS_W
Old Multi-strata Woodland	OMS_W
Old Single-strata Woodland	OSS_W
Open Herbland	OHERB
Closed Herbland	CHERB
Closed Low Shrub	CLSHR
Open Low Shrub	OLSHR
Open Mid Shrub	OMSHR
Closed Mid Shrub	CMSHR
Open Tall Shrub	OTSHR
Closed Tall Shrub	CTSHR
Agricultural	CROP
Urban	URBAN
Water	WATER
Rock	ROCK

[2]Regeneration (renewal or restoration of structures).

[3]Whitebark pine more abundant than Lodgepole pine.

[4]Lodgepole pine more abundant than Whitebark pine.

APPENDIX 3-G

Structural stages and description.

Structural Stage	Description[1]
Forest	
Stand Initiation	LgT_cc < 30 % (for example, = 0, 10, or 20%) and SS_cc ≥ 10 % and [(PT_cc + SmT_cc + MedT_cc < 20%) or (PT_cc + SmT_cc + MedT_cc ≤ 60% and PT_cc + SmT_cc + MedT_cc ≥ 20% and SmT_cc + MedT_cc < 10%)].
Stem Exclusion Open Canopy	LgT_cc < 30 % (for example, = 0, 10, or 20%) and SS_cc < 10 % and PT_cc + SmT_cc + MedT_cc ≤ 70 %.
Stem Exclusion Closed Canopy	LgT_cc < 30 % (for example, = 0, 10, or 20%) and SS_cc < 10 % and PT_cc + SmT_cc + MedT_cc > 70 %.
Understory Reinitiation	LgT_cc < 30 % (for example, = 0, 10, or 20%) and SS_cc ≥ 10 % and PT_cc + SmT_cc + MedT_cc > 60 %.
Young Multi-Story	LgT_cc < 30 % (for example, = 0, 10, or 20%) and SS_cc ≥ 10 % and PT_cc + SmT_cc + MedT_cc ≤ 60 % and SmT_cc ≥ 10% or MedT_cc ≥ 10 %.
Old Multi-Story	LgT_cc ≥ 30 % and SS_cc + PT_cc + SmT_cc + MedT_cc > 20 %
Old Single-Story	LgT_cc ≥ 30 % and SS_cc + PT_cc + SmT_cc + MedT_cc ≤ 20 %.
Woodland	
Stand Initiation	PT_cc + SmT_cc + MedT_cc + LgT_cc < 10% and SS_cc ≥ 10%.
Stem Exclusion	LgT_cc < 10% and PT_cc + SmT_cc + MedT_cc ≥ 10% and SS_cc < 10%.
Understory Reinitiation	LgT_cc < 10% and PT_cc + SmT_cc + MedT_cc ≥ 10% and SS_cc ≥ 10%.
Young Multi-story	LgT_cc < 10%, and SmT_cc + MedT_cc ≥ 10%, and PT_cc ≥ 10%, and SS_cc ≥ 10%.
Old Multi-story	LgT_cc ≥ 10%, and SS_cc + PT_cc + SmT_cc + MedT_cc ≥ 10%.
Old Single-story	LgT_cc ≥ 10%, and SS_cc + PT_cc + SmT_cc + MedT_cc < 10%.
Non-Forest / Non-Woodland	
Open Herbland	a canopy of herbaceous vegetation with < 66% projected canopy cover; < 10 % cover each of shrubs or trees; ≥ 1 stratum.
Closed Herbland	a canopy of herbaceous vegetation with ≥ 66% projected canopy cover; < 10 % cover each of shrubs or trees; ≥ 1 stratum.
Closed Low Shrub	a canopy of low (<50 cm) shrubs with < 66% projected canopy cover; shrubs dominate; tree cover < 10%; ≥ 2 strata, ≥ 2 cohorts possible.
Open Low Shrub	a canopy of low (<50.8 cm) shrubs with ≥ 66% projected crown cover; shrubs dominate; tree cover < 10%; ≥ 2 strata, ≥ 2 cohorts possible.

Structural Stage	Description[1]
Open Mid Shrub	a canopy of medium-sized (50 cm - 2 m) shrubs with < 66% projected canopy cover; shrubs dominate; tree cover < 10%; ≥ 2 strata, ≥ 2 cohorts possible.
Closed Mid Shrub	a canopy of medium-sized (50 cm - 2 m) shrubs with ≥ 66% projected crown cover; shrubs dominate; tree cover < 10%; ≥ 2 strata, ≥ 2 cohorts possible.
Open Tall Shrub	a canopy of herbaceous vegetation with ≥ 66% projected canopy cover; < 10 % cover each of shrubs or trees; ≥ 1 stratum.
Closed Tall Shrub	a canopy of tall (2 - 5 m) shrubs with ≥ 66% projected crown cover; shrubs dominate; tree cover < 10%; ≥ 2 strata, ≥ 2 cohorts possible.
Agricultural	dominated by crop and pasture land use.
Urban	dominated by rural and urban buildings and facilities.
Water	large bodies of water.
Rock	large areas of rock with < 5% vegetative canopy cover.

[1]Structural stage descriptions include the following abbreviations:

tree size class: SS - seedlings and saplings [<12.6 cm diameter at breast height (dbh)]; PT - pole trees (12.7 - 22.6 cm dbh); SmT - small trees (22.7 - 40.4 cm dbh); MedT - medium trees (40.5 - 53.1 cm dbh); LgT - large trees (> 53.2 cm dbh).

cc - crown cover; crown cover was interpreted in 10% increments and class % ages were expressed as midpoints, for example, 10% = 5 to 14%, and 20% = 15 to 24%.

APPENDIX 3-H

Trends of vegetation physiognomic types and potential vegetation groups (PVGs) from the historical to the current period for three management scenarios (consumptive demand, active management, and passive management).

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
EEIS	Agricultural	Agriculture/Urban	Other Lands	NA[8]	NA	NA	100.00	97.40	97.40	97.38
		Total Agriculture/Urban		0	0	0	100.00	97.40	97.40	97.38
		Herb	Other Lands	0	0	0	0	2.60	2.60	2.62
		Total Herb		0	0	0	0	2.60	2.60	2.62
	Total Agricultural			0	0	0	100.00	100.00	100.00	100.00
	Alpine	Herb	BLM/FS Natural Process	83.22	83.22	83.22	83.59	83.59	83.59	83.59
			BLM/FS Other	9.05	9.05	9.05	9.09	9.09	9.09	9.09
			Other Lands	7.73	7.73	7.73	7.32	7.32	7.32	7.32
		Total Herb		100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Total Alpine			100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Cold Forest	Early-seral Forest	BLM/FS Natural Process	11.36	12.90	10.97	23.21	13.15	15.96	9.67
			BLM/FS Other	7.98	8.10	8.10	13.63	9.60	11.16	7.92
			Other Lands	3.80	3.56	4.01	5.41	4.52	4.52	5.86
		Total Early-seral Forest		23.14	24.56	23.08	42.25	27.27	31.64	23.45
		Late-seral Multi-layer Forest	BLM/FS Natural Process	11.29	13.35	9.87	8.05	6.85	6.53	9.06
			BLM/FS Other	9.64	9.28	9.72	7.41	6.08	5.60	7.46
			Other Lands	3.96	3.62	4.09	2.91	2.79	2.79	3.17
		Total Late-seral Multi-layer Forest		24.89	26.25	23.68	18.37	15.72	14.92	19.69

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
		Late-seral Single-layer Forest	BLM/FS Natural Process	1.97	1.61	2.27	1.94	1.06	0.91	0.81
			BLM/FS Other	1.31	0.63	1.93	1.84	0.72	0.70	0.77
			Other Lands	0.63	0.26	0.96	0.32	0.14	0.14	0.17
		Total Late-seral Single- layer Forest		3.91	2.50	5.16	4.10	1.92	1.75	1.75
		Mid-seral Shade-intolerant Forest	BLM/FS Natural Process	13.59	13.62	12.40	8.93	15.94	16.49	15.53
			BLM/FS Other	9.09	8.47	9.19	8.74	12.23	12.94	12.56
			Other Lands	4.62	4.02	4.96	4.91	4.66	4.66	3.69
		Total Mid-seral Shade-intolerant Forest		27.30	26.11	26.55	22.58	32.83	34.09	31.78
		Mid-seral Shade-tolerant Forest	BLM/FS Natural Process	8.27	8.68	7.97	4.24	9.45	6.56	11.39
			BLM/FS Other	8.55	8.23	9.22	4.87	7.91	6.15	7.84
			Other Lands	3.88	3.69	4.26	3.34	4.78	4.78	4.01
		Total Mid-seral Shade-tolerant Forest		20.70	20.60	21.45	12.45	22.14	17.49	23.24
		Woodland	BLM/FS Natural Process	0.02	0	0.03	0.13	0.05	0.05	0.05
			BLM/FS Other	0.02	0	0.04	0.11	0.06	0.06	0.05
			Other Lands	0	0	0.01	0.01	0	0	0
		Total Woodland		0.04	0.00	0.08	0.25	0.11	0.11	0.10
	Total Cold Forest			100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Cool Shrub	Exotics	BLM/FS Natural Process	NA	NA	NA	0.02	0.03	0.03	0.04
			BLM/FS Other	NA	NA	NA	0.05	1.85	0.24	0.33
			Other Lands	NA	NA	NA	0.02	1.82	1.82	2.40
		Total Exotics		0	0	0	0.09	3.70	2.09	2.77
		Herb	BLM/FS Natural Process	1.03	0.86	1.23	0.30	0.37	0.47	0.96
			BLM/FS Other	5.53	4.94	6.24	1.76	3.29	7.56	3.80
			Other Lands	9.63	8.58	10.57	1.35	7.78	7.78	4.48
		Total Herb		16.19	14.38	18.04	3.41	11.44	15.81	9.24

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
		Shrub	BLM/FS Natural Process	4.70	4.89	4.50	5.52	5.48	5.71	4.94
			BLM/FS Other	23.98	24.89	22.98	18.58	27.70	30.35	22.80
			Other Lands	44.39	46.39	42.44	18.29	32.18	32.18	35.37
		Total Shrub		73.07	76.17	69.92	42.39	65.36	68.24	63.11
		Woodland	BLM/FS Natural Process	0.34	0.25	0.45	1.42	1.38	1.05	1.32
			BLM/FS Other	3.90	3.48	4.27	19.54	7.09	1.78	13.01
			Other Lands	6.49	5.72	7.32	33.14	11.03	11.03	10.55
		Total Woodland		10.73	9.45	12.04	54.10	19.50	13.86	24.88
	Total Cool Shrub			100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Dry Forest	Early-seral Forest	BLM/FS Natural Process	2.05	2.05	2.21	2.54	1.16	2.09	1.77
			BLM/FS Other	14.23	15.62	12.64	6.13	6.18	7.95	6.21
			Other Lands	15.44	16.72	14.81	5.71	4.42	4.42	5.80
		Total Early-seral Forest		31.72	34.39	29.66	14.38	11.76	14.46	13.78
		Exotics	BLM/FS Natural Process	NA	NA	NA	0.01	0.02	0.00	0.04
			BLM/FS Other	NA	NA	NA	0.13	0.04	0.01	0.24
			Other Lands	NA	NA	NA	0.04	0.05	0.05	0.01
		Total Exotics		0	0	0	0.18	0.11	0.06	0.29
		Herb	BLM/FS Natural Process	0.16	0.12	0.21	0.01	0.01	0.00	0.00
			BLM/FS Other	1.71	1.68	1.77	0.27	0.03	0.01	0.05
			Other Lands	3.58	3.68	3.55	0.04	0.03	0.03	0.71
		Total Herb		5.45	5.48	5.53	0.32	0.07	0.04	0.76
		Late-seral Multi-layer Forest	BLM/FS Natural Process	0.92	0.81	1.01	2.23	2.45	1.47	1.82
			BLM/FS Other	4.52	4.51	4.55	14.14	13.56	8.66	19.15
			Other Lands	4.00	3.54	4.21	6.61	16.07	16.07	12.17
		Total Late-seral Multi-layer Forest		9.44	8.86	9.77	22.98	32.08	26.20	33.14

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
		Late-seral Single-layer Forest	BLM/FS Natural Process	1.82	1.63	1.93	0.74	0.14	0.75	0.49
			BLM/FS Other	12.13	13.00	12.61	5.29	2.49	11.80	2.18
			Other Lands	13.55	13.45	13.07	5.24	0.56	0.56	3.50
		Total Late-seral Single-layer Forest		27.50	28.08	27.61	11.27	3.19	13.11	6.17
		Mid-seral Shade-intolerant	BLM/FS Natural Process	1.12	0.99	1.26	0.78	1.82	1.42	2.06
		Forest	BLM/FS Other	7.34	6.82	7.21	12.78	18.56	12.11	12.55
			Other Lands	9.20	9.17	9.07	22.33	21.77	21.77	21.26
		Total Mid-seral Shade-intolerant Forest		17.66	16.98	17.54	35.89	42.15	35.30	35.87
		Mid-seral Shade-tolerant	BLM/FS Natural Process	0.71	0.60	0.79	0.89	1.60	1.44	0.99
		Forest	BLM/FS Other	2.84	2.15	3.25	6.80	4.68	5.00	5.12
			Other Lands	3.06	2.25	3.93	7.28	4.34	4.34	3.79
		Total Mid-seral Shade-tolerant Forest		6.61	5.00	7.97	14.97	10.62	10.78	9.90
		Shrub	BLM/FS Natural Process	0.05	0.01	0.07	0.00	0.00	0.01	0.02
			BLM/FS Other	0.47	0.35	0.57	0.02	0.01	0.01	0.05
			Other Lands	1.08	0.84	1.29	0.01	0.03	0.03	0.01
		Total Shrub		1.60	1.20	1.93	0.03	0.04	0.05	0.08
	Total Dry Forest			**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
	Dry Grass	Exotics	BLM/FS Natural Process	NA	NA	NA	0.49	0.68	0.52	0.69
			BLM/FS Other	NA	NA	NA	1.31	2.41	0.49	0.66
			Other Lands	NA	NA	NA	0.33	21.95	21.95	29.09
		Total Exotics		0	0	0	2.13	25.04	22.96	30.44
		Herb	BLM/FS Natural Process	2.84	2.62	2.96	10.66	3.61	3.87	8.50
			BLM/FS Other	3.65	3.29	3.99	10.73	2.47	3.67	7.75
			Other Lands	79.50	83.07	76.89	53.63	20.60	20.60	13.70
		Total Herb		85.99	88.98	83.84	75.02	26.68	28.14	29.95

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				..... Percent of Potential Vegetation Group						
		Woodland	BLM/FS Natural Process	1.69	1.47	1.96	0.40	7.26	7.17	2.37
			BLM/FS Other	2.42	1.93	2.81	3.41	10.57	11.29	7.04
			Other Lands	9.90	7.61	11.39	19.04	30.44	30.44	30.21
		Total Woodland		14.01	11.01	16.16	22.85	48.27	48.90	39.62
	Total Dry Grass		100.00	100.00	100.00	100.00	100.00	100.00	100.00	
	Dry Shrub	Exotics	BLM/FS Natural Process	NA	NA	NA	0.02	0.16	0.26	0.57
			BLM/FS Other	NA	NA	NA	0.17	2.59	0.48	0.81
			Other Lands	NA	NA	NA	0.68	7.12	7.12	10.45
		Total Exotics		0	0	0	0.87	9.87	7.86	11.83
		Herb	BLM/FS Natural Process	3.11	2.90	3.18	0.27	2.36	2.64	3.37
			BLM/FS Other	10.69	10.27	10.74	1.44	11.25	13.80	10.56
			Other Lands	25.22	24.89	25.57	4.54	15.85	15.85	11.56
		Total Herb		39.02	38.06	39.49	6.25	29.46	32.29	25.49
		Shrub	BLM/FS Natural Process	6.31	6.47	6.30	12.32	10.10	9.71	8.67
			BLM/FS Other	20.26	20.90	20.04	39.83	27.60	27.16	30.06
			Other Lands	34.08	34.28	33.86	40.25	22.63	22.63	23.61
		Total Shrub		60.65	61.65	60.20	92.40	60.33	59.50	62.34
		Woodland	BLM/FS Natural Process	0	0	0	0	0	0	0
			BLM/FS Other	0.03	0.02	0.03	0.02	0.04	0.04	0.04
			Other Lands	0.28	0.28	0.28	0.45	0.31	0.31	0.30
		Total Woodland		0.31	0.30	0.31	0.47	0.35	0.35	0.34
	Total Dry Shrub		100.00	100.00	100.00	100.00	100.00	100.00	100.00	

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
	Moist Forest	Early-seral Forest	BLM/FS Natural Process	2.70	2.73	2.68	5.47	1.66	1.58	2.52
			BLM/FS Other	8.49	8.52	8.32	9.33	9.03	8.43	7.00
			Other Lands	11.47	12.27	10.87	6.96	12.15	12.15	15.92
		Total Early-seral Forest		22.66	23.52	21.87	21.76	22.84	22.16	25.44
		Late-seral Multi-layer Forest	BLM/FS Natural Process	4.08	3.88	3.97	2.85	4.48	4.58	3.70
			BLM/FS Other	11.61	12.23	10.97	7.25	7.07	10.71	13.15
			Other Lands	14.06	14.51	13.36	5.01	8.37	8.37	8.02
		Total Late-seral Multi-layer Forest		29.75	30.62	28.30	15.11	19.92	23.66	24.87
		Late-seral Single-layer Forest	BLM/FS Natural Process	0.44	0.24	0.63	0.47	0.25	0.24	0.29
			BLM/FS Other	2.91	2.18	3.76	4.11	0.79	1.61	2.07
			Other Lands	4.52	3.57	5.55	2.78	0.89	0.89	0.96
		Total Late-seral Single-layer Forest		7.87	5.99	9.94	7.36	1.93	2.74	3.32
		Mid-seral Shade-intolerant	BLM/FS Natural Process	2.27	2.20	2.35	1.58	1.96	1.76	2.03
		Forest	BLM/FS Other	8.74	8.77	8.69	9.27	14.34	9.99	7.57
			Other Lands	12.59	13.24	12.20	17.82	19.72	19.72	17.83
		Total Mid-seral Shade-intolerant Forest		23.60	24.21	23.24	28.67	36.02	31.47	27.43
		Mid-seral Shade-tolerant	BLM/FS Natural Process	2.89	2.87	3.05	2.13	4.15	4.33	3.97
		Forest	BLM/FS Other	6.27	6.09	6.53	8.44	7.17	7.66	8.61
			Other Lands	6.96	6.71	7.07	16.54	7.97	7.97	6.37
		Total Mid-seral Shade-tolerant Forest		16.12	15.67	16.65	27.11	19.29	19.96	18.95
	Total Moist Forest			100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Riparian Shrub	Exotics	BLM/FS Other	NA	NA	NA	0.36	0.36	0.03	0.24
			Other Lands	NA	NA	NA	0.77	0.12	0.12	0.24
		Total Exotics		0	0	0	1.13	0.48	0.15	0.48

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
		Herb	BLM/FS Natural Process	0.97	0.82	1.05	1.13	0.27	0.42	2.56
			BLM/FS Other	9.42	9.37	9.00	6.07	4.05	4.79	20.09
			Other Lands	47.12	47.19	45.00	17.92	15.54	15.54	4.29
		Total Herb		57.51	57.38	55.05	25.12	19.86	20.75	26.94
		Shrub	BLM/FS Natural Process	0.94	0.82	1.05	4.35	5.21	5.06	2.92
			BLM/FS Other	5.71	5.48	6.33	36.85	38.87	38.45	22.95
			Other Lands	35.84	36.34	37.57	32.56	35.60	35.60	46.73
		Total Shrub		42.49	42.64	44.95	73.76	79.68	79.11	72.60
Total Riparian Shrub				**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
	Riparian Woodland	Early-seral Forest	BLM/FS Natural Process	2.12	0.71	3.28	0	10.56	9.63	11.65
			BLM/FS Other	1.60	0.36	3.13	0	9.63	7.92	9.01
			Other Lands	0.69	0	1.49	0	5.59	5.59	3.73
		Total Early-seral Forest		4.41	1.07	7.90	0	25.78	23.14	24.39
		Herb	BLM/FS Natural Process	2.51	1.07	3.73	0	6.83	7.92	6.68
			BLM/FS Other	2.21	0.36	4.18	2.17	8.54	6.83	6.52
			Other Lands	0.91	0	1.79	0	4.19	4.19	4.66
		Total Herb		5.63	1.43	9.70	2.17	19.56	18.94	17.86
		Late-seral Multi-layer Forest	BLM/FS Other	0.17	0	0.45	0	0	0	0
			Other Lands	4.98	4.27	5.67	0	2.64	2.64	4.19
		Total Late-seral Multi-layer Forest		5.15	4.27	6.12	0	2.64	2.64	4.19
		Late-seral Single-layer Forest	BLM/FS Other	0.30	0	0.60	0	0	0	0
			Other Lands	5.58	3.91	6.57	5.59	0.62	0.62	1.71
		Total Late-seral Single-layer Forest		5.88	3.91	7.17	5.59	0.62	0.62	1.71

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
		Mid-seral Shade-intolerant	BLM/FS Other	0.04	0	0.15	0	0	0	0
		Forest	Other Lands	3.33	1.42	4.48	0	1.40	1.40	0.47
		Total Mid-seral Shade-intolerant Forest		3.37	1.42	4.63	0	1.40	1.40	0.47
		Mid-seral Shade-tolerant	BLM/FS Other	0.22	0	0.30	0	0	0	0
		Forest	Other Lands	3.81	1.78	4.18	0	2.48	2.48	0
		Total Mid-seral Shade-tolerant Forest		4.03	1.78	4.48	0	2.48	2.48	0
		Shrub	BLM/FS Other	0.09	0	0.15	0	0	0	0
			Other Lands	4.37	1.42	5.52	0	0.31	0.31	0.16
		Total Shrub		4.46	1.42	5.67	0	0.31	0.31	0.16
		Woodland	BLM/FS Natural Process	16.15	21.00	13.13	29.81	12.42	12.27	11.49
			BLM/FS Other	17.01	17.79	13.88	28.88	12.89	16.30	15.53
			Other Lands	33.90	45.91	27.31	33.54	21.89	21.89	24.22
		Total Woodland		67.06	84.70	54.32	92.23	47.20	50.46	51.24
Total Riparian Woodland				**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
	Rock	Rock	BLM/FS Natural Process	57.69	57.69	57.69	57.69	57.69	57.69	57.69
			BLM/FS Other	3.85	3.85	3.85	3.85	3.85	3.85	3.85
			Other Lands	38.46	38.46	38.46	38.46	38.46	38.46	38.46
		Total Rock		100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total Rock				**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
	Urban	Agriculture/Urban	BLM/FS Other	NA	NA	NA	0.19	0.19	0.19	0.19
			Other Lands	NA	NA	NA	99.81	99.81	99.81	99.81
		Total Agriculture/Urban		0	0	0	100.00	100.00	100.00	100.00
Total Urban				**0**	**0**	**0**	**100.00**	**100.00**	**100.00**	**100.00**

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
	Water	Water	BLM/FS Natural Process	6.71	6.71	6.71	6.71	6.71	6.71	6.71
			BLM/FS Other	12.95	12.95	12.95	12.96	12.96	12.96	12.96
			Other Lands	80.35	80.35	80.35	80.33	80.33	80.33	80.33
		Total Water		100.01[9]	100.01[9]	100.01[9]	100.00	100.00	100.00	100.00
	Total Water			100.01[9]	100.01[9]	100.01[9]	100.00	100.00	100.00	100.00
	Woodland	Early-seral Forest	BLM/FS Other	0.01	0	0.06	0	0	0.03	0
			Other Lands	0.21	0.16	0.24	0	0.03	0.03	0.03
		Total Early-seral Forest		0.22	0.16	0.30	0	0.03	0.06	0.03
		Exotics	BLM/FS Other	NA	NA	NA	0	0.48	0.27	0.10
			Other Lands	NA	NA	NA	0	0.69	0.69	1.03
		Total Exotics		0	0	0	0	1.17	0.96	1.13
		Herb	BLM/FS Natural Process	0.32	0.08	0.60	0	0.79	0.82	1.10
			BLM/FS Other	4.20	2.01	6.59	0	1.37	1.06	6.70
			Other Lands	7.99	5.39	10.96	0	1.30	1.30	1.75
		Total Herb		12.51	7.48	18.15	0	3.46	3.18	9.55
		Shrub	BLM/FS Natural Process	3.15	3.46	2.88	3.37	2.68	2.61	2.27
			BLM/FS Other	23.86	25.76	22.05	25.82	24.66	25.10	19.51
			Other Lands	42.42	45.17	39.42	49.38	48.21	48.21	47.66
		Total Shrub		69.43	74.39	64.35	78.57	75.55	75.92	69.44
		Woodland	BLM/FS Natural Process	0.87	0.81	0.84	0.96	0.86	0.89	0.96
			BLM/FS Other	10.38	10.31	10.01	12.64	11.95	11.98	12.16
			Other Lands	6.59	6.84	6.35	7.83	6.97	6.97	6.73
		Total Woodland		17.84	17.95	17.20	21.43	19.78	19.84	19.84
	Total Woodland			100.00	100.00	100.00	100.00	100.00	100.00	100.00

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
UCRB	Agricultural	Agriculture/Urban	Other Lands	NA	NA	NA	100.00	97.42	97.42	97.26
		Total Agriculture/Urban		0	0	0	100.00	97.42	97.42	97.26
		Herb	Other Lands	0	0	0	0	2.58	2.58	2.74
		Total Herb		0	0	0	0	2.58	2.58	2.74
	Total Agricultural			0	0	0	100.00	100.00	100.00	100.00
	Alpine	Herb	BLM/FS Natural Process	56.60	56.60	56.60	56.60	56.60	56.60	56.60
			BLM/FS Other	18.20	18.20	18.20	18.20	18.20	18.20	18.20
			Other Lands	25.20	25.20	25.20	25.20	25.20	25.20	25.20
		Total Herb		100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Total Alpine			100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Cold Forest	Early-seral Forest	BLM/FS Natural Process	6.99	8.28	6.27	12.84	9.93	12.43	7.32
			BLM/FS Other	11.37	12.21	10.86	13.14	15.26	22.15	13.22
			Other Lands	2.82	2.99	2.87	3.95	3.29	3.29	4.92
		Total Early-seral Forest		21.18	23.48	20.00	29.93	28.48	37.87	25.46
		Late-seral Multi-layer Forest	BLM/FS Natural Process	9.36	9.09	8.53	2.55	4.54	3.81	6.34
			BLM/FS Other	14.29	12.63	13.86	3.22	7.46	5.71	10.10
			Other Lands	3.17	3.17	3.09	0.29	1.88	1.88	2.04
		Total Late-seral Multi-layer Forest		26.82	24.89	25.48	6.06	13.88	11.40	18.48
		Late-seral Single-layer Forest	BLM/FS Natural Process	1.94	1.76	2.20	4.44	2.92	2.78	2.57
			BLM/FS Other	2.88	2.20	3.58	4.07	2.67	2.45	2.88
			Other Lands	0.59	0.49	0.66	0.94	0.65	0.65	0.67
		Total Late-seral Single-layer Forest		5.41	4.45	6.44	9.45	6.24	5.88	6.12

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
		Mid-seral Shade-intolerant	BLM/FS Natural Process	9.40	10.07	8.64	4.94	8.26	8.14	7.96
		Forest	BLM/FS Other	14.98	15.58	14.87	12.21	13.69	12.47	12.66
			Other Lands	3.71	3.90	3.54	2.73	3.59	3.59	2.58
		Total Mid-seral Shade-intolerant Forest		28.09	29.55	27.05	19.88	25.54	24.20	23.20
		Mid-seral Shade-tolerant	BLM/FS Natural Process	4.98	5.00	5.88	7.70	7.11	5.60	8.57
		Forest	BLM/FS Other	8.81	8.30	10.12	16.24	12.75	9.30	12.99
			Other Lands	1.99	1.92	2.13	3.78	2.75	2.75	2.04
		Total Mid-seral Shade-tolerant Forest		15.78	15.22	18.13	27.72	22.61	17.65	23.60
		Woodland	BLM/FS Natural Process	0.49	0.42	0.49	0.71	0.41	0.43	0.42
			BLM/FS Other	1.82	1.66	1.88	5.30	2.36	2.09	2.33
			Other Lands	0.42	0.32	0.51	0.96	0.49	0.49	0.39
		Total Woodland		2.73	2.40	2.88	6.97	3.26	3.01	3.14
Total Cold Forest				**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
	Cool Shrub	Exotics	BLM/FS Natural Process	NA	NA	NA	0.02	0.04	0.07	0.16
			BLM/FS Other	NA	NA	NA	1.08	1.65	0.16	1.01
			Other Lands	NA	NA	NA	1.05	0.58	0.58	0.83
		Total Exotics		0	0	0	2.15	2.27	0.81	2.00
		Herb	BLM/FS Natural Process	1.45	1.21	1.74	0.58	0.67	0.61	2.18
			BLM/FS Other	9.02	8.24	9.90	5.31	4.65	6.39	11.08
			Other Lands	4.82	3.93	5.79	2.24	4.12	4.12	2.60
		Total Herb		15.29	13.38	17.43	8.13	9.44	11.12	15.86
		Shrub	BLM/FS Natural Process	7.71	7.85	7.49	9.09	9.01	9.17	7.45
			BLM/FS Other	48.46	50.42	46.44	54.46	57.02	57.67	49.90
			Other Lands	26.50	26.99	25.95	18.27	19.10	19.10	20.36
		Total Shrub		82.67	85.26	79.88	81.82	85.13	85.94	77.71

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
		Woodland	BLM/FS Natural Process	0.11	0.06	0.16	0.55	0.52	0.40	0.45
			BLM/FS Other	0.98	0.71	1.27	3.73	1.26	0.35	2.59
			Other Lands	0.94	0.59	1.26	3.63	1.38	1.38	1.40
		Total Woodland		2.03	1.36	2.69	7.91	3.16	2.13	4.44
	Total Cool Shrub			100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Dry Forest	Early-seral Forest	BLM/FS Natural Process	3.47	3.89	3.09	5.30	2.33	4.70	3.53
			BLM/FS Other	10.82	11.62	10.39	11.27	7.62	12.05	7.76
			Other Lands	12.31	14.02	12.10	6.51	4.81	4.81	6.48
		Total Early-seral Forest		26.60	29.53	25.58	23.08	14.76	21.56	17.77
		Exotics	BLM/FS Natural Process	NA	NA	NA	0.01	0.05	0.03	0.10
			BLM/FS Other	NA	NA	NA	0.08	0.02	0.01	0.14
			Other Lands	NA	NA	NA	0.07	0.04	0.04	0.01
		Total Exotics		0	0	0	0.16	0.11	0.08	0.25
		Herb	BLM/FS Natural Process	0.41	0.41	0.39	0.19	0.01	0.01	0.02
			BLM/FS Other	1.01	0.83	1.14	0.42	0.01	0.01	0.04
			Other Lands	2.10	2.28	1.98	0.26	0.02	0.02	0.45
		Total Herb		3.52	3.52	3.51	0.87	0.04	0.04	0.51
		Late-seral Multi-layer Forest	BLM/FS Natural Process	2.80	2.66	2.58	2.31	4.13	2.21	3.24
			BLM/FS Other	6.97	5.94	7.04	5.37	9.53	4.91	11.36
			Other Lands	5.35	3.99	5.61	1.27	10.93	10.93	8.89
		Total Late-seral Multi-layer Forest		15.12	12.59	15.23	8.95	24.59	18.05	23.49
		Late-seral Single-layer Forest	BLM/FS Natural Process	3.71	4.12	3.32	0.09	0.34	1.41	1.12
			BLM/FS Other	10.42	11.19	9.54	1.17	1.71	6.85	2.36
			Other Lands	10.80	11.06	9.86	1.01	0.60	0.60	1.67
		Total Late-seral Single-layer Forest		24.93	26.37	22.72	2.27	2.65	8.86	5.15

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				..... Percent of Potential Vegetation Group						
		Mid-seral Shade-intolerant	BLM/FS Natural Process	2.08	2.13	2.05	4.37	4.49	3.76	4.28
		Forest	BLM/FS Other	6.09	5.79	6.28	10.13	15.08	10.47	12.12
			Other Lands	7.25	7.24	7.38	18.33	18.29	18.29	17.55
		Total Mid-seral Shade-intolerant Forest		15.42	15.16	15.71	32.83	37.86	32.52	33.95
		Mid-seral Shade-tolerant	BLM/FS Natural Process	2.32	2.31	2.54	3.19	4.11	3.30	3.09
		Forest	BLM/FS Other	6.23	5.66	7.11	14.90	9.39	9.02	9.45
			Other Lands	4.51	4.06	5.23	13.44	6.38	6.38	6.04
		Total Mid-seral Shade-tolerant Forest		13.06	12.03	14.88	31.53	19.88	18.70	18.58
		Shrub	BLM/FS Natural Process	0.14	0.12	0.21	0.03	0.03	0.05	0.09
			BLM/FS Other	0.35	0.14	0.67	0.09	0.08	0.10	0.21
			Other Lands	0.86	0.56	1.48	0.21	0.04	0.04	0.00
		Total Shrub		1.35	0.81	2.36	0.33	0.15	0.19	0.30
	Total Dry Forest			100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Dry Grass	Exotics	BLM/FS Natural Process	NA	NA	NA	0.24	0.31	0.25	0.40
			BLM/FS Other	NA	NA	NA	1.36	11.07	2.45	3.81
			Other Lands	NA	NA	NA	0.33	10.57	10.57	12.14
		Total Exotics		0	0	0	1.93	21.95	13.27	16.35
		Herb	BLM/FS Natural Process	2.33	2.21	2.44	6.72	1.55	1.67	4.91
			BLM/FS Other	18.87	18.53	19.15	49.96	8.88	15.04	32.10
			Other Lands	57.15	60.08	54.74	39.94	9.06	9.06	7.79
		Total Herb		78.35	80.82	76.33	96.62	19.49	25.77	44.80
		Woodland	BLM/FS Natural Process	1.71	1.53	1.86	0.12	5.22	5.16	1.77
			BLM/FS Other	10.59	9.55	11.48	0.28	31.66	34.11	15.69
			Other Lands	9.35	8.10	10.33	1.05	21.69	21.69	21.40
		Total Woodland		21.65	19.18	23.67	1.45	58.57	60.96	38.86
	Total Dry Grass			100.00	100.00	100.00	100.00	100.00	100.00	100.00

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
	Dry Shrub	Exotics	BLM/FS Natural Process	NA	NA	NA	0.12	0.16	0.14	0.13
			BLM/FS Other	NA	NA	NA	0.97	4.14	1.02	1.23
			Other Lands	NA	NA	NA	0.50	4.67	4.67	5.14
		Total Exotics		0	0	0	1.59	8.97	5.83	6.50
		Herb	BLM/FS Natural Process	2.71	2.48	2.79	1.17	2.29	2.50	2.62
			BLM/FS Other	15.90	15.41	16.12	10.44	16.91	18.17	16.44
			Other Lands	18.27	17.81	18.53	6.50	9.35	9.35	7.83
		Total Herb		36.88	35.70	37.44	18.11	28.55	30.02	26.89
		Shrub	BLM/FS Natural Process	4.90	4.96	4.97	8.99	7.80	7.61	7.50
			BLM/FS Other	28.47	29.09	28.11	48.75	39.08	40.93	42.47
			Other Lands	29.67	30.17	29.40	22.55	15.52	15.52	16.58
		Total Shrub		63.04	64.22	62.48	80.29	62.40	64.06	66.55
		Woodland	BLM/FS Natural Process	0.04	0.04	0.04	0	0.03	0.03	0.03
			BLM/FS Other	0.03	0.02	0.03	0	0.03	0.03	0.03
			Other Lands	0.01	0.01	0.01	0	0.01	0.01	0.01
		Total Woodland		0.08	0.07	0.08	0	0.07	0.07	0.07
	Total Dry Shrub			**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**
	Moist Forest	Early-seral Forest	BLM/FS Natural Process	2.84	2.97	2.63	4.12	1.76	1.48	2.90
			BLM/FS Other	10.54	11.04	9.82	9.96	12.80	11.14	8.52
			Other Lands	6.62	7.11	6.21	5.01	7.12	7.12	11.01
		Total Early-seral Forest		20.00	21.12	18.66	19.09	21.68	19.74	22.43
		Late-seral Multi-layer Forest	BLM/FS Natural Process	4.69	4.63	4.29	1.23	5.42	5.44	4.19
			BLM/FS Other	16.20	15.87	15.08	2.26	8.20	14.07	17.44
			Other Lands	9.00	9.24	8.28	0.46	4.76	4.76	3.91
		Total Late-seral Multi-layer Forest		29.89	29.74	27.65	3.95	18.38	24.27	25.54

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
		Late-seral Single-layer Forest	BLM/FS Natural Process	0.50	0.36	0.65	0.12	0.44	0.49	0.44
			BLM/FS Other	2.90	2.44	3.55	0.64	1.00	2.20	2.36
			Other Lands	2.32	1.90	2.87	0.22	0.60	0.60	0.63
		Total Late-seral Single-layer Forest		5.72	4.70	7.07	0.98	2.04	3.29	3.43
		Mid-seral Shade-intolerant	BLM/FS Natural Process	4.60	5.00	4.58	3.83	3.49	3.33	3.82
		Forest	BLM/FS Other	17.24	17.95	18.56	22.29	21.34	16.87	14.39
			Other Lands	10.19	10.58	10.56	14.12	13.06	13.06	11.58
		Total Mid-seral Shade-intolerant Forest		32.03	33.53	33.70	40.24	37.89	33.26	29.79
		Mid-seral Shade-tolerant	BLM/FS Natural Process	2.35	2.30	2.55	5.85	4.04	4.42	3.80
		Forest	BLM/FS Other	6.59	5.77	6.88	18.97	10.75	9.83	11.39
			Other Lands	3.42	2.84	3.49	10.93	5.19	5.19	3.61
		Total Mid-seral Shade-tolerant Forest		12.36	10.91	12.92	35.75	19.98	19.44	18.80
	Total Moist Forest			100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Riparian Shrub	Exotics	BLM/FS Natural Process	NA	NA	NA	0.52	0.19	0.22	0
			BLM/FS Other	NA	NA	NA	1.63	1.04	0.11	0.26
			Other Lands	NA	NA	NA	0.67	0.30	0.30	0.33
		Total Exotics		0	0	0	2.82	1.53	0.63	0.59
		Herb	BLM/FS Natural Process	0.05	0	0.10	0.30	0	0.19	0.26
			BLM/FS Other	5.48	5.16	5.78	28.29	12.84	15.48	15.96
			Other Lands	52.47	52.66	49.59	51.08	17.37	17.37	8.57
		Total Herb		58.00	57.82	55.47	79.67	30.21	33.04	24.79
		Shrub	BLM/FS Natural Process	0.72	0.79	0.66	2.00	2.64	2.41	2.56
			BLM/FS Other	4.92	4.37	5.23	8.02	24.05	22.35	21.71
			Other Lands	36.35	37.02	38.63	7.50	41.57	41.57	50.33
		Total Shrub		41.99	42.18	44.52	17.52	68.26	66.33	74.60
	Total Riparian Shrub			100.00	100.00	100.00	100.00	100.00	100.00	100.00

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
	Riparian Woodland	Early-seral Forest	BLM/FS Natural Process	0.65	0.45	0.90	0.01	2.13	2.11	2.03
			BLM/FS Other	4.66	3.04	6.08		13.32	11.00	12.45
			Other Lands	5.09	3.54	6.62	0.07	15.77	15.77	9.43
		Total Early-seral Forest		10.40	7.03	13.60	0.08	31.22	28.88	23.91
		Herb	BLM/FS Natural Process	0.82	0.53	1.09	0.04	1.61	1.53	1.33
			BLM/FS Other	5.26	3.44	6.75	0.15	8.58	7.61	8.84
			Other Lands	5.86	4.75	7.16	2.92	12.00	12.00	8.80
		Total Herb		11.94	8.72	15.00	3.11	22.19	21.14	18.97
		Late-seral Multi-layer Forest	BLM/FS Other	0.02	0	0.04	0	0	0.01	0
			Other Lands	0.19	0.07	0.28	0	0.01	0.01	0
		Total Late-seral Multi-layer Forest		0.21	0.07	0.32	0	0.01	0.02	0
		Late-seral Single-layer Forest	BLM/FS Other	0.01	0	0.04	0	0	0	0
			Other Lands	0.17	0.05	0.31	0	0.01	0.01	0.02
		Total Late-seral Single-layer Forest		0.18	0.05	0.35	0	0.01	0.01	0.02
		Mid-seral Shade-intolerant	BLM/FS Other	0.01	0	0.01	0	0	0.01	0
		Forest	Other Lands	0.10	0.05	0.18	0.03	0.02	0.02	0
		Total Mid-seral Shade-intolerant Forest		0.11	0.05	0.19	0.03	0.02	0.03	0
		Mid-seral Shade-tolerant	BLM/FS Other	0.01	0	0.03	0	0	0	0
		Forest	Other Lands	0.13	0.05	0.21	0	0.01	0.01	0.01
		Total Mid-seral Shade-tolerant Forest		0.14	0.05	0.24	0	0.01	0.01	0.01
		Shrub	BLM/FS Natural Process	0	0	0	0.01	0	0	0
			BLM/FS Other	0.02	0	0.07	0.11	0.01	0	0.01
			Other Lands	0.18	0.07	0.29	0.35	0	0	0.01
		Total Shrub		0.20	0.07	0.36	0.47	0.01	0	0.02

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
		Woodland	BLM/FS Natural Process	5.28	5.85	4.83	6.79	3.12	3.22	3.50
			BLM/FS Other	35.33	38.83	32.18	45.80	24.15	27.43	24.75
			Other Lands	36.22	39.28	32.93	43.71	19.26	19.26	28.81
		Total Woodland		76.83	83.96	69.94	96.30	46.53	49.91	57.06
	Total Riparian Woodland			100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Rock	Rock	BLM/FS Natural Process	67.23	67.23	67.23	67.23	67.23	67.23	67.23
			BLM/FS Other	29.90	29.90	29.90	29.90	29.90	29.90	29.90
			Other Lands	2.87	2.87	2.87	2.87	2.87	2.87	2.87
		Total Rock		100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Total Rock			100.00	100.00	100.00	100.00	100.00	100.00	100.00
	Urban	Agriculture/Urban	BLM/FS Other	NA	NA	NA	0.23	0.23	0.23	0.23
			Other Lands	NA	NA	NA	99.77	99.77	99.77	99.77
		Total Agriculture/Urban		0	0	0	100.00	100.00	100.00	100.00
	Total Urban			0	0	0	100.00	100.00	100.00	100.00
	Water	Water	BLM/FS Natural Process	1.65	1.65	1.65	1.66	1.66	1.66	1.66
			BLM/FS Other	8.96	8.96	8.96	9.00	9.00	9.00	9.00
			Other Lands	89.38	89.38	89.38	89.35	89.35	89.35	89.35
		Total Water		99.99[9]	99.99[9]	99.99[9]	100.01[9]	100.01[9]	100.01[9]	100.01[9]
	Total Water			99.99[9]	99.99[9]	99.99[9]	100.01[9]	100.01[9]	100.01[9]	100.01[9]
	Woodland	Early-seral Forest	BLM/FS Natural Process	0.47	0.33	0.74	0	0.03	0.10	0.39
			BLM/FS Other	4.23	3.32	4.95	0	1.78	2.46	2.98
			Other Lands	0.09	0	0.22	0	0	0	0.03
		Total Early-seral Forest		4.79	3.65	5.91	0	1.81	2.56	3.40

Management[1] Region	PVG	Physiognomic Type	Land Ownership Group[2] and Management Class[3]	Historical[4] Average	Historical Minimum	Historical Maximum	Current	Scenario CD[5]	Scenario AM[6]	Scenario PM[7]
				Percent of Potential Vegetation Group						
		Exotics	BLM/FS Natural Process	NA	NA	NA	0	0.03	0.08	0.05
			BLM/FS Other	NA	NA	NA	0	0.65	0.44	0.24
			Other Lands	NA	NA	NA	0	0.26	0.26	0.37
		Total Exotics		0	0	0	0	0.94	0.78	0.66
		Herb	BLM/FS Natural Process	0.44	0.13	0.79	0	0.58	0.58	1.05
			BLM/FS Other	4.34	2.02	6.88	0	1.49	0.73	5.91
			Other Lands	8.14	6.31	10.60	0	0.86	0.86	0.99
		Total Herb		12.92	8.46	18.27	0	2.93	2.17	7.95
		Shrub	BLM/FS Natural Process	1.62	1.63	1.49	1.78	1.47	1.47	1.15
			BLM/FS Other	16.07	17.10	14.67	18.16	16.93	17.71	12.98
			Other Lands	36.34	40.44	32.33	43.28	42.52	42.52	42.33
		Total Shrub		54.03	59.17	48.49	63.22	60.92	61.70	56.46
		Woodland	BLM/FS Natural Process	4.74	5.14	4.29	5.49	5.18	5.05	4.63
			BLM/FS Other	18.85	19.25	18.35	25.38	22.68	22.19	21.43
			Other Lands	4.66	4.36	4.69	5.91	5.55	5.55	5.47
		Total Woodland		28.25	28.75	27.33	36.78	33.41	32.79	31.53
		Total Woodland		100.00	100.00	100.00	100.00	100.00	100.001	100.00

[1]Management Region: EEIS = Eastside Environmental Impact Statement assessment area; UCRB = Upper Columbia River Basin Environmental Impact Statement assessment area.

[2]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[3]Management Class: BLM- and FS-administered lands stratified by Natural Process management (wilderness and wilderness-like) and Other which is management of non-wilderness-like roadless lands and roaded lands.

[4]Historical Average = circa 1850 to 1900 (average of initiated model simulations); Historical Minimum = minimum value from 400-year simulation output; Historical Maximum = maximum value from 400-year simulation output; Current = circa 1991.

[5]CD = Consumptive Demand Management Scenario.

[6]AM = Active Management Scenario.

[7]PM = Passive Management Scenario.

[8]NA = Not Applicable.

[9]Numbers have been rounded and therefore do not always add up to 100.00 percent.

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Previous

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APPENDIX 3-I

Common and scientific names of plant species discussed in the "Rangeland Ecology and Grazing Management" section of this chapter.

Common Name	Scientific Name
African rue	*Peganum harmala*
Aspen	*Populus tremuloides*
Basin big sagebrush	*Artemisia tridentata tridentata*
Basin wildrye	*Elymus cinereus*
Big sagebrush	*Artemisia tridentata*
Bitterbrush	*Purshia tridentata*
Bluebunch wheatgrass	*Agropyron spicatum*
Bulbous bluegrass	*Poa bulbosa*
Bull thistle	*Cirsium vulgare*
Camelthorn	*Alhagi pseudalhagi*
Canada thistle	*Cirsium arvense*
Cheatgrass	*Bromus tectorum*
Common crupina	*Crupina vulgaris*
Cottonwood	*Populus trichocarpa*
Crested wheatgrass	*Agropyron cristatum*
Dalmation toadflax	*Linaria dalmatica*
Diffuse knapweed	*Centaurea diffusa*
Distaff thistle	*Carthamus lanatus*
Dryland alfalfa	*Medicago* sp.
Dyer's woad	*Isatis tinctoria*
Halogeton	*Halogeton glomeratus*
Iberian starthistle	*Centaurea iberica*
Idaho fescue	*Festuca idahoensis*
Intermediate wheatgrass	*Agropyron intermedium*
Kentucky bluegrass	*Poa pratensis*
Leafy spurge	*Euphorbia esula*
Lewis flax	*Linum perenne* var. *lewisii*
Low sagebrush	*Artemisia arbuscula*
Matgrass	*Nardus stricta*
Mediterranean sage	*Salvia aethiopis*
Medusahead	*Taeniatherum caput-medusae*
Mountain big sagebrush	*Artemisia tridentata vaseyana*
Mountain mahogany	*Cercocarpus montanus*
Musk thistle	*Carduus nutans*
Needlegrass	*Stipa* spp.
Orange hawkweed	*Hieracium aurantiacum*
Orchardgrass	*Dactylis glomerata*
Oxeye daisy	*Chrysanthemum leucanthemum*

Common Name	Scientific Name
Ponderosa pine	*Pinus ponderosa*
Pubescent wheatgrass	*Agropyron trichophorum*
Purple loosestrife	*Lythrum salicaria*
Purple starthistle	*Centaurea calcitrapa*
Reed canarygrass	*Phalaris arundinacea*
Rush skeletonweed	*Chondrilla juncea*
Russian knapweed	*Centaurea repens*
Russian wildrye	*Elymus junceus*
Saltcedar	*Tamarix ramosissima*
Scotch thistle	*Onopordum acanthium*
Sheep fescue	*Festuca ovina*
Small burnet	*Sanguisorba minor*
Spiny hopsage	*Grayia spinosa*
Spotted knapweed	*Centaurea maculosa*
Squarrose knapweed	*Centaurea virgata*
Stiff sagebrush	*Artemisia rigida*
Sulfur cinquefoil	*Potentilla recta*
Syrian bean-caper	*Zygophyllum fabago*
Threetip sagebrush	*Artemisia tripartita*
Tall wheatgrass	*Agropyron elongatum*
Ventenata	*Ventenata dubia*
Wyoming big sagebrush	*Artemisia tridentata wyomingensis*
Western juniper	*Juniperus occidentalis*
Whitetop (Hoary cress)	*Cardaria draba*
Winterfat	*Eurotia lanata*
Willow	*Salix* spp.
Yellow hawkweed	*Hieracium pratense*
Yellow starthistle	*Centaurea solstitialis*
Yellow toadflax	*Linaria vulgaris*

Sources of nomenclature used in this appendix are Hitchcock and Cronquist (1976) and Whitson and others (1991).

APPENDIX 3-J

Floral and vertebrate taxa observed in western juniper woodlands (obtained from numerous sources listed in Eddleman and others 1994).

Scientific Name
Annual, Biennial Forb[1]
Alyssum desertorum
Amsimkia intermedia
Blepharipappus scaber
Clarkia pulchella
Coldenia grandiflora
Collinsia parviflora
Collomia grandiflora
Cordylanthus ramosus
Cryptantha affinis
Cryptantha ambigua
Descurainia pinnata
Descurainia richardsonii
Draba verna
Epilobium minutum
Epilobium paniculatum
Eriogonum vimineum
Erodium cicutarium
Euphorbia spp.
Galium bifolium
Gayophytum humile
Gayophytum nuttallii
Hemizonia pungens
Holosteum umbellatum
Lactuca ludoviciana
Lagophylla ramosissima
Layia glandulosa
Lepidium perfoliatum
Linanthus harknessi
Lupinus microcarpus
Madia gracilis
Madia sativa
Microsteris gracilis
Mimulus breweri

Scientific Name
Montia perfoliata
Navarretia sp.
Orthocarpus tenuifolius
Phacelia linearis
Plectritis macrocera
Polemonium micranthum
Polygonum majus
Ranunculus testiculatus
Ranunculus occidentalis
Sanguisorba minor
Sisymbrium altissimum
Taraxacum ceratophorum
Tragopogon dubius
Verbascum thapsus
Annual Grass[1]
Agrostis interrupta
Bromus brizaeformis
Bromus japonicus
Bromus mollis
Bromus tectorum
Festuca bromoides
Festuca microstachys
Festuca octoflora
Taeniatherum asperum
Perennial Forb[1]
Achillea millefolium
Agoseris glauca
Agoseris grandiflora
Allium acuminatum
Allium douglasii
Antennaria rosea
Antennaria dimorpha
Arabis hoboelii
Arabis puberula
Arabis sparsiflora
Aster campestris
Astragalus beckwithii
Astragalus curvicarpus
Astragalus filipes
Astragalus lentiginosus
Astragalus purshii
Astragalus reventus
Astragalus stenophyllus

Scientific Name
Balsamorhiza careyana
Balsamorhiza sagittata
Calochortus macrocarpus
Castilleja applegatei
Castilleja chromosa
Chaenactis douglasii
Cheilanthes gracillima
Cirsium arvense
Crepis acuminata
Crepis intermedia
Erigeron bloomeri
Erigeron elegantulus
Erigeron filifolius
Erigeron linearis
Erigeron poliospermus
Erigeron pumilus
Eriogonum heracleoides
Eriogonum microthecum
Eriogonum niveum
Eriogonum ovalifolium
Eriogonum sphaerocephalum
Eriogonum strictum
Eriogonum thymoides
Eriogonum umbellatum
Eriophyllum lanatum
Fritillaria pudica
Geum campanulatum
Hydrophyllum capitatum
Leptodactylon pungens
Linum perenne
Lithophragma bulbifera
Lomatium canbyi
Lomatium cous
Lomatium macrocarpum
Lomatium triternatum
Lupinus caudatus
Lupinus laxiflorus
Lupinus lepidus
Mertensia longiflora
Microseris nutans
Microseris troximoides
Orobanche uniflora
Penstemon humilis

Scientific Name
Penstemon gracilis
Penstemon laetus
Penstemon richardsoni
Penstemon speciosus
Petalostemon ornatum
Phacelia hastata
Phlox douglasii
Phlox hoodii
Phlox longifolia
Potentilla glandulosa var. *intermedia*
Ranunculus occidentalis
Senecio canus
Senecio integerrimus
Sisyrinchium douglasi
Sisyrinchium idahoense
Stellaria americana
Stellaria nitens
Trifolium dubium
Trifolium macrocephalum
Trifolium microcephalum
Zygadenus paniculatus
Perennial Grass[1]
Agropyron saxicola
Agropyron smithii
Agropyron spicatum
Bromus carinatus
Danthonia unispicata
Elymus cinereus
Festuca idahoensis
Keoleria cristata
Oryzopsis humenoides
Poa ampla
Poa bulbosa
Poa compressa
Poa cusickii
Poa pratensis
Poa sandbergii
Sitanion hystrix
Stipa columbiana
Stipa comata
Stipa occidentalis
Stipa thurberiana
Sedge[1]
Carex rossii
Carex geyeri
Kobresia simpliciuscula

Scientific Name
Shrub[1]
Artemisia arbuscula
Artemisia tridentata ssp. *tridentata*
Artemisia tridentata ssp. *wyomingensis*
Artemisia tridentata ssp. *vaseyana*
Artemisia rigida
Cercocarpus ledifolius
Chrysothamnus nauseosus
Chrysothamnus viscidiflorus
Grayia spinosa
Holodiscus dumosus
Purshia tridentata
Ribes cereum
Symphoricarpos oreophilus
Tetradymia canescens
Tetradymia glabrata
Tree[1]
Juniperus occidentalis ssp. *occidentalis*
Pinus ponderosa

Scientific Name	Common Name
Amphibian	
Ambystoma macrodactylum	Long-toed Salamander
Pseudacris regilla	Pacific Treefrog
Bird	
Accipiter cooperii	Cooper's Hawk
Accipiter striatus	Sharp-shinned Hawk
Alectoris chukar	Chukar
Aquila chrysaetos	Golden Eagle
Asio otus	Long-eared Owl
Bombycilla cedrorum	Cedar Waxwing
Bombycilla garrulus	Bohemian Waxwing
Bubo virginianus	Great Horned Owl
Buteo jamaicensis	Red-tailed Hawk
Buteo lagopus	Rough-legged Hawk
Buteo regalis	Ferruginous Hawk
Carduelis pinus	Pine Siskin
Carpodacus mexicanus	House Finch
Cathartes aura	Turkey Vulture
Catherpes mexicanus	Canyon Wren
Chordeiles minor	Common Nighthawk
Colaptes auratus	Northern Flicker

Scientific Name	Common Name
Corvus corax	Common Raven
Cyanocitta stelleri	Steller's Jay
Dendroica coronata	Yellow-rumped Warbler
Dendroica nigrescens	Black-throated Gray Warbler
Dendroica townsendi	Townsend's Warbler
Empidonax oberholseri	Dusky Flycatcher
Empidonax wrightii	Gray Flycatcher
Eremophila alpestris	Horned Lark
Falco mexicanus	Prairie Falcon
Falco sparverius	American Kestrel
Glaucidium gnoma	Northern Pygmy Owl
Gymnorhinus cyanocephalus	Pinyon Jay
Hirundo pyrrhonota	Cliff Swallow
Hirundo rustica	Barn Swallow
Lanius execubitor	Northern Shrike
Lanius ludovicianus	Loggerhead Shrike
Madestes townsendi	Townsend's Solitaire
Myiarchus cinerascens	Ash-throated Flycatcher
Oreoscoptes montanus	Sage Thrasher
Parus gambeli	Mountain Chickadee
Phalaenoptilus nuttallii	Common Poorwill
Pica pica	Black-billed Magpie
Pipilo chlorurus	Green-tailed Towhee
Riparia riparia	Bank Swallow
Salpinctes obsoletus	Rock Wren
Selasphorus rufus	Rufous Hummingbird
Sialia currucoides	Mountain Bluebird
Speotyto cunicularia	Burrowing Owl
Spizella breweri	Brewer's Sparrow
Stelgidopteryx serripennis	Northern Rough-winged Swallow
Sturnus vulgaris	European Starling
Tachycineta bicolor	Tree Swallow
Tachycineta thalassina	Violet-green Swallow
Turdus migratorius	American Robin
Tyrannus verticalis	Western Kingbird
Zenaida macroura	Mourning Dove
Mammal	
Antrozous pallidus	Pallid Bat
Canis latrans	Coyote
Dipodomys ordii	Ord's Kangaroo Rat
Equus caballus	Domestic Horse (Feral)
Erethizon dorsatum	Common Porcupine

Scientific Name	Common Name
Felis concolor	Mountain Lion
Lasionycteris noctivagans	Silver-haired Bat
Lepus californicus	Black-tailed Jackrabbit
Lynx rufus	Bobcat
Mustela frenata	Long-tailed Weasel
Myotis ciliolabrum	Western Small-footed Myotis
Myotis evotis	Long-eared Myotis
Myotis lucifugus	Little Brown Myotis
Myotis volans	Long-legged Myotis
Myotis yumanensis	Yuma Myotis
Neotoma cinerea	Bushy-tailed Woodrat
Odocoileus hemionus	Mule or Black-tailed Deer
Onychomys leucogaster	Northern Grasshopper Mouse
Ovis canadensis	Mountain (or Bighorn) Sheep
Perognathus parvus	Great Basin Pocket Mouse
Peromyscus maniculatus	Deer Mouse
Peromyscus truei	Pinon Mouse
Plecotus townsendii	Townsend's Big-eared Bat
Spermophilus lateralis	Golden-mantled Ground Squirrel
Spermophilus townsendii	Townsend's Ground Squirrel
Tamias amoenus	Yellow-pine Chipmunk
Tamias minimus	Least Chipmunk
Taxidea taxus	American Badger
Reptile	
Charina bottae	Rubber Boa
Coluber constrictor	Racer
Contia tenuis	Sharp-tailed Snake
Crotalus viridis	Western Rattlesnake
Elgaria multicarinatas	Southern Alligator Lizard
Eumeces skiltonianus	Western Skink
Hypsiglena torquata	Night Snake
Masticophis taeniatus	Striped Whipsnake
Phrynosoma douglassi	Short-horned Lizard
Pituophis melanoleucus	Gopher Snake
Sceloporus graciosus	Sagebrush Lizard
Sceloporus occidentalis	Western Fence Lizard
Uta stansburiana	Side-blotched Lizard

APPENDIX 3-K

Averaged disturbance probabilities of probability sets for scenario modeling designed for wilderness-like lands.

Potential Vegetation Group	Physiognomic Type Group	Scenario			
		Historical	Consumptive Demand	Active	Passive
			Wildfire		
Cold Forest	Early-seral Forest	0.0039	0.0036	0.0030	0.0035
Cold Forest	Late-seral Multi-layer Forest	0.0149	0.0136	0.0114	0.0138
Cold Forest	Late-seral Single-layer Forest	0.0109	0.0056	0.0046	0.0055
Cold Forest	Mid-seral Shade-intolerant For.	0.0122	0.0102	0.0085	0.0102
Cold Forest	Mid-seral Shade-tolerant Forest	0.0105	0.0100	0.0083	0.0098
Cold Forest	Woodland	0.0050	0.0048	0.0040	0.0045
Dry Shrub	Exotics	NA[1]	0.0545	0.0454	0.0522
Dry Shrub	Herbland	0.0121	0.0096	0.0080	0.0086
Dry Shrub	Shrubland	0.0127	0.0233	0.0194	0.0235
Dry Shrub	Woodland	0.0205	0.0051	0.0043	0.0097
Moist Forest	Early-seral Forest	0.0073	0.0034	0.0028	0.0067
Moist Forest	Late-seral Multi-layer Forest	0.0170	0.0073	0.0061	0.0144
Moist Forest	Late-seral Single-layer Forest	0.0151	0.0066	0.0055	0.0117
Moist Forest	Mid-seral Shade-intolerant For.	0.0152	0.0058	0.0048	0.0115
Moist Forest	Mid-seral Shade-tolerant Forest	0.0133	0.0057	0.0048	0.0112
			Prescribed Fire		
Cold Forest	Early-seral Forest	NA	0.0013	0.0086	NU[2]
Cold Forest	Late-seral Multi-layer Forest	NA	0.0021	0.0150	NU
Cold Forest	Late-seral Single-layer Forest	NA	0.0017	0.0201	NU
Cold Forest	Mid-seral Shade-intolerant For.	NA	0.0017	0.0156	NU
Cold Forest	Mid-seral Shade-tolerant Forest	NA	0.0025	0.0125	NU
Cold Forest	Woodland	NA	0[3]	0.0150	NU
Dry Shrub	Exotics	NA	0	0	NU
Dry Shrub	Herbland	NA	0.0015	0.0076	NU
Dry Shrub	Shrubland	NA	0.0020	0	NU
Dry Shrub	Woodland	NA	0	0.0030	NU
Moist Forest	Early-seral Forest	NA	0	0.0025	NU
Moist Forest	Late-seral Multi-layer Forest	NA	0	0.0077	NU
Moist Forest	Late-seral Single-layer Forest	NA	0	0.0060	NU
Moist Forest	Mid-seral Shade-intolerant For.	NA	0	0.0089	NU
Moist Forest	Mid-seral Shade-tolerant Forest	NA	0	0.0064	NU

Potential Vegetation Group	Physiognomic Type Group	Scenario			
		Historical	Consumptive Demand	Active	Passive
			Successional Change Grazing		
Dry Shrub	Herbland	0.0030	0.0054	0.0043	0.0039
Dry Shrub	Shrubland	0.0071	0.0053	0.0035	0.0030
Dry Shrub	Woodland	0.0200	0.0015	0.0008	0.0010
			Non-impactive Grazing		
Cold Forest	Woodland	0.0010	0.0008	0.0013	0.0005
Dry Shrub	Exotics	NA	0.0034	0.0052	0.0020
Dry Shrub	Herbland	0.0249	0.0846	0.0122	0.0430
Dry Shrub	Shrubland	0.0172	0.0031	0.0061	0.0013
Dry Shrub	Woodland	0	0.0010	0.0017	0.0007
			Exotics		
Dry Shrub	Herbland	NA	0.0043	0.0016	0.0047
Dry Shrub	Shrubland	NA	0.0048	0.0026	0.0018

[1]NA = Not Applicable, was not an applicable item for the scenario or did not exist in the historical period.

[2]NU = Not Used, was not applicable to the scenario and a probability was not inserted.

[3]0 = Actual probability modeled was zero.

APPENDIX 3-L

Averaged disturbance probabilities of probability sets for modeling scenarios on non-wilderness-like lands.

Potential Vegetation Group	Physiognomic Type Group	Scenario			
		Historical	Consumptive Demand	Active	Passive
			Wildfire		
Dry Forest	Early-seral Forest	0.0244	0.0044	0.0030	0.0040
Dry Forest	Exotics	NA[1]	0.0009	0.0010	0.0010
Dry Forest	Herbland	0.0200	0.0009	0.0010	0.0010
Dry Forest	Late-seral Multi-layer Forest	0.0389	0.0084	0.0060	0.0080
Dry Forest	Late-seral Single-layer Forest	0.0361	0.0038	0.0030	0.0040
Dry Forest	Mid-seral Shade-intolerant Forest	0.0349	0.0075	0.0060	0.0080
Dry Forest	Mid-seral Shade-tolerant Forest	0.0297	0.0074	0.0060	0.0070
Dry Forest	Shrubland	0.03600	0.0009	0.0010	0.0010
Dry Shrub	Exotics	NA	0.0606	0.0450	0.0545
Dry Shrub	Herbland	0.0121	0.0064	0.0050	0.0058
Dry Shrub	Shrubland	0.0127	0.0244	0.0180	0.0220
Dry Shrub	Woodland	0.0205	0.0067	0.0050	0.0060
Moist Forest	Early-seral Forest	0.0073	0.0040	0.0030	0.0040
Moist Forest	Late-seral Multi-layer Forest	0.0170	0.0070	0.0050	0.0070
Moist Forest	Late-seral Single-layer Forest	0.0151	0.0050	0.0040	0.0050
Moist Forest	Mid-seral Shade-intolerant Forest	0.0152	0.0050	0.0040	0.0050
Moist Forest	Mid-seral Shade-tolerant Forest	0.0133	0.0050	0.0040	0.0050
			Prescribed Fire		
Dry Forest	Early-seral Forest	NA	0[2]	0.0030	0
Dry Forest	Exotics	NA	0.0080	0.0240	0.0080
Dry Forest	Late-seral Multi-layer Forest	NA	0.0050	0.0630	0.0030
Dry Forest	Late-seral Single-layer Forest	NA	0.0047	0.0570	0.0030
Dry Forest	Mid-seral Shade-intolerant Forest	NA	0.0051	0.0170	0.0060
Dry Forest	Mid-seral Shade-tolerant Forest	NA	0.0085	0.0300	0.0090
Dry Shrub	Exotics	NA	0	0	0
Dry Shrub	Herbland	NA	0.0009	0.0080	0.0168
Dry Shrub	Shrubland	NA	0.0011	0.0010	0.0243
Dry Shrub	Woodland	NA	0	0.0300	0.0054
Moist Forest	Early-seral Forest	NA	0	0.0030	0
Moist Forest	Late-seral Multi-layer Forest	NA	0	0.0080	0
Moist Forest	Late-seral Single-layer Forest	NA	0	0.0060	0
Moist Forest	Mid-seral Shade-intolerant Forest	NA	0	0.0100	0
Moist Forest	Mid-seral Shade-tolerant Forest	NA	0	0.0060	0

Potential Vegetation Group	Physiognomic Type Group	Scenario			
		Historical	Consumptive Demand	Active	Passive
			Non-impactive Grazing		
Dry Forest	Early-seral Forest	NU[3]	0.0095	0.0130	0.0095
Dry Forest	Exotics	NA	0.1800	0.2400	0.1800
Dry Forest	Herbland	NU	0.0225	0.0300	0.0225
Dry Forest	Shrubland	NU	0.0225	0.0300	0.0225
Dry Shrub	Exotics	NU	0.0442	0.0500	0.0453
Dry Shrub	Herbland	0.0249	0.2206	0.2910	0.2646
Dry Shrub	Shrubland	0.0172	0.0700	0.0940	0.0778
Dry Shrub	Woodland	0.005	0.0100	0.0130	0.0113
			Successional Change Grazing		
Dry Forest	Early-seral Forest	NU	0.0200	0.0040	0.0095
Dry Shrub	Herbland	0.003	0.0163	0.0040	0.0122
Dry Shrub	Shrubland	0.0071	0.0266	0.0150	0.0223
Dry Shrub	Woodland	0.0200	0.0052	0.0020	0.0035
			Exotics		
Dry Shrub	Herbland	NA	0.0281	0.0050	0.0166
Dry Shrub	Shrubland	NA	0.0258	0.0040	0.0164
			Seeding and Exotic Control		
Dry Shrub	Exotics	NA	0.0010	0.0170	0.0154
Dry Shrub	Herbland	NU	0	0.0200	0.0100
Dry Shrub	Shrubland	NU	0.0010	0.0190	0.0156
			Harvest		
Dry Forest	Late-seral Multi-layer Forest	NA	0.0394	0.0200	0.0184
Dry Forest	Late-seral Single-layer Forest	NA	0.0345	0.0150	0.0161
Dry Forest	Mid-seral Shade-intolerant Forest	NA	0.0209	0.0090	0.0098
Dry Forest	Mid-seral Shade-tolerant Forest	NA	0.0157	0.0170	0.0073
Dry Shrub	Woodland	NA	0.0084	0.0140	0.0070
Moist Forest	Late-seral Multi-layer Forest	NA	0.0228	0.0215	0.0127
Moist Forest	Late-seral Single-layer Forest	NA	0.0231	0.0091	0.0129
Moist Forest	Mid-seral Shade-intolerant Forest	NA	0.0137	0.0172	0.0077
Moist Forest	Mid-seral Shade-tolerant Forest	NA	0.0166	0.0164	0.0093

Potential Vegetation Group	Physiognomic Type Group	Scenario			
		Historical	Consumptive Demand	Active	Passive
			Thinning		
Dry Forest	Early-seral Forest	NA	0.0274	0.0210	0.0128
Dry Forest	Late-seral Multi-layer Forest	NA	0.0120	0.0120	0.0056
Dry Forest	Late-seral Single-layer Forest	NA	0	0.0120	0
Dry Forest	Mid-seral Shade-intolerant Forest	NA	0.0133	0.0100	0.0062
Dry Forest	Mid-seral Shade-tolerant Forest	NA	0.0168	0.0140	0.0078
Moist Forest	Early-seral Forest	NA	0.0344	0.0163	0.0192
Moist Forest	Late-seral Multi-layer Forest	NA	0	0.0070	0
Moist Forest	Mid-seral Shade-intolerant Forest	NA	0.0100	0.0157	0.0056
Moist Forest	Mid-seral Shade-tolerant Forest	NA	0.0038	0.0131	0.0021

[1]NA = Not Applicable, was not an applicable item for the scenario or did not exist in the historical period.

[2]NU = Not Used, was not applicable to the scenario and a probability was not inserted.

[3]0 = Actual probability modeled was zero.

APPENDIX 3-M

Background information for proper functioning systems analysis.

I. Management Emphasis[1] Categories

A. Ecosystem Management Emphasis Categories

Conservation (C) - planned management to prevent exploitation, destruction, or neglect.

A conservation emphasis assumes that the area of assessment has a dominant landscape component that is functioning relatively well as a native or naturalized system and is producing associated human needs and values within the capabilities of the system. These landscapes generally have moderate to high ecological integrity and socioeconomic resiliency. Integrity is based on the wholeness of elements and relationships of the primary ecological systems (geologic, geomorphic, climatic, hydrologic, carbon-nutrient, food web, evolutionary, and toxins). There may be inclusions (less than 20% of the area) with conservation or restoration emphasis.

*The geologic, geomorphic, pedogenic, climatic, hydrologic, and carbon-nutrient systems are functioning similar to the native (HRV) system, and are shifting in a resilient manner to current and potential future climate change and geologic events. Resilient change in response to climate change or geologic events would mean shifts in land forms (geomorphic), soil development (pedogenic), water flow or transpiration (hydrologic), and vegetation types (carbon-nutrient) that are in sync with the changes in climate and the geologic events (for example, erosion rates would not be excessive or forest soils would not be developing on grassland soils as climates changed to warmer conditions).

*Terrestrial and aquatic systems (species and habitats) have a relatively complete array of native diversity. This does not mean that the composition is equivalent to native (HRV). However, the opportunity to manage for systems somewhat similar to native (HRV) should be available.

A conservation emphasis assumes that relatively low management activity energy is needed for active restoration of terrrestrial, aquatic, hydrologic, carbon-nutrient and pedogenic systems because their current and future trends are relatively stable in response to disturbance and human effects.

A conservation emphasis assumes that human values and needs will flow from management systems that are designed to simulate the changes and disturbances that would occur within or relatively close to native (HRV) patterns.

A conservation emphasis assumes that a coarse-filter strategy of managing landscape patterns of succession/disturbance regimes similar to HRV will conserve and recover most native species diversity. Stronghold or relic populations of threatened, endangered, candidate, or sensitive species may need short-term protection from disturbance of habitat that would occur in an HRV regime in order to expand the population to adjacent habitats.

[1] The strategy of conserve, restore and produce as a basis for ecosystem management was developed by Jeff Blackwood and other Project staff, based on the concepts in "Forest Service Ethics and Course to the Future" by Jack Ward Thomas, and coordinated with BLM leadership.

Restoration (R) - to bring back to a former or original condition, pattern, or process.

A restoration emphasis assumes that the area of assessment has a dominant landscape component that is not functioning well as a native, naturalized, or non-native system and/or in the production of human needs and values within the capability of the system. Ecological integrity is usually low and socioeconomic resiliency is low or at risk. There may be inclusions (less than 20% of the area) of conservation and restoration emphases.

*The geologic, geomorphic, pedogenic, climatic, hydrologic, and carbon-nutrient systems are not functioning similar to the native (HRV) of the paleoecologic system, and are not resilient to current and potential future disturbance, climate change and geologic events.

*Terrestrial and aquatic systems (species and habitats) are not functioning like native systems. Generally the composition and structure will be well outside of native (HRV). There may be permanent alteration to biophysical potentials.

A restoration emphasis assumes that moderate management activity energy is needed for active restoration of terrrestrial, aquatic, hydrologic, carbon-nutrient, and/or pedogenic systems because their current and future trends are unstable in response to disturbance and human effects. Productivity may be at risk as well as increased risk of erratic disturbance events.

A restoration emphasis assumes that human values and needs will not flow from managed systems unless there is active restoration to shift composition, structure, and disturbance to a system that would be more consistent with native (HRV) patterns. It is likely that altered biophysical systems cannot be managed for consistency with native (HRV) patterns because cause-and effect responses have changed. These systems will require a different type of management to provide for resiliency and predictable response to disturbance, while conserving productivity and native diversity. Some processes and functions may be similar to native (HRV), while others may be different in order to account for the altered causes and effects.

A restoration emphasis assumes that a coarse-filter strategy of managing landscape patterns of succession/disturbance regimes similar to native (HRV) will not conserve and recover native species diversity. Active restoration of "lost" functions and species may recover the landscapes to a functioning condition that can then be managed with a conservation or production strategy. Stronghold or relic populations of threatened, endangered, candidate, or sensitive species will need protection from disturbance of habitat that would occur in or outside the native (HRV) regime in order to expand the population to adjacent habitats.

Production (P) - output of a commodity, value, or need.

A production emphasis assumes that the area of assessment has a dominant landscape component that is functioning relatively well as a native, naturalized or non-native system in association with traditional production of human needs, commodities, and values. Ecological integrity is usually moderate to high and as is socioeconmic resiliency. In some cases ecological integrity may be low and substantial mitigation is needed in order maintain trends to equilibrium. There may be inclusions (less than 20% of the area) of conservation and restoration.

*The geologic, geomorphic, pedogenic, climatic, hydrologic, and carbon-nutrient systems may or may not be functioning similar to the native (HRV). However these systems are shifting in a resilient manner to current and potential future climate change and geologic events. Resilient change in response to climate change or geologic events would mean shifts

in land forms (geomorphic), soil development (pedogenic), water flow or transpiration (hydrologic), and vegetation types (carbon-nutrient) that are in sync with the changes in climate and the geologic events (for example, erosion rates would not be excessive or forest soils would not be developing on grassland soils as climates changed to warmer conditions) such that they would not affect the capacity to produce human commodities, values, and needs.

*Terrestrial and aquatic systems (species and habitats) may or may not function like native systems. Generally the composition and structure will be well outside of HRV and there may be permanent alteration to biophysical potentials. However the departure from native (HRV) and alteration of biophysical potentials does not affect the capacity to sustain human commodities, values, and needs. The risks to productivity, current native diversity, and human values and needs caused by departure from native (HRV) system processes are relatively low in these systems, or high risks can be mitigated with increased management activity.

A production emphasis assumes that relatively high management activity energy is needed for active production of human commodities, values, and needs, while conserving the productive capacity and current native diversity of the terrrestrial, aquatic, hydrologic, carbon-nutrient, and/or pedogenic systems.

A production emphasis assumes that human commodities, values, and needs will flow from management systems with mitigation to conserve current native composition, structure, and disturbance. The systems may not be consistent with native (HRV) patterns but they are managed consistent with biophysical potentials, not against internal system disturbance trends. This will enhance the ability of the system to achieve multiple emphases of production, conservation, and restoration. It is likely that altered biophysical systems cannot be managed for consistency with native (HRV) because cause-and-effect responses have changed. These systems will require a different type of management to conserve productivity and provide for resiliency and predictable response to disturbance. Active mitigation will be needed to conserve current native diversity. Some processes and functions may be similar to native (HRV), while others may be different in order to account for altered causes and effects. Some systems may need to be artificially supported to maintain or enhance production emphasis.

A production emphasis assumes that a coarse-filter strategy of managing landscape patterns of succession/disturbance regimes similar to native (HRV) or with mitigation will conserve the current native species diversity. Active restoration of "lost" functions and species may occur in association with some production activities to recover landscapes to a more native functioning condition that will more efficiently achieve production objectives. Stronghold or relic populations of threatened, endangered, candidate, or sensitive species will need protection from disturbance of habitat that would occur in order to expand the population to adjacent habitats.

Restoration/Conservation (RC) - dominant component of the area is a landscape strategy for restoration and conversion to conservation. The objective is to rapidly restore the area because of its adjacency to an area with a conservation strategy, that has an objective for expansion.

Restoration/Production (RP) - dominant component of the area is in a landscape strategy for restoration, while producing at reduced levels. This strategy is designed to restore the area in order to achieve a long-term strategy of sustainable production.

Conservation/Production (CP) - dominant component of the area is a landscape strategy for conservation, but with considerable opportunities for production of human commodities and values while maintaining ecological processes. This strategy is designed to conserve the area while producing sustainable commodities and values.

Mixed (MM) - the various conservation, restoration, and production strategies are mixed within the assessment area to achieve proper functioning systems with multiple ecosystem management objectives for conservation, restoration, and production. This strategy is common for larger landscapes, subregions, and regions.

B. Traditional Management Emphasis Categories

Traditional Commodity (TC) - output of a commodity, value, or need.

A traditional commodity emphasis assumes that the area of assessment has a dominant landscape component that is managed for traditional production of human needs, commodities, and values. Emphasis is on the multiple, but relatively independent management of various resources (fire protection, timber, forage, recreation, wildlife, fisheries, and water) for sustained yield of the resource.

*The geologic, geomorphic, pedogenic, climatic, hydrologic, and carbon-nutrient systems are typically not functioning similar to the native (HRV) system. These systems are typically not responding in a resilient manner to current and potential future climate change and geologic events.

*Terrestrial and aquatic systems (species and habitats) generally are not functioning as native systems. Generally the composition and structure will be well outside of HRV and there may be high risk or actual permanent alteration to biophysical potentials. The departure from HRV and alteration of biophysical potentials often result in reduced production or risk to production of human commodities, values, and needs. Attempts to mitigate for loss of system capabilities, reduced native diversity, and increasing risk of species extinctions typically are unsuccessful or require very high investments of management activities.

A traditional commodity emphasis assumes that relatively high management activity energy is needed for active production of human commodities, values, and needs with substantial emphasis on protection to conserve current native diversity of the terrrestrial, aquatic, hydrologic, carbon-nutrient, and/or pedogenic systems. Energy invested in commodities and protection of systems is often precluded by disturbance events.

A traditional commodity emphasis assumes that human commodities, values and needs will flow from management systems that are often in conflict with ecological relationships and landscape limitations. Mitigation is typically used to conserve current native composition, structure, and disturbance, but these efforts are often unsuccessful because of conflicts with ecological relationships and landscape limitations. Most systems will need to be artificially supported to maintain commodity production, but the long-term outcome is typically a loss of commodity production capability.

A traditional commodity production emphasis assumes that a single species approach for recovery of threatened, endangered, candidate, or sensitive species is used to conserve current native species diversity. Stronghold or relic populations of threatened, endangered, candidate, or sensitive species will be protected from human disturbance of habitats. However, these habitats may be at high risk to system disturbances as well as in conflict with other species habitats.

Traditional Reserve (TR) - protection of current native habitats, aesthetic values, and roadless recreation values.

A traditional reserve emphasis assumes that the area of assessment has a dominant landscape component that is managed for protection of current native habitas, aesthetic values, and roadless recreation values. Emphasis is on multiple, but relatively independent management of various resources (fire protection, forage, roadless recreation, wilderness, wildlife, fisheries, and water) for sustained yield of the resource.

*The geologic, geomorphic, pedogenic, climatic, hydrologic, and carbon-nutrient systems are typically not functioning similar to the native (HRV) system. These systems are typically not shifting in a resilient manner to current and potential future climate change and geologic events.

*Terrestrial and aquatic systems (species and habitats) may be functioning to some extent as native systems. Generally the composition and structure will be well outside of HRV and there may be low to moderate risk of permanent alteration to biophysical potentials. The departure from HRV often results in moderate risk of severe disturbance and potential loss of aesthetic values, native diversity, and biophysical potential. Attempts to mitigate for loss of system capabilities, reduced native diversity, and increasing risk of species extinctions typically are unsuccessful because of the high cost of investments and lack of funds for this type of land use management.

A traditional reserve emphasis assumes that low management activity energy is needed for management of human values and needs. However, substantial emphasis is required for protection to control disturbance and conserve current native diversity of the terrrestrial and aquatic systems.

A traditional reserve emphasis assumes that human values and needs will flow from management systems that are in conflict with ecological relationships and landscape limitations. Mitigation is typically used to conserve current native composition, structure, and disturbance, but these efforts are often unsuccessful because of conflicts with disturbance relationships and landscape limitations. Most systems will need to be artificially managed to control disturbance and provide protection to current conditions. The long-term outcome is typically a loss of native diversity and system capability.

A traditional reserve emphasis assumes that the protection of areas from disturbance and roads will protect native species and habitats. A single species approach for recovery of threatened, endangered, candidate, or sensitive species is used to conserve current native species diversity. Stronghold or relic populations of threatened, endangered, candidate, or sensitive species will be protected from human disturbance of habitats. However, these habitats may be at high risk to system disturbances as well as in conflict with other species habitats.

Traditional Mixed (TM) - mixed traditional commodity production is a mosaic with protection of current native habitats, aesthetic values, and roadless recreation values, where none of the types of management predominate in the area.

II. Background information on CRBSUM prescription (Rx) models.

Table 3-M1. Landscape management prescriptions (Rx).

BLM/FS	Rx	Legend Name
Ecological Prescriptions		
*	A1	Restoration[1] with PNF/P[2]
*	A2	Roaded Land High Restoration with Production[1]
*	A3	Roaded Land High Restoration with Production and Area or PVG Emphasis
*	N1	Conservation[1]
*	N4	Roaded Land Moderate Restoration with Production
Traditional Reserve Prescriptions		
*	C1	Roadless Land with Moderate Fire Suppression
*	N6	Roadless Land with Moderate Fire Suppression and PNF/U[3]
*	P1	Roadless Land Reserve with Moderate Fire Suppression
Traditional Commodity Prescriptions		
*	C2	Roaded Land High Commodity with Low Ecological Mitigation
*	C3	Roaded Land High Commodity with No Ecological Mitigation
*	N3	Roaded Land Moderate Commodity with Low Ecological Mitigation
*	N5	Roaded Land Moderate Comodity with High Exotic Weeds
*	N8	Roaded Land Moderate Commodity with Moderate Ecological Mitigation
*	P3	Roaded Land Very High Commodity with No Ecological Mitigation
Traditional Commodity in Sensitive Areas		
*	N2	Sensitive Visual[4] Area with Moderate Harvest & Livestock
*	N7	Sensitive Visual Area with Moderate Harvest & Low Livestock
	P2	Sensitive Visual Area with Low Commodity & High Wildfire

[1]Management Emphasis definitions:

1) Conservation-- Emphasis provides for the protection of rare native elements and systems while maintaining proper functioning systems and restoring systems where there is low risk to rare elements or systems. Some human commodities may be produced but the emphasis is on human values related to protection of native diversity, aesthetics, and recreation.

2) Restoration-- Emphasis provides for subsidizing ecological and landscape processes and functions to shift the transistion toward proper functioning systems. Considerable human commodities may be produced that are compatible with restoration, as well as conservation of inclusions of rare elements and systems, but the emphasis is on shifting landscapes that are in high departure from the native regime toward proper functioning ecological relationships.

3) Production-- Emphasis provides for production of human needs and values by managing in concert with native ecological and landscape processes to maintain or shift to proper functioning systems. This will typically require subsidies to represent native ecological cause-and-effect relationships at landscape levels, along with some restoration and conservation, but the emphasis is on design of system responses that produce commodities and other values.

4) Traditional-- Emphasis on the independent managment model for producing commodity values, protecting visually or environmentally sensistive areas, or managing reserves to protect semi-primitive characteristics.

[2]Prescribed natural fire program with planned ignition.

[3]Prescribed natural fire program with unplanned ignition.

[4]Traditional sensitive visual area managment similar to traditional reserve.

Table 3-M2—Management prescription sets (Rx) for Historical Range of Variability (HRV) and scenario modeling.

Rx	Description
HI	Prescription set to model 100-year and 400-year simulations of HRV.
Ecological Prescriptions	
A1	Prescription set with high levels of ecological restoration. Generally designed for areas that have moderate to high departure from HRV, in roadless or conservation areas.
A2	Prescription set with high levels of ecological restoration. Generally designed for areas that have moderate to high departure from HRV, in areas with road access.
A3	Prescription set with high levels of ecological restoration. Generally designed for areas that have moderate to high departure from HRV, in areas with road access where specific areas or PVGs are prioritized.
N1	Prescription set with moderate levels of ecological restoration. Generally designed for maintenance or slower transition of areas that have low to moderate departure from HRV.
N4	Prescription set with moderate levels of ecological restoration typically for use in sensitive areas or where areas have low to moderate departure from HRV, in areas with road access.
Traditional Reserve Prescriptions	
C1	Prescription set for traditional wilderness, park, and semi-primitive area management with minimal ecological mitigation and high fire suppression emphasis.
N6	Prescription set for traditional wilderness and semi-primitive area management with minimal ecological mitigation, conservative prescribed natural fire, unplanned ignition plans, and moderate fire suppression emphasis.
P1	Prescription set for traditional reserve management with low to moderate probability of successful wildfire suppression.
Traditional Commodity Prescriptions	
C2	Prescription set for traditional commodity and resource value production at high levels with some ecological mitigation.
C3	Prescription set for traditional commodity and resource value production at high levels with no ecological mitigation.
N3	Prescription set for traditional commodity and resource value production at high levels and some ecological mitigation with higher livestock grazing than N8, and low to moderate probability of successful wildfire suppression.
N5	Prescription set for moderate level traditional commodity and resource value production with low emphasis on exotic weed control on rangeland.
N8	Prescription set for high traditional commodity and resource value production and some ecological mitigation.
P3	Prescription set for traditional commodity and resource value production at high levels with no ecological mitigation.
Traditional Commodity in Sensitive Areas	
N2	Prescription set for high level traditional commodity and resource value production in visually sensitive areas with somewhat higher livestock grazing than N7 and minimal ecological mitigation.
N7	Prescription set for moderate level traditional commodity and resource value production in visually sensitive areas with minimal ecological mitigation.
P2	Prescription set for moderate levels of traditional commodity and resource value production in **visually** sensitive areas with no ecological mitigation and low probability of successful wildfire suppression.

Table 3-M3— Prescription (Rx) transition rates.

Prescription (Rx)[1]	Type of Model[2]	ME[3]	TR[4]
HI	Native	NA	NA
Ecological Prescriptions			
A1	Ecological	R	H
A2	Ecological	RP	H
A3	Ecological	RP	M
N1	Ecological	C	L
N4	Ecological	CP	L
Traditional Reserve Prescriptions			
C1	Independent	TR	M
N6	Independent	TR	L
P1	Independent	TR	L
Traditional Commodity Prescriptions			
C2	Independent	TC	H
C3	Independent	TC	H
N3	Independent	TC	H
N5	Independent	TC	M
N8	Independent	TC	H
P3	Independent	TC	H
Traditional Commodity in Sensitive Areas			
N2	Independent	TM	H
N7	Independent	TM	M
P2	Independent	TM	M

[1] Prescription (Rx); see tables 3-M1 and 3-M2 for list of names and descriptions.

[2] Type of model:

1) Native model refers to the patterns of ecological and landscape systems during the pre-Euro-American settlement system, which is synonymous with the historical range of variability (HRV) regime.

2) Ecological model refers to management to transition to or maintain proper functioning systems (PFS), while producing human needs and values - given current conditions this infers that ecological and landscape processes and functions be subsidized with human technological energy in ways that are similar to native ecological cause and effects as controlled by landscape processes, while producing compatible human needs and values.

3) Independent model refers to management for specific human values or needs in ways that are relatively independent of native ecological and landscape cause and effect relationships.

[3] Management emphasis definitions:

1) Conservation - emphasis provides for the protection of rare native elements and systems, while maintaining proper functioning systems and restoring systems where there is low risk to rare elements or systems. Some human commodities may be produced but the emphasis is on human values related to protection of native diversity, aesthetics, and recreation.

2) Restoration - emphasis provides for subsidizing ecological and landscape processes and functions to shift the transition towards proper function systems. Considerable human commodities may be produced that are compatible with restoration, as well as conservation of inclusions of rare elements and systems, but the emphasis is on shifting landscapes that are in high departure from the native regime toward proper functioning ecological relationships.

3) Production - emphasis provides for production of human needs and values by managing in concert with native ecological and landscape processes to maintain or shift to proper function systems. This will typically require subsidies to represent native ecological cause and effect relationships at landscape levels, along with some restoration and conservation, but the emphasis is on design of system responses that produce commodities and other values.

4) Traditional - emphasis on the independent management model for producing commodity values, protecting visually or environmentally sensitive areas, or managing reserves to protect semi-primitive characteristics.

Management emphasis categories:

C - conservation

R - restoration

P - production

RP - restoration/production

RC - restoration/conservation

CP - conserve/produce

TC - traditional commodity

TR - traditional reserve

TM - traditional mixed commodity and reserve

[4] Transition rates - this is the rate of transition to or maintenance of the desired system for the type of model. There is only a moderate or high category because of the dynamic nature of wildland ecological relationships and landscape processes. Low or non levels of rates do not maintain or result in transition to the desired system.

H - high

M - moderate

L - low

III. Example checklist of Ecological Processes and Functions for PFS of Landscape Systems

Hydrologic and Land System

- Geologic Subsystem
  - Geologic material
  - Risk of geologic events
- Geomorphic Subsystem
  - Landform - mountains, foothills, breaks, plains, valleys
  - Landforming process - glaciation, erosional, alluvial
  - Range in elevation
- Pedogenic Subsystem
  - Soil Family
  - Soil Temperature Regime
  - Soil Moisture Regime
  - Erosion rates
- Climatic Subsystem
  - Range in average precipitation
  - Range in average temperature
  - Growing Season
- River/Stream Subsystem
  - Stream Order
  - Channel Type
  - Perennial/Intermittent
  - River/Stream Flow Regime
  - Erosion/Sedimentation
  - Riparian Bank Conditions
  - Roads
  - Mines - placer, hardrock
  - Mine drainage

- Carbon-nutrient System
  - Vegetation Type
  - Potential Vegetation Type
  - Anderson Fuel Model
  - Photosynthesis
  - Fire-Decay-Insect/Disease-Stress Risk
  - Nitrogen and other nutrients
  - Succession/Disturbance Regime Classification Subsystem Classification
    - Cycling
      - Accelerated Cycle
      - Long Cycle
      - Moderate Cycle
      - Retrogressive Cycle
      - Short Cycle
      - Very Long Cycle
    - Maintenance
      - Frequent Maintenance
      - Less Frequent Maintenance
      - Irregular Maintenance
  - General Landscape Pattern Classification Subsystem
    - Wildland Patterns
      - Forest Native (HRV)
      - Forest Traditional Commodity
      - Forest Traditional Reserve
      - Range Native (HRV)
      - Range raditional Commodity
      - Forest Traditional Reserve
      - Forest-Range Native (HRV)
      - Forest-Range Traditional Commodity
      - Forest-Range Traditional Reserve
      - Non-forest Alpine
      - Non-forest Desert
      - Naturalized
    - Anthropogenic (human development) Patterns
      - Agriculture
      - Urban-Industrial
      - Rural Subdivision

  - Food Web System
    - Terrestrial Subsystem
    - Large Ungulate Guilds
    - Predator Guilds
    - Small Mammal Guilds
    - Fur Bearer Guilds
    - Dominant Plant Species (correlated to vegetation type)
    - TES&C Species
    - Exotic Species
    - Large Snags & Down Logs
    - Large Live Emergent Trees

Aquatic Subsystem
- Native Fish Coldwater Guilds
- Native Anadrymous Fish Guilds
- Native Fish Warmwater Guilds
- Amphibian Guilds
- Riparian Vegetation Types
- TES&C Species
- Exotic Species
- Large Woody Material

Avian Subsystem
- Bird Guilds
- Cavity Nesters
- TES&C Species
- Exotic Species

Evolutionary System
- Extinction - rate of extinction
- Adaptations - human or native disturbance regime
  - adaptations of dominant species
- Migration - seasonal migrations fragmented or nonfragmented
  - migrations in response to climate change or disturbance events
- Exotics - effects on native species

Toxins/Pollutants System
- Carbon-nutrients in water or air
- Toxic/acidic elements in water or air
- Carbon/Air Particulates

Human System
- Land Use - ranching, agriculture, logging, recreation type, subdivision, utilities
- Economic Resiliency
- Rural Economic Stability
- Ranching Viability
- Jobs - direct
- Jobs - indirect
- Road Access
- Trail Access - motorized & nonmotorized
- Trail Access - nonmotorized
- Aesthetic Values
- Recreation
- Management emphasis - Traditional (TC, TR, or TM) or EM (C, R, P, RC, RP)

APPENDIX 3-N

Ecological reporting unit potential vegetation group tables*

Table 3N.1—Current and historical period physiognomic types for the cold forest potential vegetation group (PVG) for Northern Glaciated Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Forest	25	24	25	26
	Early-seral Riparian Woodland	+[3]	0	+	+
	Late-seral Multi-layer Forest	1	21	25	26
	Late-seral Single-layer Forest	21	12	8	7
	Mid-seral Forest	53	44	43	41
	Mid-seral Riparian Woodland	1	0	+	+
Other	Early-seral Forest	30	27	26	25
	Early-seral Riparian Woodland	+	0	+	+
	Late-seral Multi-layer Forest	2	21	23	25
	Late-seral Single-layer Forest	22	11	6	6
	Mid-seral Forest	45	41	45	44
	Mid-seral Riparian Woodland	1	0	+	+
All	Early-seral Forest	26	25	25	26
	Early-seral Riparian Woodland	+	0	+	+
	Late-seral Multi-layer Forest	1	21	25	25
	Late-seral Single-layer Forest	21	11	7	7
	Mid-seral Forest	51	43	43	42
	Mid-seral Riparian Woodland	1	0	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5 percent.

* These tables are missing from the section on System Dynamics.

Table 3N.2—Current and historical period cold forest potential vegetation group (PVG) Shade Intolerance/Shade Tolerance for the Northern Glaciated Mountains Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Shade Intolerant Forest	20	18	23	25
	Early-seral Shade Tolerant Forest	5	5	1	1
	Late-seral Shade Intolerant Multi-layer Forest	1	13	16	15
	Late-seral Shade Intolerant Single-layer Forest	21	10	7	7
	Late-seral Shade Tolerant Multi-layer Forest	+[3]	9	9	10
	Late-seral Shade Tolerant Single-layer Forest	0	2	+	+
	Mid-seral Shade Intolerant Forest	6	33	31	35
	Mid-seral Shade Tolerant Forest	47	10	12	7
	Riparian Woodland	1	0	+	+
Other	Early-seral Shade Intolerant Forest	21	21	24	23
	Early-seral Shade Tolerant Forest	9	6	2	2
	Late-seral Shade Intolerant Multi-layer Forest	1	11	13	14
	Late-seral Shade Intolerant Single-layer Forest	22	8	5	5
	Late-seral Shade Tolerant Multi-layer Forest	1	10	11	11
	Late-seral Shade Tolerant Single-layer Forest	0	2	1	1
	Mid-seral Shade Intolerant Forest	10	30	31	35
	Mid-seral Shade Tolerant Forest	35	12	13	9
	Riparian Woodland	1	0	+	+
All	Early-seral Shade Intolerant Forest	21	19	24	24
	Early-seral Shade Tolerant Forest	6	6	1	2
	Late-seral Shade Intolerant Multi-layer Forest	1	12	15	15
	Late-seral Shade Intolerant Single-layer Forest	21	9	7	6
	Late-seral Shade Tolerant Multi-layer Forest	+	9	10	11
	Late-seral Shade Tolerant Single-layer Forest	0	2	+	1
	Mid-seral Shade Intolerant Forest	7	32	31	35
	Mid-seral Shade Tolerant Forest	44	11	12	7
	Riparian Woodland	1	0	+	+

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5 percent.

Table 3N.3—Current and historical period physiognomic types for the cool shrub potential vegetation group (PVG) for the Southern Cascades Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		..... Percent			
BLM/FS	Early-seral Woodland	55	59	9	12
	Exotic Herbland	5	0	0	0
	Late-seral Single-layer Woodland	0	0	+[3]	0
	Mid-seral Woodland	11	27	13	8
	Upland Herbland	+	5	16	21
	Upland Shrubland	29	9	62	60
Other	Early-seral Woodland	90	58	9	10
	Exotic Herbland	0	0	0	0
	Late-seral Single-layer Woodland	0	+	0	0
	Mid-seral Woodland	6	4	12	11
	Upland Herbland	0	13	20	17
	Upland Shrubland	4	25	60	62
All	Early-seral Woodland	69	59	9	11
	Exotic Herbland	3	0	0	0
	Late-seral Single-layer Woodland	0	+	+	0
	Mid-seral Woodland	9	14	12	9
	Upland Herbland	+	9	18	19
	Upland Shrubland	19	18	61	61

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5%.

Table 3N.4—Current and historical period physiognomic types for the cool shrub potential vegetation group (PVG) for Upper Snake Ecological Reporting Unit (ERU).

Land Ownership Group[1]	Physiognomic Type	Current Year[2]	Historical Year 0	Historical Year 50	Historical Year 100
		Percent			
BLM/FS	Early-seral Woodland	25	3	4	5
	Exotic Herbland	1	0	0	0
	Late-seral Single-layer Woodland	0	+[3]	+	0
	Mid-seral Woodland	8	9	7	5
	Upland Herbland	18	4	39	37
	Upland Shrubland	49	83	50	53
Other	Early-seral Woodland	20	1	5	4
	Exotic Herbland	0	0	0	0
	Late-seral Single-layer Woodland	0	+	+	0
	Mid-seral Woodland	10	2	6	5
	Upland Herbland	20	9	32	33
	Upland Shrubland	50	88	57	58
All	Early-seral Woodland	23	2	4	5
	Exotic Herbland	1	0	0	0
	Late-seral Single-layer Woodland	0	+	+	0
	Mid-seral Woodland	9	6	7	5
	Upland Herbland	19	7	36	35
	Upland Shrubland	49	85	54	56

[1]Land Ownership Group: BLM/FS lands = BLM- and FS-administered lands; Other lands = all land other than BLM- and FS-administered lands; All lands = BLM/FS lands + Other lands.

[2]Current year = circa 1991; Historical year 0 = circa 1850 to 1900 (initiated model simulation); Historical year 50 = simulation output at year 50; Historical year 100 = simulation output at year 100.

[3]+ = < 0.5 percent.

List of Acronyms

ASQ	Allowable Sale Quantity
AUM	Animal Unit Month
BEA	Bureau of Economic Analysis
BLM	Bureau of Land Management
BMPs	Best Management Practices
BTUs	British Thermal Units
CFR	Code of Federal Regulations
CRBSUM	Columbia River Basin Succession Model
EIS	Environmental Impact Statement
EEIS	Eastside EIS Planning/Management Area
EPA	Environmental Protection Agency
ERU	Ecological Reporting Units
ESI	Existing Scenic Integrity
FACA	Federal Advisory Committe Act
FEMAT	Forest Ecosystem Management Assessment Team
FIRE	BEA designation, Finance, Insurance and Real Estate industries
FS	Forest Service
FSH	Forest Service Handbook
GIS	Geographic Information System
GPM	General Planning Model
GSP	Gross State Product
HUCs	Hydrologic Unit Codes
LWD	Large Woody Debris
ICBEMP	Interior Columbia Basin Ecosystem Management Project
ICRB	Interior Columbia River Basin
INFISH	Inland Native Fish Strategy
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWFP	Northwest Forest Plan
PACFISH	Pacific Anadromous Fish Strategy
PILT	Payments in Lieu of Taxes
RAC	Resource Advisory Committee
RHCA	Riparian Habitat Conservation Area
RMA	Riparian Management Area
ROS	Recreation Opportunity Spectrum
PVG	Potential Vegetation Group
PVT	Potential Vegetation Type
RVD	Recreation Visitor Day
SER	Species-Environment Relations (database)
SIC	Standard Industrial Code
SIT	Science Integration Team
TES	Threatened and Endangered Species
UCRB	Upper Columbia River Basin EIS Planning/Management Area
USDA	United States Department of Agriculture
USDI	United States Department of Interior
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Metric Conversion

Mile (mi)=1.61 Kilometers (km)

Kilometer (km)=.62 Miles (mi)

Square Kilometers (km^2)=.39 Square Miles (mi^2)

Centimeter (cm)=.3937 Inches (in)

Meter (m)=3.28 Feet (ft)

Hectare (ha)=10,000 Square Meters (m^2)

Hectare (ha)=2.47 Acres (ac)

Acre (ac)=43,560 Square Feet (ft^2)

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This paper provides detailed information about current conditions and trends for the biophysical and social systems within the basin. Social and economic conditions within the assessment area differ considerably depending to a great extent on population, diversity of employment opportunities, and changing demographics. This information can be used by land managers to develop broad management goals and priorities and provides the context for decisions specific to smaller geographic areas.

Keywords: Columbia basin, biophysical systems, social systems, ecosystem.

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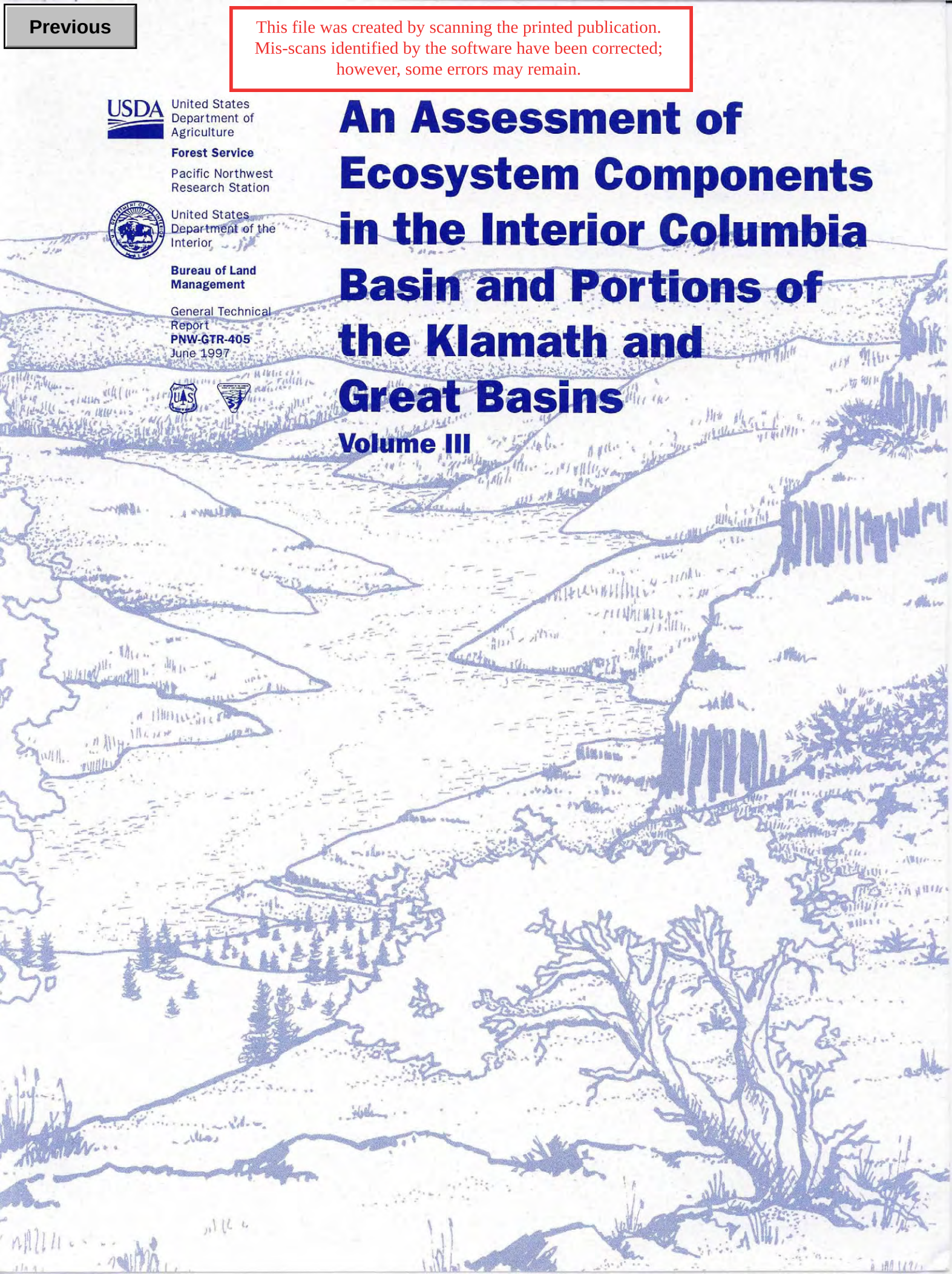
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An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins

Volume III





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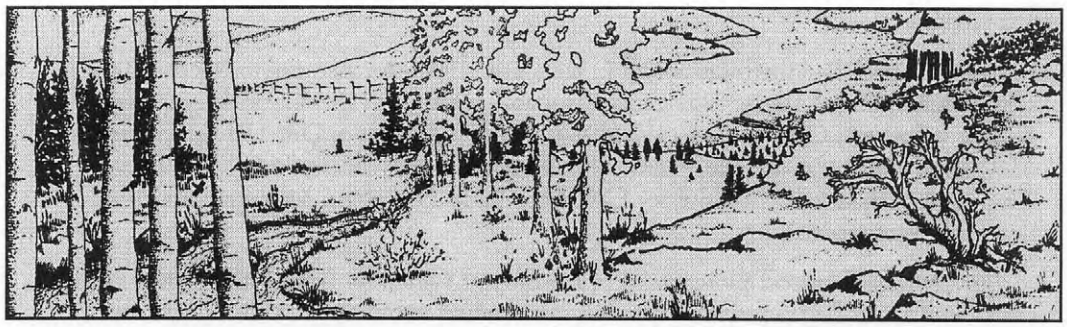


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Interior Columbia Basin Ecosystem Management Project

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An Assessment of Ecosystem Components in the Interior Columbia Basin

And Portions of the Klamath and Great Basins: Volume III

Thomas M. Quigley
Sylvia J. Arbelbide
Technical Editors

Volume III contains pages 1,057 through 1,713

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June 1997
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Abstract

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The *Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins* provides detailed information about current conditions and trends for the biophysical and social systems within the Basin. This information can be used by land managers to develop broad land management goals and priorities and provides the context for decisions specific to smaller geographic areas. The Assessment area covers about 8 percent of the U.S. land area, 24 percent of the Nation's National Forest System lands, 10 percent of the Nation's BLM-administered lands, and contains about 1.2 percent of the Nation's population. This results in a population density that is less than one-sixth of the U.S. average. The area has experienced recent, rapid population growth and generally has a robust, diverse economy. As compared to historic conditions, the terrestrial, aquatic, forest, and rangeland systems have undergone dramatic changes. Forested landscapes are more susceptible to fire, insect, and disease than under historic conditions. Rangelands are highly susceptible to noxious weed invasion. The disturbance regimes that operate on forest and rangeland have changed substantially, with lethal fires dominating many areas where non-lethal fires were the norm historically. Terrestrial habitats that have experienced the greatest decline include the native grassland, native shrubland, and old forest structures. There are areas within the Assessment area that have higher diversity than others. Aquatic systems are now more fragmented and isolated than historically and the introduction of non-native fish species has complicated current status of native fishes. Core habitat and population centers do remain as building blocks for restoration. Social and economic conditions within the Assessment area vary considerably, depending to a great extent on population, diversity of employment opportunities, and changing demographics. Those counties with the higher population densities and greater diversity of employment opportunities are generally more resilient to economic downturns. This Assessment provides a rich information base, including over 170 mapped themes with associated models and databases, from which future decisions can benefit.

Keywords: Columbia basin, biophysical systems, social systems, ecosystem.

VOLUME CONTENTS



VOLUME I

Chapter 1 - Introduction

- **Executive Summary-Biophysical Environments**
- **Executive Summary-Landscape Dynamics**
- **Executive Summary-Broadscale Assessment of Aquatic Species and Habitats**
- **Executive Summary-Terrestrial Ecology**
- **Executive Summary-Economic Assessment**
- **Executive Summary-Social Assessment**
- **Executive Summary-Information System Development and Documentation**

Chapter 2 - Biophysical Environments of the Basin

VOLUME II

Chapter 3 - Landscape Dynamics of the Basin

VOLUME III

Chapter 4 - Broadscale Assessment of Aquatic Species and Habitats

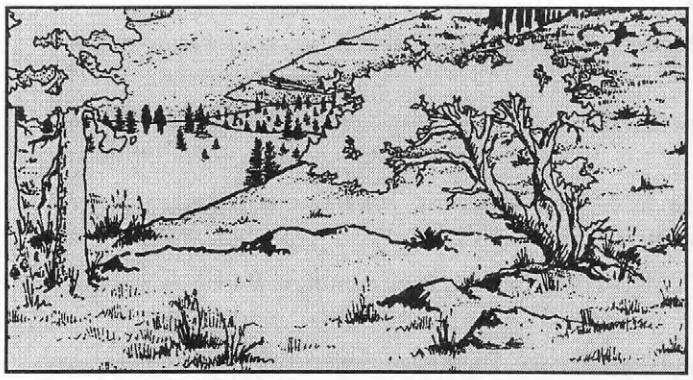
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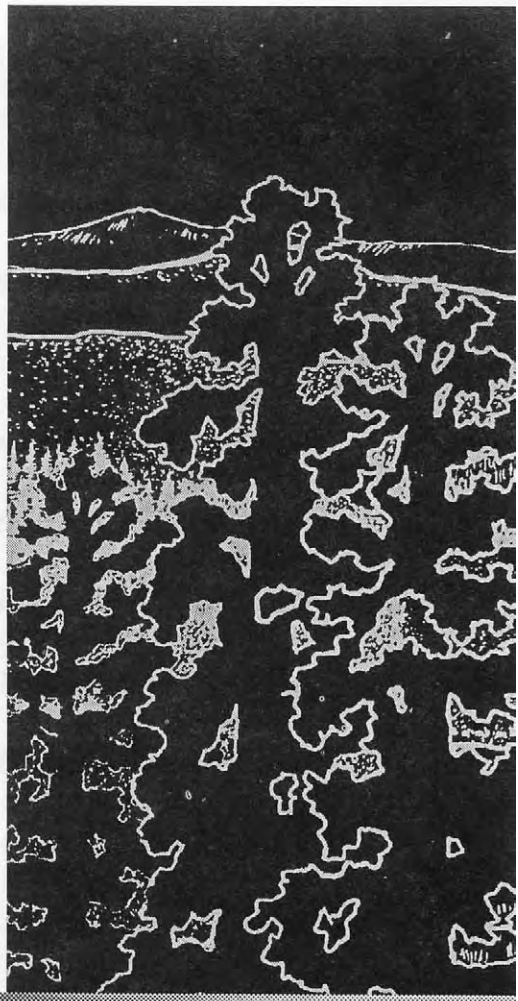
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Chapter 7 - Social Assessment of the Basin

Chapter 8 - Information System Development and Documentation





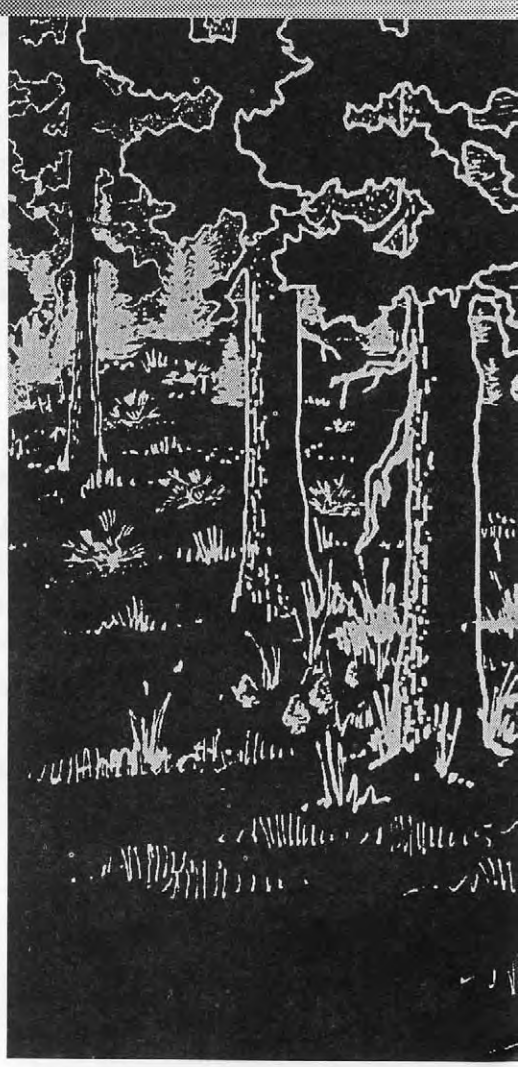
CHAPTER 4

Broadscale Assessment of Aquatic Species and Habitats

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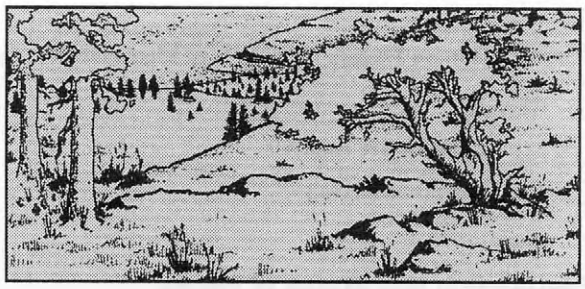
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TABLE OF CONTENTS



Introduction 1073

Factors Influencing the Integrity of Aquatic Ecosystems 1081

Influence of Natural Processes on Aquatic Ecosystems 1081

Influence of the Marine Environments on Freshwater Aquatic Ecosystems 1083

Influence of Wildfire on Freshwater Aquatic Ecosystems 1084

Influence of Human Activities on Aquatic Ecosystems 1084

Changes in Extent and Type of Riparian Vegetation in the Basin 1085

Influence of Human Activities on Water Quality 1086

Influence of Dams, Water Storage and Withdrawals 1093

Influence of Farming and Grazing 1099

Influence of Timber Harvest Activities 1100

Influence of Roads 1102

Influence of Mining Activities 1104

Influence of Non-native Fish Species Introductions 1105

Influence of Hatcheries 1107

Influence of Commercial and Recreational Harvest 1108

Influence of General Recreation Activities 1109

General Influence of Habitat Fragmentation and Simplification 1110

Assessment of Land-use Effects on Instream Habitat Conditions 1115

Historical Changes in Large-pool and Deep-pool Habitats in the Columbia River Basin 1116

Basin-wide Analysis of Stream Inventories 1118

Distribution and Sampling Issues 1118

Analyzed Channel Features 1122

Landscape Characterization 1124

Physiographic and Geophysical Variables 1124

Vegetation Indices 1126
Human Factors--Ownership, Management Class, and Roads 1130
Results 1130
Quantitative Analysis 1134
Analytical Results 1136
Summary 1137
Distribution and Status of Fishes 1141
Overview of Approach and Data Sources 1146
Key Salmonids Current-Status Database 1146
Species-assemblage Database 1148
Historical Ranges 1148
Current Fishes 1149
Ichthyological Provinces 1149
Species List and Relative Abundance 1150
Species Assemblages 1151
Analytical Approach 1151
Characterizations 1157
Rare and Sensitive Fishes 1160
Key Salmonids 1161
Analysis Using Classification Trees 1161
Example Classification Tree Analysis 1164
Application to the Seven Key Salmonids 1168
Interpretation of Classification Trees 1172
Validation 1174
Discussion of Key Salmonids Status, Distribution and Management 1174
Bull Trout (*Salvelinus confluentus*) 1176
Yellowstone Cutthroat Trout (*Oncorhynchus clarki bouvieri*) 1185
Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*) 1193
Redband Trout (*Oncorhynchus mykiss*) 1200
Steelhead (*Oncorhynchus mykiss*) 1213
Chinook Salmon (*Oncorhynchus tshawytscha*) 1223
Introduced Salmonids 1236
Current Distribution and Status 1236
Key Factors 1238
Summary 1238

Community Integrity and Conservation Emphasis Areas 1138
Population Strongholds 1139
Native Species Richness 1241
Diversity and Evenness 1241
Uniqueness 1241
Fringe Distributions 1245
Genetic Integrity 1248
Narrowly Distributed Endemic and Federally Listed Species 1248
Integrity of the Fish Assemblage 1249
Wild Trout Waters 1253
Supplemental Analysis of Road Impacts 1253
Focus on non-anadromous salmonids 1253
Methods 1254
Results 1256
Discussion 1258
Summary and Conclusions 1260
Rare and Sensitive Species: Status Summaries 1267
White Sturgeon (*Acipenser transmontanus*) 1268
Klamath Lamprey (*Lampetra similis*) 1270
River Lamprey (*Lampetra ayresii*) 1270
Pacific Lamprey (*Lampetra tridentata*) 1271
Goose Lake Lamprey (*Lampetra tridentata ssp.*) 1275
Pit-Klamath Brook Lamprey (*Lampetra lethophaga*) 1275
Sockeye Salmon (*Oncorhynchus nerka*) 1278
Chum Salmon (*Oncorhynchus keta*) 1282
Coho Salmon (*Oncorhynchus kisutch*) 1284
Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*) 1285
Lahontan Cutthroat Trout (*Oncorhynchus clarki henshawi*) 1289
Sunapee Char (*Salvelinus alpinus oquassa*) 1291
Pygmy Whitefish (*Prosopium coulteri*) 1291
Burbot (*Lota lota*) 1292
Sand Roller (*Percopsis transmontana*) 1292
Northern Roach (*Hesperoleucus symmetricus mitrulus*) 1293

Alvord Chub (*Gila alvordensis*) 1298
Borax Lake Chub (*Gila boraxobius*) 1298
Catlow Tui Chub (*Gila bicolor* ssp.) 1301
Oregon Lakes Tui Chub (*Gila bicolor oregonensis*) 1303
Summer Basin Tui Chub (*Gila bicolor* ssp.) 1303
Sheldon Tui Chub (*Gila bicolor eurysoma*) 1306
Hutton Tui Chub (*Gila bicolor* ssp.) 1307
Leatherside Chub (*Gila copei*) 1307
Foskett Speckled Dace (*Rhinichthys osculus* ssp.) 1311
Lost River Sucker (*Deltistes luxatus*) 1311
Warner Sucker (*Catostomus warnerensis*) 1314
Goose Lake Sucker (*Catostomus occidentalis lacusanserinus*) 1316
Shortnose Sucker (*Chasmistes brevirostris*) 1318
Klamath Largescale Sucker (*Catostomus snyderi*) 1320
Wood River Bridgelip Sucker (*Catostomus columbianus hubbsi*) 1322
Torrent Sculpin (*Cottus rhotheus*) 1322
Shorthead Sculpin (*Cottus confusus*) 1325
Pit Sculpin (*Cottus pitensis*) 1327
Slender Sculpin (*Cottus tenuis*) 1327
Margined Sculpin (*Cottus marginatus*) 1330
Wood River Sculpin (*Cottus leiopomus*) 1332
Shoshone Sculpin (*Cottus greenei*) 1332
Malheur Sculpin (*Cottus bairdi* ssp.) 1335
Conclusions 1337

Issues and Opportunities 1339

Major Issues 1340
Catastrophic Wildfire and Active Forest Restoration 1340
The Role of Federal Lands in Managing Anadromous Fishes 1342
Effects of Roads on Sedimentation and Fishes 1345
Stronghold Watersheds and Unroaded Areas 1347
Opportunities for Conservation 1354
A Broad-scale Context 1356

Subbasin Classification 1357
Application at the Mid-scale 1360
Example Within a Subbasin 1361
Potential Opportunities 1363
Application at a Fine-Scale: Riparian Areas and Cumulative Watershed Effects 1364
Riparian Area Management 1365
Cumulative Watershed Effects 1370
Discussion 1372
Conservation 1373
Watershed Rehabilitation 1373
Forest Rehabilitation 1373
Information and Research Needs 1375
Riparian Management 1375
Understanding the Rare Event 1376
Stream Habitat Inventory 1376
Aquatic Species 1377
Fishes 1377
Aquatic Invertebrates 1378
Short-term Research and Data Needs (1-3 years) 1379
Long-term Research (1-15 years) 1379
Lake and Stream Productivity in Relation to Lithologic Variables 1379
Monitoring 1380
Acknowledgments 1381
References 1383
Glossary 1431
Appendix 4A 1433
Appendix 4B 1444
Appendix 4C 1448
Appendix 4D 1468
Appendix 4E 1472
Appendix 4F 1487
Appendix 4G 1490

LIST OF TABLES

Table 4.1	Summary characterization of Ecological Reporting Units	1075
Table 4.2	Hierarchical framework of hydrology for the assessment area	1077
Table 4.3	Mid-scale riparian vegetation changes by Ecological Reporting Unit.	1087
Table 4.4	Potential effects of land-use activities on lakes in the Interior Columbia Basin Ecosystem Management Project assessment area	1089
Table 4.5	Water quality impaired waters.	1091
Table 4.6	Irrigation diversions and net depletions by hydrologic region.	1096
Table 4.7	Changes in total irrigated land in the Columbia River Basin since 1900.	1098
Table 4.8	Kilometers of Forest Service and BLM roads within the Interior Columbia Basin Ecosystem Management Project assessment area	1103
Table 4.9	Comparison of changes in large and deep pools in the Coast Range and western Cascades by Ecological Reporting Unit.	1119
Table 4.10	Number of reaches and total length of inventoried stream in each Ecological Reporting Unit.	1121
Table 4.11	Thirteen variables and the variable descriptions that were used to characterize inventoried stream channels for the entire Columbia River Basin.	1123
Table 4.12	Descriptions of predictor landscape variables used in the stream inventory analysis and the analysis of fish distribution.	1125
Table 4.13	Criteria for classifying mapped lithologies.	1127
Table 4.14	Potential production of woody debris and stream shading for vegetation cover classes and structural stages.	1128
Table 4.15	Management and ownership classification of subwatersheds identified using cluster analysis.	1132
Table 4.16	Relative abundance of native and introduced species.	1143
Table 4.17	Summary statistics for 16 species assemblages identified in the association analysis.	1154
Table 4.18	Dominant taxa found within 16 species assemblages identified in the association analysis.	1156
Table 4.19	Key factors influencing status for rare and sensitive fish in the Basin.	1162
Table 4.20	The pruned classification tree relating status of stream-type chinook salmon to landscape variables.	1165
Table 4.21	Cross-classification table of predicted versus observed values for stream-type chinook salmon.	1167
Table 4.22	Summaries of the classification trees developed for seven key salmonids.	1169
Table 4.23	Cross-classification of the observed status calls with the predicted values for three anadromous taxa.	1170

Table 4.24	Cross-classification of the observed status calls with the predicted values in spawning and rearing areas for four non-anadromous salmonids.	1171
Table 4.25	Sample size (N) and estimated probability of presence for seven key salmonids, cross-referenced with observed status	1171
Table 4.26	Cross-classification table of status calls (known present and known absent) and model predictions (predicted present and predicted absent) versus recently obtained data.	1175
Table 4.27	Summary of the current status and distribution classifications (number of subwatersheds) for bull trout throughout the Ecological Reporting Units of the Basin.	1178
Table 4.28	Summary of total known and predicted classifications (number of subwatersheds) for status of bull trout.	1178
Table 4.29	Summary of the current status and distribution classifications (number of subwatersheds) for Yellowstone cutthroat trout throughout the Ecological Reporting Units of the Basin.	1186
Table 4.30	Summary of total known and predicted classifications (number of subwatersheds) for status of Yellowstone cutthroat trout.	1186
Table 4.31	Summary of the current status and distribution classifications (number of subwatersheds) for westslope cutthroat trout throughout the Ecological Reporting Units of the Basin.	1195
Table 4.32	Summary of total known and predicted classifications (number of subwatersheds) for status of westslope cutthroat trout.	1195
Table 4.33	Summary of the current status and distribution classifications (number of subwatersheds) for redband trout (sympatric and allopatric) throughout the Ecological Reporting Units of the Basin.	1205
Table 4.34	Summary of the current status and distribution classifications (number of subwatersheds) for sympatric redband trout throughout the Ecological Reporting Units of the Basin.	1205
Table 4.35	Summary of the current status and distribution classifications (number of subwatersheds) for allopatric redband trout throughout the Ecological Reporting Units of the Basin.	1206
Table 4.36	Summary of total known and predicted classifications (number of subwatersheds) for status of redband trout (sympatric and allopatric) pooled.	1206
Table 4.37	Summary of total known and predicted classifications (number of subwatersheds) for status of sympatric redband trout.	1207
Table 4.38	Summary of total known and predicted classifications (number of subwatersheds) for status of allopatric redband trout.	1207
Table 4.39	Summary of the current status and distribution classifications (number of subwatersheds) for summer steelhead throughout the Ecological Reporting Units of the Basin.	1215

Table 4.40	Summary of total known and predicted classifications (number of subwatersheds) for status of summer steelhead.	1215
Table 4.41	Summary of the current status and distribution classifications (number of subwatersheds) for stream-type chinook salmon throughout the Ecological Reporting Units of the Basin.	1225
Table 4.42	Summary of the current status and distribution classifications (number of subwatersheds) for ocean-type chinook salmon throughout the Ecological Reporting Units of the Basin.	1225
Table 4.43	Summary of total known and predicted classifications (number of subwatersheds) for status of stream-type chinook salmon.	1229
Table 4.44	Summary of total known and predicted classifications (number of subwatersheds) for status of ocean-type chinook salmon.	1229
Table 4.45	Descriptions of landscape variables used in the logistic regression analysis of subsampled groups of non-anadromous salmonids.	1256
Table 4.46	Results of logistics regression analysis for subsampled groups of non-anadromous salmonids.	1257
Table 4.47	Average road densities by population status for subsampled groups of non-anadromous salmonids.	1259
Table 4.48	Summary comparison of the known and predicted present and strong distributions for each of the seven key salmonids.	1261
Table 4.49	Current population status of seven key salmonids in the Basin and their relationship to habitat provided by Forest Service and BLM administered land.	1343
Table 4.50a	Proportion (percent) of special emphasis watersheds (identified by various assessments) containing unroaded area on Forest Service- and BLM-administered lands.	1349
Table 4.50b	Hectares of unroaded area in special emphasis watersheds identified by various assessments, on Forest Service- and BLM-administered lands.	1350
Table 4.50c	Total hectares of special emphasis watersheds identified by various assessments, on Forest Service- and BLM-administered lands.	1351
Table 4.51	Percent of special emphasis watersheds within the current range of key salmonids.	1352
Table 4.52	Assessments on aquatic and riparian systems in the Pacific Northwest conducted during the last five years.	1355

LIST OF FIGURES

Figure 4.1 Hierarchical division of hydrological drainage areas. 1079

Figure 4.2 Major types of water quality impairment by Ecological Reporting Units. 1092

Figure 4.3 Historical range (shaded bars), current range (bars), and current mode ( ) of water temperature for streams east of the Cascade Mountains in Washington and Oregon. 1092

Figure 4.4 Cumulative number of federal and nonfederal dams in the Pacific Northwest. 1095

Figure 4.5 Cumulative volume of water impounded by federal and non-federal dams in Pacific Northwest from 1860 to 1990. 1095

Figure 4.6 Uses of dams in the Interior Columbia Basin Ecosystem Management Project assessment area. 1095

Figure 4.7 Spatial variation of four primary offstream uses of water in the region. 1097

Figure 4.8 Fragmentation of watersheds in northern Idaho and western Montana. 1112

Figure 4.9 Changes in large pools (>20m^2 and 0.8m deep) from 1935-1945 to 1991-1994 on Columbia River Basin streams. 1116

Figure 4.10 Changes in deep pools (>20m^2 and 1.6m deep) from 1935-1945 to 1991-1994 on Columbia River Basin streams. 1117

Figure 4.11 Portrayal of stream inventory sampling by stream order. 1122

Figure 4.12 Box plots of *pool frequency* and *large pool frequency* for streams with gradients less than 0.02 arrayed by road density and ownership/management classes. 1133

Figure 4.13 Box plots of *R6 wood frequency* for streams with gradients less than 0.02 arrayed by road density classes and ownership/management. 1133

Figure 4.14 Box plots of *surface fines* for streams with gradients less than 0.02 arrayed by road density classes and ownership/management. 1134

Figure 4.15 Scatter plot of large-wood frequency vs. *large pool frequency.* 1138

Figure 4.16 Dichotomous rule set for grouping observations based on the presence/absence of select taxa with the highest degree of association with other taxa. 1153

Figure 4.17 Box and whisker plots illustrating the distribution of total species across watersheds grouped according to the rules developed in the association analysis. 1155

Figure 4.18 Plots of native species versus introduced species for each watershed within each of the 16 species assemblages. 1159

Figure 4.19 Graphical representation of pruned classification tree for stream-type chinook salmon. 1166

Figure 4.20 Proportion of watersheds supporting strong populations of key salmonids by road density class and land ownership. 1239
Figure 4.21 Frequency (or number) of subwatersheds classified as known or predicted spawning and rearing areas for each of the seven key salmonids, including both allopatric and sympatric redband trout, within each of the Ecological Reporting Units. 1246
Figure 4.22 Box and whisker plots illustrating the range of fish assemblage integrity values by Ecological Reporting Unit. 1249
Figure 4.23 Histograms showing the frequency of road density class, mean road density, geometric mean road density, and upstream road density. 1255
Figure 4.24 Cumulative relative frequencies for absent, and absent or depressed versus geometric mean density. 1258
Figure 4.25 Illustration of a subbasin approach to conservation and rehabilitation of native fishes. 1362
Figure 4.26 Examples of slope-sensitive adjustments to RHCA widths with associated probabilities of exceedence. 1368
Figure 4.27 Examples of volume-driven risk associated with adjustments to RHCA widths. 1369

LIST OF MAPS

Map 4.1 Ecological Reporting Units in the Interior Columbia Basin Ecosystem Management Project area. 1078
Map4.2 Impaired water bodies within the ICBEMP assessment area. 1090
Map 4.3 Locations of dams for which information is maintained by the states (2,103 dams within the ICBEMP assessment area). 1094
Map 4.4 Inventoried stream reaches, Ecological Reporting Units (ERU), and subbasin delineations for the assessment area. 1120
Map 4.5 Spatial distribution of 12 vegetation types identified using cluster anlaysis. 1129
Map 4.6 Spatial distribution of ownership and management classes identified using cluster analysis. 1131
Map 4.7 Current distribution of brook, introduced rainbow, and brown trout by watershed, based on the assemblages database. 1152
Map 4.8 Spatial distribution of the 16 species assemblages identified in the association analysis by watershed. 1158
Map 4.9 Current presence, absence, and estimated probability of occurrence within the historical range for bull trout by subwatershed. 1170
Map 4.10 Distribution of areas predicted to be suitable for bull trout spawning and initial rearing. 1179

Map 4.11 Current distribution of spawning and rearing areas classified or predicted as strong or depressed for bull trout by subwatershed. 1181
Map 4.12 Current presence, absence, and estimated probability of occurrence within the historical range for Yellowstone cutthroat trout by subwatershed. 1187
Map 4.13 Current distribution of spawning and rearing areas classified or predicted as strong or depressed for Yellowstone cutthroat trout by subwatershed. 1189
Map 4.14 Current presence, absence, and estimated probability of occurrence within the historical range for westslope cutthroat trout by subwatershed. 1196
Map 4.15 Current distribution of spawning and rearing areas classified or predicted as strong or depressed for westslope cutthroat trout by subwatershed. 1197
Map 4.16 Current presence, absence, and estimated probability of occurrence within the historical range for sympatric redband trout by subwatershed. 1202
Map 4.17 Current presence, absence, and estimated probability of occurrence within the historical range for allopatric redband trout by subwatershed. 1203
Map 4.18 Current distribution of spawning and rearing areas classified or predicted as strong or depressed for sympatric redband trout by subwatershed. 1208
Map 4.19 Current distribution of spawning and rearing areas classified or predicted as strong or depressed for allopatric redband trout by subwatershed. 1209
Map 4.20 Current presence, absence, and estimated probability of occurrence within the historical range for steelhead by subwatershed. 1216
Map 4.21 Current distribution of spawning and rearing areas classified or predicted as strong or depressed for steelhead by subwatershed. 1217
Map 4.22 Watersheds supporting wild, native populations of steelhead and chinook salmon that have had little or no influence from introduced non-indigenous stocks. 1219
Map 4.23 Current presence, absence, and estimated probability of occurrence within the historical range for stream-type chinook by subwatershed. 1226
Map 4.24 Current presence, absence, and estimated probability of occurrence within the historic range for ocean-type chinook by subwatershed. 1227
Map 4.25 Current distribution of spawning and rearing areas classified or predicted as strong or depressed for stream-type chinook by subwatershed. 1230

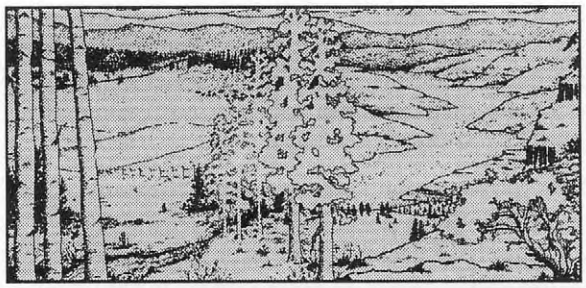
Map 4.26 Current distribution of spawning and rearing areas classified or predicted as strong or depressed for ocean-type chinook by sub-watershed. 1231
Map 4.27 Number of key salmonids classified or predicted as strong by subwatershed. 1240
Map 4.28 Number of native species reported by watershed. 1242
Map 4.29 Historical number of key salmonids potentially present by subwatershed. 1243
Map 4.30 Current number of key salmonids remaining from historical distribution by subwatershed. 1244
Map 4.31 Subwatersheds classified as fringe areas in the distribution of key salmonids. 1247
Map 4.32 Number of narrowly distributed endemic species reported by watershed. 1250
Map 4.33 Number of species formally listed under the Endangered Species Act reported by watershed. 1251
Map 4.34 Distribution of fish assemblage integrity scores by watershed. 1252
Map 4.35 Historical and current distribution plus introduced sites of white sturgeon. 1269
Map 4.36 Historical and current distribution of Klamath lamprey. 1272
Map 4.37 Historical and current distribution of river lamprey. 1273
Map 4.38 Historical and current distribution of Pacific lamprey. 1274
Map 4.39 Historical and current distribution of Goose Lake lamprey. 1276
Map 4.40 Historical and current distribution of Pit-Klamath brook lamprey. 1277
Map 4.41a Historical and current distribution plus introduced sites of sockeye salmon. 1280
Map 4.41b Historical spawning and rearing areas of sockeye salmon. 1281
Map 4.42 Historical and current distribution of chum salmon. 1283
Map 4.43 Historical and current distribution of coho salmon. 1276
Map 4.44 Historical and current distribution plus introduced sites of coastal cutthroat trout. 1287
Map 4.45 Historical and current distribution plus introduced sites of Lahontan cutthroat trout. 1290
Map 4.46 Historical and current distribution of pygmy whitefish. 1294
Map 4.47 Historical and current distribution plus introduced sites of burbot. 1295
Map 4.48 Historical and current distribution of sand roller. 1296
Map 4.49 Historical and current distribution of northern roach. 1297
Map 4.50 Historical and current distribution of Alvord chub. 1299
Map 4.51 Historical and current distribution of Borax Lake chub. 1300

Map 4.52	Historical and current distribution of Catlow tui chub.	1302
Map 4.53	Historical and current distribution of Oregon Lakes tui chub.	1304
Map 4.54	Historical and current distribution of Summer Basin tui chub.	1305
Map 4.55	Historical and current distribution of Sheldon tui chub.	1308
Map 4.56	Historical and current distribution of Hutton tui chub.	1309
Map 4.57	Historical and current distribution of leatherside chub.	1310
Map 4.58	Historical and current distribution of Foskett speckled dace.	1312
Map 4.59	Historical and current distribution of Lost River sucker.	1313
Map 4.60	Historical and current distribution plus introduced sites of Warner sucker.	1314
Map 4.61	Historical and current distribution of Goose Lake sucker.	1317
Map 4.62	Historical and current distribution of shortnose sucker.	1319
Map 4.63	Historical and current distribution of Klamath largescale sucker.	1321
Map 4.64	Current distribution of Wood River bridgelip sucker.	1323
Map 4.65	Current distribution of torrent sculpin.	1324
Map 4.66	Current distribution of shorthead sculpin.	1326
Map 4.67	Historical and current distribution of pit sculpin.	1328
Map 4.68	Historical and current distribution of slender sculpin.	1329
Map 4.69	Historical and current distribution of margined sculpin.	1331
Map 4.70	Historical and current distribution of Wood River sculpin.	1333
Map 4.71	Historical and current distribution of Shoshone sculpin.	1334
Map 4.72	Historical and current distribution of Malheur sculpin.	1336
Map 4.73	Designated wilderness and predicted unroaded areas are important anchors for known and predicted strong populations of seven key fish species in the Basin.	1353
Map 4.74	Classification of subbasins (about 280,000 hectares) relative to the presence of a highly functional aquatic ecosystem.	1358

Continue

Previous

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INTRODUCTION

The idea of rebuilding the fish and wildlife of an industrialized ecosystem is heroically optimistic—a hope that might not have occurred to anyone except those who had rehabilitated the Willamette basin in Oregon or Lake Washington near Seattle. The extension of those learning experiences to the multi jurisdictional, multi functional situation of the Columbia basin — a large ecosystem — requires coordinated action and learning on a new scale

- Kai N. Lee (1993)

In this chapter, we report on a broad-scale scientific assessment of aquatic resources conducted as part of the Interior Columbia Basin Ecosystem Management Project. Our assessment area, collectively referred to as the Basin, includes the Columbia River Basin east of the crest of the Cascade Mountains (Washington, Oregon, Idaho, western Montana, and small portions of Nevada, Utah, and Wyoming), and those portions of the Klamath Basin and the Great Basin in Oregon.

To many people, salmon characterize the Pacific Northwest. Salmon have been a cornerstone of the culture, economy, recreation, and history of the region. Salmon, trout, and other salmonids require relatively clean, cold-water environments, and because they are among the better known and monitored aquatic resources, salmonids, as a group, provide sensitive barometers to the overall health of aquatic habitats in the region (Marcot and others 1994).

Salmon is not the only fishery resource within the Basin. Fifty-two native fish species occur in the Columbia River system; thirteen of these species are found nowhere else (McPhail and Lindsey 1986). Including subspecies and the Oregon portions of the upper Klamath and Great Basin systems, the entire Basin supports 88 native fish taxa, of which 28 are narrowly distributed endemics. Forty-five of the 88 taxa are considered to be threatened, endangered, sensitive, or otherwise of special concern. In general, the fish faunas in the Great Basin and upper Klamath areas are less diverse than in the Columbia River system, but they are more highly specialized and contain a greater percentage of narrowly distributed endemic fishes.

Native fishes and other aquatic faunas throughout the assessment area are on the decline. Chinook and sockeye salmon in the Snake River are listed as endangered under the Endangered Species Act. Bull trout, once widely distributed in central Oregon, Idaho, and western Montana, warrant protection (U.S. Government 1995). Genetically pure populations of Yellowstone cutthroat trout are limited to a fraction of their historical stream habitat in the upper Snake River drainage (Gresswell 1995; Varley and Gresswell 1988). Only a small portion of the historic range of westslope cutthroat trout in Idaho and Montana still sustains genetically pure populations (McIntyre and Rieman 1995; Rieman and Apperson 1989). Redband trout within the Basin are poorly understood, but many subbasins appear to contain genetically unique strains that have declined concomitant with habitat

degradation (Behnke 1992; Williams and others 1989). Such changes in salmonid populations may be indicative of broad declines in other aquatic resources such as stream habitats and riparian areas in the Columbia River basin.

The aquatic resources in the upper Klamath and Great Basin portions of the assessment area also have declined. For example, members of the sucker family (Catostomidae) in the upper Klamath basin, which supported important Native American subsistence fisheries and sport fisheries until the early 1980s, are now listed as endangered pursuant to the Endangered Species Act (U.S. Government 1988). Other native fishes of the Upper Klamath basin have declined as water quality has been reduced and the abundance of non-native species has increased. Most native fishes of the relatively sparse fish fauna in the Great Basin are federally listed as endangered, threatened, or are candidates for Endangered Species Act of 1973 (Public Law 93-205, as amended) protection because of activities that degrade important riparian habitats. Aquatic macroinvertebrates, including a surprisingly diverse springsnail (Hydrobiidae) fauna in the Great Basin, also have declined (Hershler 1995).

Many factors contribute to the decline of the fishery resources in the Basin. Dams and hydroelectric operations, introductions of hatchery and other non-native species, excessive harvest, and other factors have been identified. Degradation and loss of freshwater habitats, however, are a consistent and pervasive problem facing the aquatic faunas in the Basin and throughout much of the western United States (Nehlsen and others 1991; Williams and others 1989; Young 1995). Management of Federal lands can play a critical role in the condition of aquatic systems. Continued declines of fisheries resources suggest that past management practices have been insufficient to reverse the trend. Broad-scale ecosystem approaches are needed to halt habitat degradation, to maintain existing high-quality habitats, and to aid in the recovery of declining fish and aquatic invertebrate resources.

Restoring the general condition of streams and their watersheds in the Basin will yield benefits beyond conservation of fishes. Overall biodiversity, from microbes that perform valuable ecosystem services to top carnivores, may benefit from restorative actions. Other important but often unappreciated natural processes, such as recharging underground aquifers and providing large woody debris to stream systems, would also be maintained (Maser and Sedell 1994; Naiman 1992). Water quality, recreation, drought resistance, and flood protection would be enhanced by improving watershed condition. We are beginning to understand and appreciate the natural geomorphic, hydrologic, and biotic processes that shape stream systems. To effectively apply these processes to stream restoration, however, we also need a clearer understanding of the effects of human activities on natural processes.

In creating this assessment we addressed four primary objectives. First, we broadly characterized the geophysical and biological settings that define the natural potential of the Basin to support aquatic resources. Second, we identified anthropogenic factors that affect aquatic habitats and the species they support, either directly or through indirect disruption of natural processes. Special emphasis was given to effects of Federal land management. Third, we conducted a broad-scale assessment of the current condition of aquatic habitats and species. Though we focused primarily on fishes, ancillary information was also gathered on molluscs, other invertebrates, and aquatic plants. Finally, we worked to synthesize our information such that it might provide a regional context for Federal management agencies to devise proper management strategies for aquatic and riparian habitats.

This broad-scale assessment of aquatic resources is organized in six sections. The first section describes the primary elements of change, both natural and human-caused, that affect the integrity of aquatic ecosystems across the Basin. In the second section, the relationship between small-scale stream features, landscape-scale environmen-

tal features, and human activities is examined using stream-inventory data. Next, we describe the distribution and status of fishes in the Basin, identify critical and high integrity areas, and explore linkages between fish communities, the landscape, and human activities. The following section describes rare and sensitive species in the assessment area. Ecological risks and management opportunities at various scales are then discussed, and the last section contains information and research needs for improved management and conservation of aquatic resources.

The breadth and depth of this assessment require close attention to spatial scale. For comparative purposes, 13 Ecological Reporting Units (ERUs) were defined based on bedrock, hydrological characteristics, vegetation patterns, and climate (table 4.1, map 4.1). At finer scales, topography was used to define a hierarchical system of increasingly smaller watersheds (table 4.2, fig. 4.1).

Within the Basin, for example, 164 large subbasins are defined. Examples of subbasins include the Bitterroot River in Montana, South Fork Boise River in Idaho, Middle Fork John Day River in Oregon, and Wenatchee River in Washington. The subbasins are further divided into watersheds, which average approximately 22,820 hectares in size. These watersheds are then divided into smaller subwatersheds, each approximately 7,830 hectares in size. These divisions follow the hierarchical framework of aquatic ecological units recently described by Maxwell and others (1995), which provides further descriptions of these elements. Subwatersheds form the basic sample unit for analysis and description of many of the elements discussed in the following sections. ERU boundaries are not congruent with subbasin boundaries but do follow subwatershed boundaries. That is, subwatersheds within subbasins may be divided among more than one ERU.

Table 4.1— Summary characterization of Ecological Reporting Units.

Northern Cascades

Bedrock:	Cenozoic andesites and basalts with extensive metamorphism
Topography:	steep volcanic foothills and mountains with narrow intermountain valleys and highly dissected stream networks
Vegetation:	gradient of pine/fir with sagebrush through fir/cedar to fir/hemlock as elevation increases
Elevation:	152-3,658 m (500-12,000 ft)
Climate:	25-381 cm (10-150 inches) annual precipitation

Southern Cascades

Bedrock:	Cenozoic andesites, tephra, and basalts
Topography:	moderately steep volcanic foothills and mountains with narrow intermountain valleys highly dissected with stream networks
Vegetation:	pine/fir with sagebrush, juniper, and meadows at low elevations; proportions of white fir, silver fir, and meadows increasing with elevation
Elevation:	152-3,048 m (500-10,000 ft); *extremely variable*
Climate:	25-254 cm (10-100 in)annual precipitation; extremely variable

Upper Klamath

Bedrock:	Cenozoic volcanics and sediments
Topography:	steep volcanic mountains, foothills, and plains and low to moderately dissected stream networks
Vegetation:	sagebrush, juniper, and pine with meadows and fir at low elevations; gradient from white and red fir to silver fir mixed with meadows at the higher elevations
Elevation:	457-2,743 m (1,500-9,000 ft)
Climate:	51-127 cm (20-50 in) annual precipitation

Table 4.1 (continued).

Northern Great Basin

Bedrock:	Cenozoic alluvial and volcanic materials
Topography:	low relief plains with some isolated mountains with low dissected stream networks; area contains the closed basins of Lake Abert, and Summer, Warner, Harney, Malhuer, and Alvord lakes
Vegetation:	vegetation is primarily salt desert shrub, sagebrush, and juniper with some meadows
Elevation:	1,219-2,195 m (4,000-7,200 ft); little variation
Climate:	15-51 cm (6-20 in) annual precipitation

Columbia Plateau

Bedrock:	Cenozoic basalts
Topography:	low relief plains and breaks with few stream networks
Vegetation:	sagebrush, bluebunch wheatgrass, and Idaho fescue
Elevation:	61-1,372 m (200-4,500 ft) elevation
Climate:	23-51 cm (9-20 in) annual precipitation

Blue Mountains

Bedrock:	Paleozoic and Cenozoic sediments and Cenozoic basalts
Topography:	low to moderate relief plains, foothills, and mountains with narrow intermountain valleys and breaks; stream networks uncommon
Vegetation:	sagebrush and grasslands mixed with pine and fir at the low elevations; grand fir more common at the mid-elevations with small amounts of subalpine fir mixed with meadows at the higher elevations
Elevation:	762-3,048 m (2,500-10,000 ft)
Climate:	25-127 cm (10-50 in) annual precipitation

Northern Glaciated Mountains

Bedrock:	Precambrian and Cenozoic sediments and metasedimentary materials
Topography:	low to steep relief foothills and mountains with narrow to wide intermountain valleys and highly dissected stream networks
Vegetation:	fir and pine mixed with grasslands, sagebrush, and meadows at lower elevations; grand fir and cedar (sometimes hemlock) in middle elevations; and subalpine fir mixed with meadows at the higher elevation
Elevation:	305-2,896 m (1,000-9,500 ft)
Climate:	38-254 cm (15-100 in) annual precipitation

Upper Clark Fork

Bedrock:	Precambrian and Mesozoic granite and metasedimentary materials
Topography:	steep glaciated mountain ranges; moderately steep foothills with moderately wide intermountain valleys and highly dissected stream networks
Vegetation:	fir and pine on foothills mixed with cottonwood, aspen, grasslands, sagebrush, and meadows in the valleys at the lower elevations; subalpine fir mixed with meadows more common at the middle to higher elevations
Elevation:	914-2,896 m (3,000-9,500 ft)
Climate:	36-203 cm (14-80 in) annual precipitation

Lower Clark Fork

Bedrock:	Precambrian metasedimentary materials
Topography:	steep mountain ranges with steep foothills and narrow mountain valleys and breaks with highly dissected and incised stream networks
Vegetation:	fir and pine on foothills mixed with grasslands and meadows in the valleys at lower elevations; fir and cedar more common at middle elevations; subalpine fir mixed with meadows at higher elevations
Elevation:	366-2,591 m (1,200-8,500 ft)
Climate:	76-203 cm (30-80 in) annual precipitation

Table 4.1 (continued).

Owyhee Uplands

Bedrock:	Cenozoic basalts
Topography:	low relief plains with isolated breaks, mountains and foothills, with low dissection and few stream networks
Vegetation:	salt desert shrub, sagebrush, and juniper with some meadows
Elevation:	1,219-2,438 m (4,000-8,000 ft)
Climate:	18-38 cm (7-15 in) annual precipitation

Upper Snake

Bedrock:	Cenozoic basalts
Topography:	low relief plains with low dissection and few stream networks
Vegetation:	salt desert shrub, sagebrush, and juniper with some meadows
Elevation:	914-1,829 m (3,000-6,000 ft)
Climate:	13-30 cm (5-12 in) annual precipitation

Snake River Headwaters

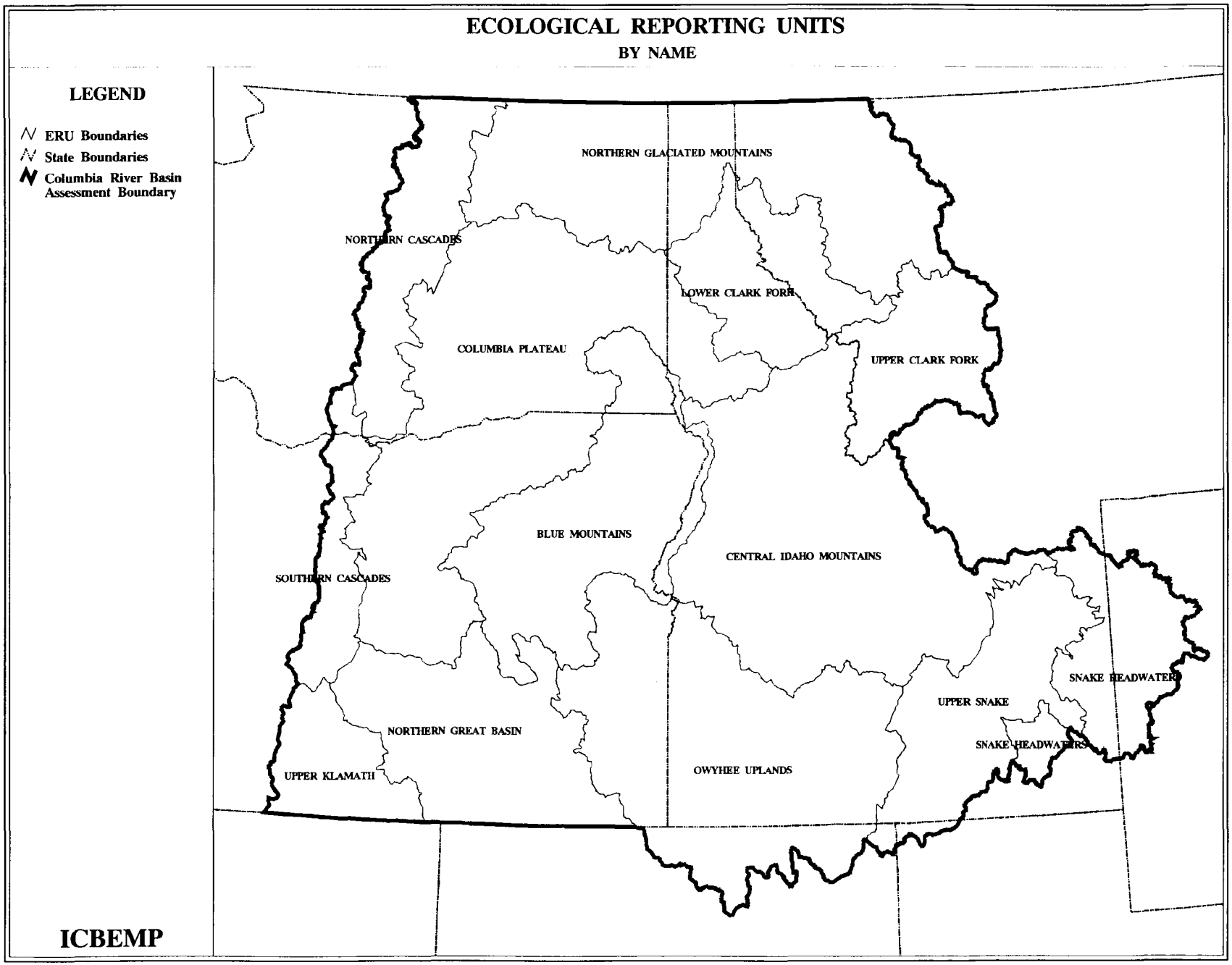
Bedrock:	Precambrian to Cenozoic complex sediments, metasediments, metamorphics, and volcanics
Topography:	steep glaciated and nonglaciated mountain ranges with intermountain valleys, foothills, and high plains; stream dissection low in the valleys and plains; foothills and mountains highly dissected with numerous stream networks
Vegetation:	fir and pine mixed with sagebrush and meadows on high plains, foothills, and lower mountain slopes; subalpine fir mixed with meadows and mountain sagebrush are found at the higher elevations
Elevation:	1,524-3,962 m (5,000-13,000 ft)
Climate:	41-114 cm (16-45 in) annual precipitation

Central Idaho Mountains

Bedrock:	Cenozoic and Mesozoic granite and Cenozoic volcanics and Precambrian quartzite
Topography:	glaciated and nonglaciated mountain ranges and foothills; narrow intermountain valleys and breaks of moderate to steep relief highly dissected by stream networks
Vegetation:	fir mixed with sagebrush, grasslands, and meadows on valleys, breaks, and lower mountain slopes; subalpine fir mixed with meadows and mountain sagebrush and grasslands more common at the higher elevations
Elevation:	914-3,352 m (3,000-11,000 ft)
Climate:	30-203 cm (12-80 in) annual precipitation

Table 4.2— Hierarchical framework of hydrology for the assessment area.

Hydrological Unit	Total Number within Assessment Area	Average Size
Subbasins	164	356,496 hectares (880,890 acres)
Watersheds	2,562	22,820 hectares (56,387 acres)
Subwatersheds	7,467	7,830 hectares (19,347 acres)



Map 4.1— Ecological Reporting Units in the Interior Columbia Basin Ecosystem Management Project area.

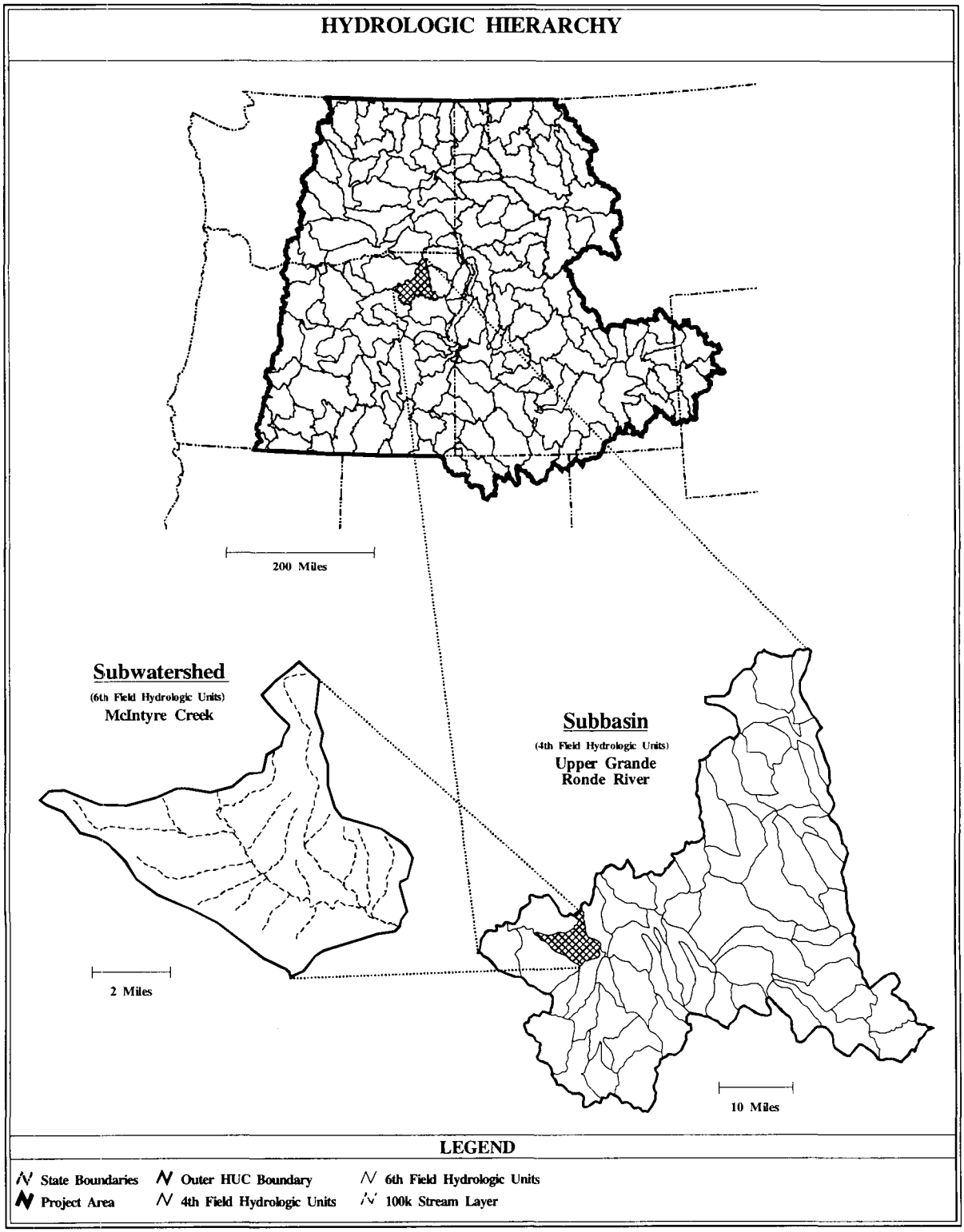
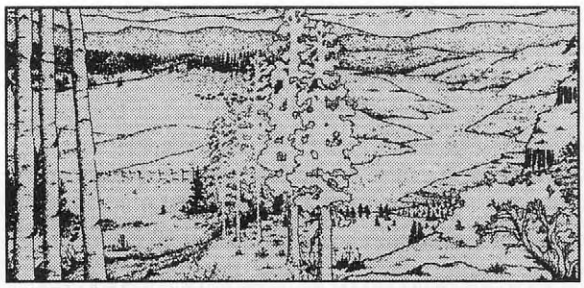


Figure 4.1— Hierarchical division of hydrological drainage areas. A) The entire assessment area (Basin) showing subbasins, with the Upper Grand Ronde subbasin shaded. B) The Upper Grand Ronde subbasin showing subwatersheds. C) The McIntyre Creek subwatershed, showing the 1:100,000 hydrography.

FACTORS INFLUENCING THE INTEGRITY OF AQUATIC ECOSYSTEMS



Geologic and geomorphic processes that formed and continue to affect the assessment area include tectonism, volcanism, glaciation, erosion, sediment transport, and deposition. The first three processes are not influenced by humans. The other processes are dominant forces shaping the landscape but may be influenced by human actions. All of these processes, in concert with the underlying physical environment, establish the template for and constrain the successional pathways for aquatic habitats and their associated communities. Human disturbances shape the status of the abiotic and biotic elements, but the physical setting and natural disturbances ultimately constrain the landscape's potential. In this section we consider the natural processes affecting landscapes and aquatic ecosystems within the Basin and discuss the effects of human disturbance.

Influence of Natural Processes on Aquatic Ecosystems

At the scale of watersheds and valley-bottoms, the physiography of the Columbia River basin is a relict of the Pleistocene (1.6 million - 10,000 years ago). At the local scale of channels and hill slopes, the physiography is influenced by disturbance processes that have occurred over the last few thousand years. Different histories (geologic, tectonic, glacial, recent) and different processes (hydrologic and sediment regimes) within and among subbasins and ERUs contribute to the diversity of aquatic habitats in the Basin (see Biophysical Environments chapter, this document).

During the last 4,000 years, volcanoes of the Cascade Range have erupted about twice per century. Effects of blasts, lava flows, floods, or other volcanic deposits are extensive. Long-term effects associated with erosion of tephra deposits (volcanic ash, pumice, and other debris) are apparent far from the volcanic source. For example, the pyroclastic surge of the 1980 eruption of Mount St. Helens leveled trees as far as 28 km from the crater and affected a 600 square kilometer area (Moore and Sisson 1981).

Probabilities of significant future volcanic episodes and tephra deposition are highest in the Northern Cascades and lowest in the eastern portions of the assessment area [Blue Mountains, Northern Glaciated Mountains, Lower and Upper Clark Fork, Owyhee Uplands, Central Idaho Mountains, Upper Snake, Snake Headwaters ERUs (Biophysical Environments chapter)]. Although the potential for ash deposits at a location in the western part of the assessment area in any single year is very small, it is virtually certain that within 200 years there will be a significant eruption within or adjacent to the assessment area. Actions taken to protect threatened or endangered species may have a longer-term positive impact if such timeframes and occurrences are considered at the onset.

Earthquakes also shape local physiography. Major landslides and permanent and temporary damming of rivers that are associated with such events can have significant effects on aquatic systems.

Earthquakes do not occur uniformly throughout the assessment area, and the areas of highest probability for major earthquakes are found in the Snake River Headwaters. The portion of the Upper Snake River located in Nevada, the Upper Clark Fork, Central Idaho Mountains, Northern Cascades, and Southern Cascades ERUs are also high risk earthquake areas (Biophysical Environments chapter). In these areas, there is a 10 percent probability that large seismic events could occur within a 50-year period.

During the Pleistocene, silt and fine-sand outwash from alpine and continental glaciers and glacial outburst floods were entrained by wind and redeposited as thick blankets of loess. These sequential layers of loess comprise much of the agricultural land in the Columbia Valley, Columbia Plateau, and Snake River Plain (Malde 1991). Because loess deposits are easily eroded by wind or water, large volumes of air and water-borne sediment are frequent byproducts of erosion. Although gravelly alluvial fan and valley-fill complexes in or near mountainous areas were also deposited during the Pleistocene, sediment production from hill slopes was much greater than at present. Because modern streams rarely mobilize the coarsest material that composes these fans, streams are usually constrained to movement within banks of fine-grained Holocene loess and alluvium. This is particularly true for the highly erosive Columbia Basin Plateau and Palouse area in eastern Washington.

Because of the size and complex topographic structure of the Basin, patterns of precipitation are not uniform. Distribution of vegetation in the area reflects the long-term precipitation patterns (Biophysical Environments chapter). For a given year, some areas of the Basin can be wetter than normal, while others are drier. Such anomalies suggest that future shifts in the seasonal weather system could affect portions of the Basin differently.

The hydrologic regime in the assessment area varies both spatially and temporally. Timing, duration, and magnitude of high and low flows, connection with groundwater, water quality and quantity, and temperature are influenced by the diverse physiography found among ERUs and within watersheds. Temporal variability of the hydrologic regime is due to weather and climate cycles as well as geomorphic factors such as channel deposition, changing channel width, and variation in the pattern of riparian vegetation.

Confined high-gradient streams are often shaped by rare large events that flush sediments relatively quickly downstream. The low gradient morphology of unconfined streams is generally more responsive to upstream disturbances and less-frequent disturbance events. The lowest gradient streams are the most responsive to gross channel morphological change from chronic disturbances (Biophysical Environments chapter).

Modern floods do not equal the magnitude of the Pleistocene floods, but they are important events nonetheless. Floods are naturally occurring events which vary in size and frequency depending on climatic factors and, to a lesser extent, on management practices. Wolman and Miller (1960) postulate that most flood-induced geomorphic changes are caused by intermediate (approximately two year recurrence intervals) events. The area affected by any single flood may be limited to a stream reach or extend to cover large river basins (such as the Columbia River basin in 1948).

The variability in climatic and geologic processes within the Basin has resulted in a complex variety of aquatic habitats. In turn, habitat heterogeneity can be key to the expression and maintenance of biological diversity in terrestrial and aquatic environments (Gresswell and others 1994; Schlosser 1991). The maintenance of habitat complexity in the Basin then becomes critical if we are to conserve the natural diversity of aquatic biota in the face of disturbance. Although climatic and geologic processes cannot be managed, human response to them can be planned, and in some cases, human disturbances might be modified to maintain desired habitat complexity in the context of natural disturbance regimes (Reeves and others 1995).

Influence of the Marine Environments on Freshwater Aquatic Ecosystems

Another significant factor beyond human control that affects aquatic species integrity is the natural fluctuations in the marine environment. In the last 15 years, the role of ocean conditions, which are driven by atmospheric circulation patterns, and their effects on anadromous salmonids have received increasing interest (Pearcy 1992). Traditionally, most salmonid research has focused on the freshwater environment and biologists attributed variation in population size solely to conditions in freshwater. Recent work strongly suggests that the abundance of anadromous salmonids and other fishes may be significantly affected by short- and long-term variation in atmospheric and oceanic circulation patterns (Francis and Sibley 1991; Ware and Thomson 1991). The evidence suggests that northeast Pacific Ocean conditions shifted in the mid-1970s, and anadromous salmonid populations along the entire West Coast of North America have responded to these large-scale changes (Francis and Sibley 1991; Pearcy 1992). The role of freshwater habitats must be considered in the context of larger-scale fluctuations in anadromous fish populations brought on by climate and oceanic conditions.

Cycles in marine productivity have the potential to mask the effects of degradation in freshwater habitats. Lawson (1993) presented a conceptual model for considering the combined effects of oceanic cycles and habitat degradation in freshwater. As freshwater habitats are degraded, populations of anadromous fishes do not decline in a linear fashion. Instead, a general downward trend is masked by long-term oscillations in ocean productivity. During periods of unfavorable ocean conditions, the consequences of degradation in freshwater habitats are most evident, and the risk of local extirpation is greatest. However, when periods of favorable ocean conditions are coupled with declining freshwater habitats, anadromous fish populations may appear to be stable or even increasing. Thus, favorable ocean conditions can lead to false beliefs of overall improvement in freshwater habitat quality. Similarly, haphazard restoration strategies may appear to be successful as population numbers increase, even though those increases are merely the fortuitous result of improving oceanic conditions. Once again, it is important to be aware of the larger context when assessing affects of management activities in a naturally fluctuating environment.

Long-term variations in ocean productivity also have a significant bearing on harvest and hatchery management. Harvest projections and limits are typically based on maximum sustained yield models that assume a constant environment. Because such models assume linear relationships between production and yield, they are particularly problematic in a changing environment or in one that is tending in a direction different from that in which the model was developed.

Similarly, the survival and production of hatchery-reared fishes may vary significantly with oceanic conditions (Pearcy 1992). In the 1950s and 1960s, coho salmon hatcheries in Oregon were enthusiastically endorsed by commercial fishers (who tripled in number over a 10-year period) and fishery managers because of early success that was largely the result of favorable oceanic conditions. When environmental conditions shifted in the mid-1970s, survival of hatchery-reared coho decreased, and the overharvested fishery took an increasing toll on wild stocks (Pearcy 1992). The results were significant economic hardship for coastal fishing communities and precipitous declines in wild coho populations.

Although the amount of time that anadromous salmonids reside in freshwater habitat may be relatively short, condition of the habitat is critical, especially considering the natural fluctuations of conditions during their multi-year residence in the ocean. Freshwater habitats of high quality can ameliorate periods of poor ocean production, and it is becoming increasingly apparent that high-quality freshwater habitat is not a luxury but a necessity to the survival of anadromous salmonids. The oscillating conditions of ocean productivity and decline of Pacific salmon and steelhead emphasize the need for monitoring and restoring habitat elements, such as spawning and rearing habitat throughout the Columbia River basin.

Influence of Wildfire on Freshwater Aquatic Ecosystems

Wildfire has been a common agent of change in the assessment area since the Mesozoic (Cope and Chaloner 1985), and present aquatic systems have evolved in response to, and in concordance with, fire (Meyer and others 1992; Swanson 1981). The effects of fire on aquatic systems may be direct and immediate (for example, increased water temperature, chemical input) or indirect occurring over an extended period, but ultimately fire results in a natural mosaic of habitats and populations. The persistence of species in freshwater aquatic systems is linked to adaptation to periodic perturbations such as those resulting from fire (Warren and Liss 1980). In fact, the metapopulation concept is focused on the periodic loss of habitat patches (local extirpations) and subsequent re-invasion by individuals from neighboring patches (dispersal) (Hanski and Gilpin 1991). In an ecologically functioning stream network which provides sufficient stream connectivity for species refuge, reestablishment of fishes is generally rapid (Rieman and others, in press; Sedell and others 1990).

Long-term effects of fire usually result from erosion. Erosional processes potentially change channel morphology, sediment composition and concentration, food availability, and recruitment and distribution of large woody debris (Minshall and others 1990). The intensity and scale of these effects are related to the size and intensity of fire, geology, topography, and size of the stream system, and amount, intensity, and timing of subsequent precipitation events. Physical properties of soil that influence water retention are altered by heating, and in some cases, soils become water repellent after severe burns (McNab and others 1989). The amount of vegetation remaining in a watershed after a fire directly influences runoff and erosion by physically mediating the force of precipitation on soil surfaces, altering the evapotranspiration cycle, and providing soil stability through root systems. Runoff rate and pattern and subsequent erosion potential are directly affected by the amount of organic debris left in the watershed.

Revegetation of burned areas is influenced by the intensity and duration of a fire (Knight 1987), and the amount and type of new vegetation are related to changes in water yield and nutrient retention in the watershed. Erosional effects of fire generally peak within 10 years following the event (Brown 1989).

Influence of Human Activities on Aquatic Ecosystems

By the late 1800s, human activities had begun to alter the assessment area landscape, including the hydrologic function of rivers and streams and features that served as important habitat for aquatic life. By 1860 livestock grazing had reduced extensive willow coverage along many streams to scattered patches (Elmore and Kaufman 1994; Vavra and others 1994). Virtually every major tributary in the basin that was navigable (by canoe) had been altered by removing waterfalls, boulders, and log jams. Throughout the Basin the story was the same: sloughs and backwaters were isolated; pools were filled; log jams were cleared; and boulders were blasted. Clearing streams and rivers for passage of boats and milling of logs reduced the interaction of the stream system and flood-plain vegetation. Constructing drains, ditches, and dikes in valley bottoms and lowlands also reduced terrestrial-aquatic interaction. Flood control levees diminished or eliminated complex sloughs and side channels that were valuable rearing areas for salmonids and riparian dependent species. Human activities in many Idaho and Montana watersheds were extensive by the 1920s, and some areas (for example, Flathead Lake in the Northern Glaciated Mountains ERU) had been substantially altered by that time.

Marble Creek on the St. Joe River in Idaho provides one example of these activities. In 1911 there were numerous debris jams that had existed for many years (Blake 1971). In a 29-kilometer stretch ending at Homestead Creek, more than 1,180 cubic meters (500,000 board feet) of marketable

timber were removed from the stream channel. An additional amount of wood was used to fuel steampowered equipment used in the logging operation. Fishing in the creek prior to 1911 had been described as exceptional, but Blake (1971) noted that large fish vanished after log drives.

In the early 1900s, the construction of large dams began as isolated areas of the Columbia River basin like the Central Idaho Mountains and the Wenatchee River system were gradually settled. Water withdrawals for irrigation were also developed early and rapidly. From the 1860s to 1930s dredges and hydraulic mining followed each new gold or silver discovery. Low-gradient reaches of streams were excavated, and whole valleys were transformed. Large reaches in low-gradient sections were inundated with fine sediments. Vast wetlands were filled and became farms and hay fields. Because many lakes were barren of fish, numerous species were introduced to provide recreational fishing.

In short, the ecological integrity of streams, lakes, and wetlands was significantly compromised by the 1920s. Increasing human population, technological advances (for example, centrifugal pumps), and availability of heavy equipment after World War II greatly accelerated the development of new irrigation projects, timber harvest, dam construction, and road building. Individually and in combination, these activities continued to fragment and compromise the remaining hydrologically connected and vegetated reaches of streams.

Changes in Extent and Type of Riparian Vegetation in the Basin

To determine riparian vegetation changes in the Basin, we conducted an analysis at the mid-scale (subbasins). Our approach was to determine current condition of riparian vegetation and changes in vegetation type and cover from historical potential as well as from the past 40 to 60 years. We used methods appropriate to both the extensive spatial and temporal scales and the limited resolution of the data.

The analysis focused on an analysis of trends in physiognomic types, major vegetation cover types, and major vegetation structural stages. This riparian zone vegetation characterization and analysis of trends are based on the midscale vegetation analysis of the upland vegetation as described in Hessburg and others (1995). Within the assessment area, the 164 subbasins were stratified using broad biophysical environment settings into 16 strata. Using this stratification, a random sample of 43 subbasins was selected for further subsampling. Mid-scale subwatershed characterizations were used to describe changes in subbasins representative of the Basin. Aerial photography was used to compare recent historical conditions (early 1930s to mid-1950s) to current (mid-1980s to present) conditions. Vegetation patches were defined using multiple attributes of vertical and horizontal structure and composition. A complete list of the photo-interpreted attributes can be found in Hessburg and others (1995). The existing vegetation attribute was characterized using cover type classes of forest, woodland, shrubland, herbland, and non-forest/non-range. Significant change ($p \leq 0.20$) from recent historical to current conditions was determined by examining the 80 percent confidence interval around the mean difference for the subbasin. More details of the analysis procedure of the mid-scale vegetation data are outlined in Hessburg and others (1995).

The mid-scale aerial photography used in the vegetation analysis, and the 7.5 minute U.S. Geological Survey (USGS) quadrangle maps (1:24,000 scale) used to map and characterize valley bottom settings and stream channel segments, were used to analyze the riparian vegetation at the mid-scale. The valley bottom setting and channel segment maps were overlaid on the mid-scale vegetation maps to produce a coverage of riparian zone vegetation. The riparian sample area consisted of the strip of vegetation, 20 to 30 meters in width, adjacent to all surface hydrography (that is, around the perimeters of lakes and wetlands greater than 0.5 hectares in area, and on both sides of all mapped perennial and intermittent stream channels).

Not all vegetation cover types and structural stages in this zone are wetland vegetation types; some are more typically associated with upland vegetation.

The analysis was based on sample areas within the Basin (and ERUs). Sample sites have a higher proportion of Forest Service (FS) and Bureau of Land Management (BLM) lands than private, tribal, or other Federal lands as compared to the proportions within the entire Basin. We looked at cover types, structure, and physiognomic types in a comparison of recent historical to current levels. This section highlights some of those attributes that directly influence the aquatic environment and the ERUs where the most significant changes occurred.

The data indicate that many areas in the Basin are showing a reduction in the large tree component in riparian zones. This can affect the amount of shading provided to streams and the potential large woody debris recruitment. Those ERUs showing a loss of large trees are the Northern Cascades, Upper Klamath, Columbia Plateau, Blue Mountains, and Snake Headwaters. Some of these (primarily the Columbia Plateau and the Upper Klamath) did not have a large percentage of large trees either historically or currently but have shown significant losses. ERUs showing some increase in the large tree component of the riparian zone are Southern Cascades, Northern Glaciated Mountains, and Lower Clark Fork. The increase in the large tree component appears to be inconsistent with those results found at the broad scale for the Southern Cascades and Northern Glaciated Mountains ERUs. This inconsistency is most likely attributed to the difference in land ownership at the broad scale (all land ownership) and the ownership at the mid scale where sample areas were predominantly Forest Service- and BLM-administered lands.

In an analysis of mid-scale vegetation classification, significant changes occurred in most ERUs (table 4.3). There was a decline in shrublands in the riparian zones in more than half of the ERUs. Shrublands predominantly shifted to forests and herblands, through succession or disturbance.

The mid-scale results in shrub loss are consistent with the broadscale results with the exception of two ERUs. Both the Lower Clark Fork and Upper Klamath ERUs showed a significant loss in riparian shrub communities in the broad-scale analysis. In the Upper Klamath, those losses occurred primarily on private lands. This was not the case in the Lower Clark Fork. It is likely that the difference in time period played a role in the inconsistent results. The broad scale compared presettlement conditions to current, while the mid-scale analysis looked at changes over the last 40 to 60 years. The more significant losses may have occurred prior to the aerial photography.

Forests (which include cottonwood, aspen, and willow, typically riparian associated species), woodlands and herblands increased in area or stayed approximately the same. There was a decrease in six of the thirteen ERUs of these cover types, with significant decreases in the Snake Headwaters and Columbia Plateau. Significant increases in woodlands occurred in five ERUs. In the Northern Great Basin, Blue Mountains, and Columbia Plateau this increase is attributed to the conversion of shrubland to juniper stands. Nonforest cover types (agriculture, urban, rock, and water) stayed the same in most ERUs with some increase in the Northern Cascades, Upper Clark Fork, and Upper Snake ERUs. The findings in the sample areas at the mid-scale level are similar to those reported by others [McIntosh and others 1994a; U.S. Department of Agriculture (USDA), Forest Service 1993; Wissmar and others 1994b].

Influence of Human Activities on Water Quality

The extent and intensity of land development and land-use activities within the Basin have increased during the past century. Environmental disturbances from non-mechanized, agriculturally based settlements have evolved into perturbations associated with urban and suburban development, industrialization, and intensive large-scale and mechanized agricultural practices. Even areas that have been developed solely for recreational use

Table 4.3— Mid-scale (1:20,000) riparian vegetation changes by Ecological Reporting Unit. Only statistically significant changes are shown ($p \leq 0.20$).

Ecological Reporting Unit	Number of Subsampled Subwatersheds	Forest	Woodland	Herbland	Shrubland
Blue Mountains	46	+	+	*	-
Central Idaho Mountains	43	*	*	+	-
Columbia Plateau	38	+	+	*	-
Lower Clark Fork	5	+	*	*	*
Northern Cascades	48	*	+	*	-
Northern Glaciated Mountains	41	*	*	*	*
Northern Great Basin	4	+	+	+	-
Owyhee Uplands	23	*	+	+	-
Snake Headwaters	16	*	*	*	-
Southern Cascades	16	*	*	+	*
Upper Clark Fork	32	*	*	*	*
Upper Klamath	14	*	*	*	*
Upper Snake	15	*	*	*	-

+ = significant increase from historic condition
- = significant decrease from historic condition
* = no statistically significant change

have not escaped degradation. Aquatic ecosystem perturbations related to these activities include: 1) thermal pollution; 2) toxicity due to the presence of organic compounds (synthetic and natural) and heavy metal ions; 3) introduction of pathogenic organisms; 4) organic wastes that result in potentially catastrophic changes in dissolved oxygen levels; 5) acidification; 6) elevated sedimentation rates; and 7) increased eutrophication (Ellis 1989).

Eutrophication is indicative of deteriorating water quality associated with a buildup of nutrients, especially nitrogen and phosphorus. Increased rates of nutrient loading can be related to changes and/or disturbances within a watershed (Brugam and Vallarino 1989; Dojlido and Best 1993; Stauffer 1991). Development activities that contribute to increased nutrient levels include point sources such as industrial effluents and waterborne sewage systems and nonpoint sources such as agricultural operations, residential development and septic systems, road construction, and forest practices. (Dojlido and Best 1993; Spencer 1991; Thralls 1991).

Nonpoint source pollution may be the most problematic cause of water quality deterioration because the origin of perturbation is often difficult to identify and control. Residential development (often a response to the recreational potential of the area) around or near lakes, reservoirs, and wetlands is directly associated with much of this nonpoint source pollution. Analysis of lakes in the Basin (appendix 4A) concluded that lakes in the Columbia Plateau, Northern Great Basin, and Upper Klamath ERUs have very high total

phosphorus values. Although the phosphorus values may be affected by volcanically influenced soils, anthropogenic activities may also influence lake productivity. Development can also result in increases of nitrogen and phosphorus in surface waters resulting from septic system effluents (Scott 1991; Sorrie 1994; Stauffer 1991), runoff from fertilized lawns and agricultural lands (Lewis and others 1984; Power and Schepers 1989), and runoff from highways and roads (Ehrenfeld and Schneider 1991; Lewis and others 1984).

Nonpoint source pollution is extensive in the assessment area. In Montana, for example, nonpoint source pollution caused by anthropogenic land use is the major cause of declining groundwater and surface water quality (Thralls 1991). Spencer (1991) found that settlement and subsequent economic development (timber harvest, forest products production, and road and railroad construction) of Montana's Flathead Basin increased rates of sediment deposition in three lakes. Even in remote areas such as Oregon's Odell Lake, inputs of nutrients from septic systems associated with a resort, nearby campgrounds, and summer homes built along the lake shoreline seriously affect water quality in the lake (Odell Pilot Watershed Analysis 1994). Moderate eutrophication of Pine and Otter lakes in western Washington appeared to coincide with the construction of recreational cabins and suburban homes around the lakes (Brugam 1987; Brugam and Vallarino 1989).

Analysis of lakes in the Basin (appendix 4A) reported the potential effects of land-use activities on lakes in the assessment area (table 4.4). Lakes in the eastern part of the Northern Glaciated Mountains and Lower Clark Fork ERUs may be the most sensitive to disturbance. These lakes have low levels of total phosphorous and are commonly located in terrain that is more accessible to development and recreation. Lakes in the Northern Cascades, Southern Cascades, Upper Clark Fork, Central Idaho Mountains, and Blue Mountains also had low levels of total phosphorus, and are generally sensitive to nutrient additions from any source. Lakes that are most sensitive to atmospheric pollution sources (low-alkalinity lakes) are located in the Central Idaho Mountains, upper Clark Fork, Blue Mountains, Northern Cascades, and Southern Cascades ERUs. Because these lakes are generally sensitive to nutrient additions from any source, natural or prescribed forest fire, particularly low intensity spring and fall burns that release large quantities of smoke and ash and deliver nutrients to surface waters, may affect water quality.

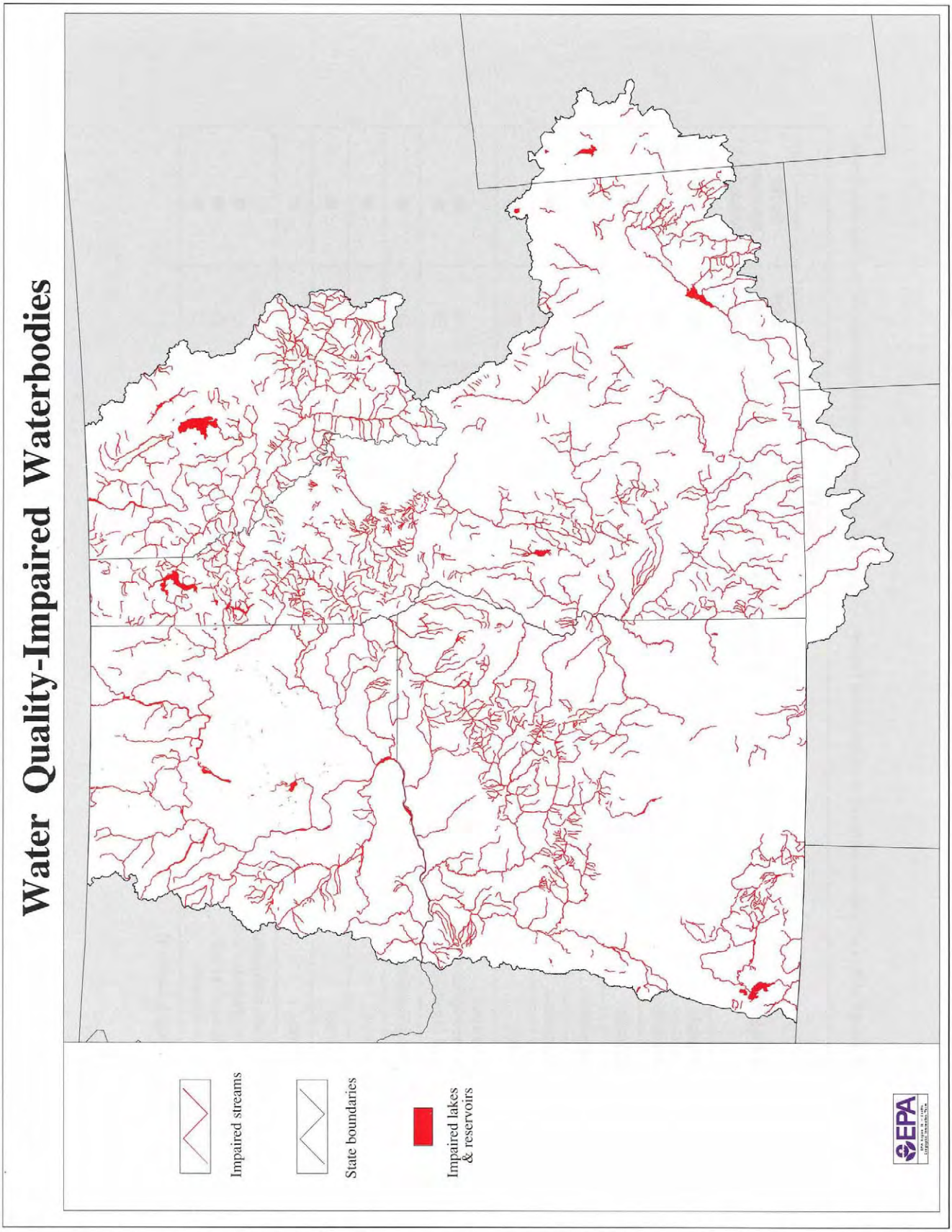
Overall water quality impairment (42,271 stream km; map 4.2) estimated by the Environmental Protection Agency (EPA) appears to be modest in comparison to total length of streams within the assessment area (428,500 stream km; table 4.5). Water temperature, turbidity and sedimentation, nutrients, and streamflow alteration were the most common causes of water-quality impairments reported, but the predominant factors varied among ERUs (fig. 4.2). Because these estimates are based on existing and accessible data from locally specific state and federal monitoring programs, they likely underestimate the real extent and distribution of impairment.

Results of a recent assessment of water temperature extending from the Canadian border to the Oregon/Nevada border also identified areas where conditions have changed substantially from historical condition; however, changes were not uniform across the study area (fig. 4.3; USDA Forest Service 1993). Streams in the Northern Glaciated Mountains and Northern Cascades ERUs displayed little change, but in the Blue Mountains, Southern Cascades, Northern Great Basin, and Upper Klamath ERUs, stream temperatures were elevated and often exceeded state water quality standards for temperature. Because many of the streams with elevated temperatures were not identified by Environmental Protection Agency assessment reports, it appears that water quality concerns within the Basin may be more severe than previously described.

Table 4.4— Potential effects of land-use activities on lakes in the Interior Columbia Basin Ecosystem Management Project assessment area.

	IMPACTS						
Ecological Reporting Unit	**Timber Production**	**Grazing**	**Mining**	**Recreation**	**Development**	**Water Transfers/ Irrigation**	**Exotic Species Introductions**
Columbia Plateau	NA	●	○	○	○	●	●
Northern Great Basin	NA	●	○	○	○	●	●
Owyhee Uplands	NA	●	○	○	○	●	●
Northern Cascades	●	○	○	❑	❑	○	●
Southern Cascades	●	○	○	❑	❑	○	●
Upper Klamath	●	●	○	○	○	●	●
Snake Headwaters							
Yellowstone Highlands	❑	❑	○	❑	○	○	●
Overthrust Mountains	●	❑	❑	❑	○	○	●
Central Idaho Mountains	●	❑	❑	❑	○	❑	●
Upper Clark Fork	●	❑	❑	❑	○	❑	●
Lower Clark Fork	●	❑	❑	❑	❑	○	●
Blue Mountains	●	❑	❑	❑	○	❑	●
Northern Glaciated Mountains							
Okanogan Highlands - west	●	❑	❑	○	○	○	●
Flathead Valley - central	●	❑	❑	❑	❑	○	●
N. Rockies - eastern	●	❑	❑	❑	○	○	●

Slight - ● (or highly localized)
Moderate - ❑
Major - ○
Insufficient sample - NA



Map 4.2— Impaired water bodies within the ICBEMP assessment area WQ1 reported by the Environmental Protection Agency. Nearly 42,377 km of rivers, streams, and lake shore lines are shown. Impairment status derived from the 1994 State/EPA water body lists required under Section 303(d) of the Clean Water Act (CWA), except for Oregon and Washington. Sec. 303(d) waterbodies are those for which existing pollution controls are deemed inadequate to provide for attainment of State water quality standards & designated beneficial uses. Oregon waterbodies shown are from the States' draft 1994/1996 CWA 303(d) list, Dec. 1995. This list is subject to revision based upon results of public comment, proposed modifications to State water quality standard, and EPA approval of the State's final list. Washington data developed under Section 305(b) were used in lieu of the 303(d) list because impairment data for more waterbodies were available, in GIS-compatible format. These waterbodies are not fully supporting designated beneficial uses.

Table 4.5— Water quality impaired waters reported by the States[1] and the Environmental Protection Agency as kilometers of streams and rivers in the portions of States within the Interior Columbia Basin Ecosystem Management Project assessment area.

	Total Stream Kilometers	Any Impairment	Temperature Impairment	Nutrient Impairment	Sediment/ Siltation/ Turbidity Impairment	Flow Impairment
Oregon (1994/96)	121,000	13,072	11,842	450	1,525	2,032
Forest Service		4,068	3,965	0	515	215
BLM		1,040	917	79	105	126
Washington (305b)	79,100	6,376	4,530	53	No Data	4,106
Forest Service		930	328	0	No Data	717
BLM		42	22	0	No Data	26
Idaho (303d)	159,300	16,132	4,235	5,566	14,182	4,368
Forest Service		4,828	733	493	4,133	477
BLM		2,172	826	630	1,911	815
Montana (303d)	50,400	6,295	1,692	1,831	4,883	2,883
Forest Service		2,188	436	159	1,694	894
BLM		112	32	16	90	73
Wyoming (303d)	7,700	115	0	0	74	0
Forest Service		63	0	0	56	0
BLM		4	0	0	4	0
Nevada (303d)	11,000	281	259	22	0	0
Forest Service		18	2	15	0	0
BLM		77	77	0	0	0
TOTALS						
All States	**428,500**	**42,271**	**22,558**	**7,922**	**20,664**	**13,389**
Forest Service		**12,095**	**5,464**	**667**	**6,398**	**2,303**
BLM		**3,447**	**1,874**	**725**	**2,110**	**1,040**

[1]The Utah Department of Environmental Quality reports no impaired streams or rivers within the project area in Utah.

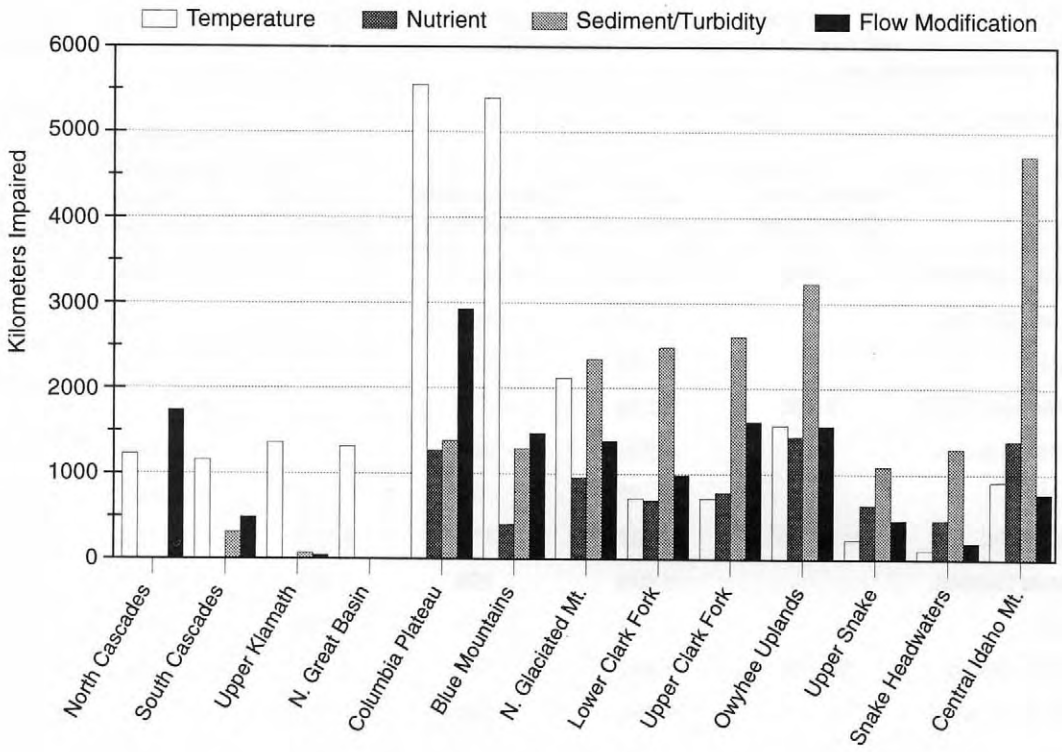


Figure 4.2— Major types of water quality impairment by Ecological Reporting Units within the Basin. Sediment and turbidity were not reported for Washington which lowers the estimate for this type in the Columbia Plateau and Northern Cascades and northern Blue Mountains. Note many streams are reported for multiple impairment types.

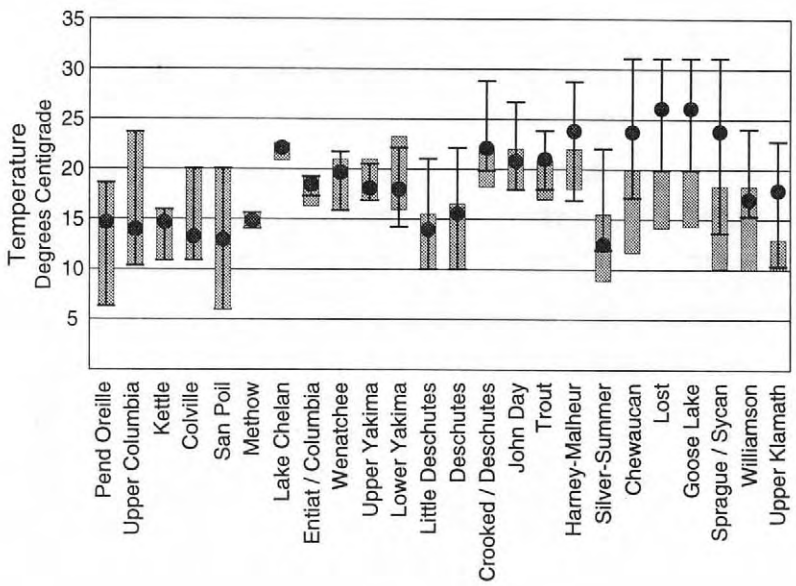


Figure 4.3— Historical range (shaded bars), current range (bars), and current mode (•) of water temperature for streams east of the Cascade Mountains in Washington and Oregon (USDA Forest Service 1993).

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Influence of Dams, Water Storage and Withdrawals

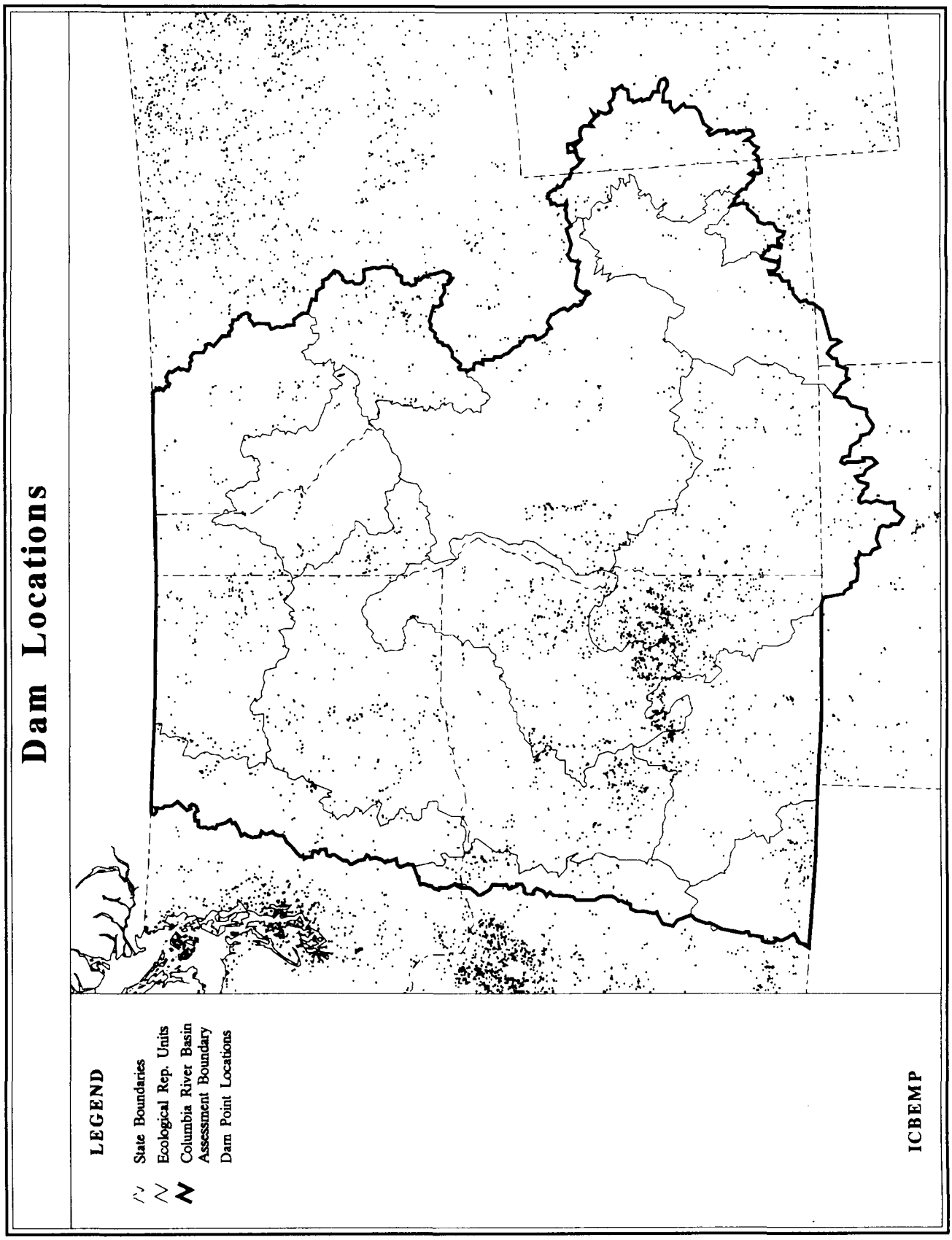
One of the most significant changes in the assessment area is associated with efforts to store, control, and direct water. Thousands of dams, ranging from tiny stock ponds in the driest regions to the largest hydroelectric facilities on the Columbia River (Grand Coulee Dam with a storage capacity of 6.4 billion cubic meters), are presently found in the area. Of these, there are at least 1,239 dams with storage capacity in excess of 62,000 cubic meters within the assessment area. Because federal inventory and inspection are required only for the larger dams (greater than two meters in height with storage capacity greater than 62,000 cubic meters, or greater than 7.6 meters in height with storage capacity greater than 18,500 cubic meters) and those with downstream hazard potential, the total number of dams is unknown. Many states record only those dams required for federal inventory. The actual number of dams in the assessment area could be several times greater than those reported because 74 percent of 1,600 dams identified in eastern Oregon have less than 62,000 cubic meter capacities (map 4.3; information compiled from state inventory of dams databases).

Construction of dams in the Columbia River basin has greatly reduced the accessible range of anadromous fishes and has interrupted migrating patterns of migratory forms of non-anadromous fishes. Spawning and rearing areas for anadromous fishes in the upper Columbia River basin were isolated after the Grand Coulee (1941) and Chief Joseph (1955) dams were completed. Since 1967, Hells Canyon Dam has blocked anadromous fish access to the Snake River and tributaries above the dam. A similar loss of most spawning and rearing habitats followed the construction of Cabinet Gorge Dam on the Clark Fork River above Lake Pend Oreille (Pratt and Huston 1993). Such problems are not limited to large dams. The National Research Council (1995) analyzed data from the state databases in Oregon, Washington, Idaho, and California and found that most small dams do not have fish passage facilities. The extent to which these dams impede migration or affect spawning and rearing habitats of fishes has not been documented.

Even with fish passage facilities, detrimental effects from dams occur as a result of direct mortality of juveniles in turbines and bypass systems. Indirect mortality is caused by delays in migration of adults and juveniles as a result of inability to find routes around dams, slack water, physiological stress, and increased susceptibility to predators. Efforts to mitigate the effects of dams by barging and trucking fish around dams also are not without problems. Collecting, handling, and transporting juvenile chinook salmon past McNary Dam on the Columbia River resulted in cumulative levels of stress, including such physiological parameters as decreases in white blood cell counts, osmoregulatory ability, and swimming performance (Maule and others 1988). Even for those fish that successfully circumvent dams, the combination of physiological stress, confusion, and discharge by tubes into restricted areas below dams renders them vulnerable to predation. From 1983 to 1986, mortality of juvenile salmonids due to predation by squawfish, walleye, and smallmouth bass in John Day Reservoir averaged 2.7 million, or approximately 14 percent of all juvenile salmonids that successfully passed through or around McNary Dam (Rieman and others 1991).

Trends in the number of dams constructed over time (fig. 4.4) and impounded water volumes (fig. 4.5) indicate that many streams and rivers have experienced a rapid and massive change in their hydrology. Even though the rate of increase in storage volume has leveled since the mid-1970s, the total number of dams continues to increase, suggesting that new construction is focused on smaller dams (National Research Council 1995).

The combined storage capacity of all dams for which there is information in state databases exceeds 79 billion cubic meters of water. Although many dams have multiple functions, irrigation (the most common use) accounts for 48 percent of dams and 54 percent of total storage capacity. Recreational use is secondary (19% of all dams). Hydropower accounts for only 6 percent of all dams, but 66 percent of total storage capacity is associated with power generation. Figure 4.6 shows the different proportions of dams uses in the assessment area.



Map 4.3—Locations of dams for which information is maintained by the States (2,103 dams within the Basin). Data were provided by state Dam Inventory databases (Montana and Nevada data was provided by the US Army Corps of Engineers National Inventory of Dams). Data quality and completeness varies by state.

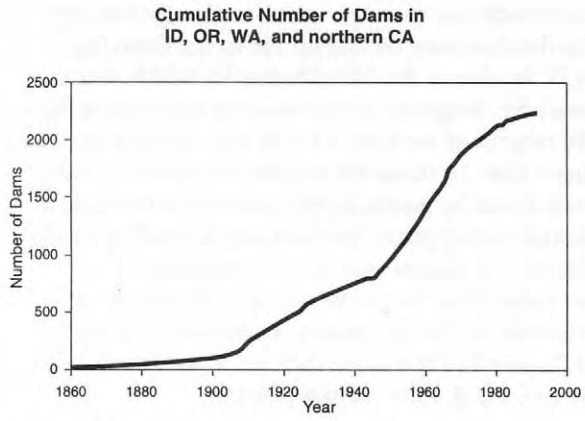


Figure 4.4— Cumulative number of federal and nonfederal dams in the Pacific Northwest (Idaho, Oregon, Washington, and northern California) from 1860 to 1990. (Data from individual State water-resources agencies; minimum size of dams varies by state).

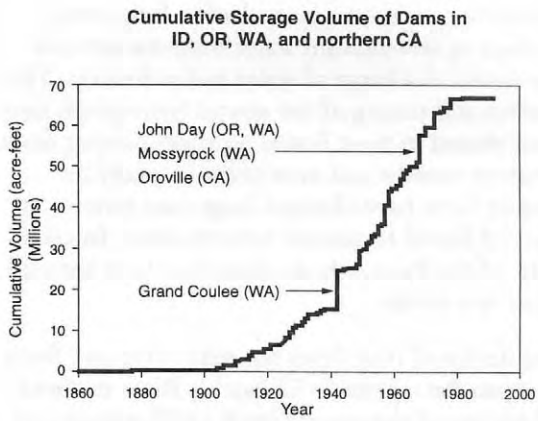


Figure 4.5— Cumulative volume of water impounded by federal and nonfederal dams in Pacific Northwest (Idaho, Oregon, Washington, and northern California) from 1860 to 1990. (Data from individual State water-resources agencies; minimum size of dams varies by state).

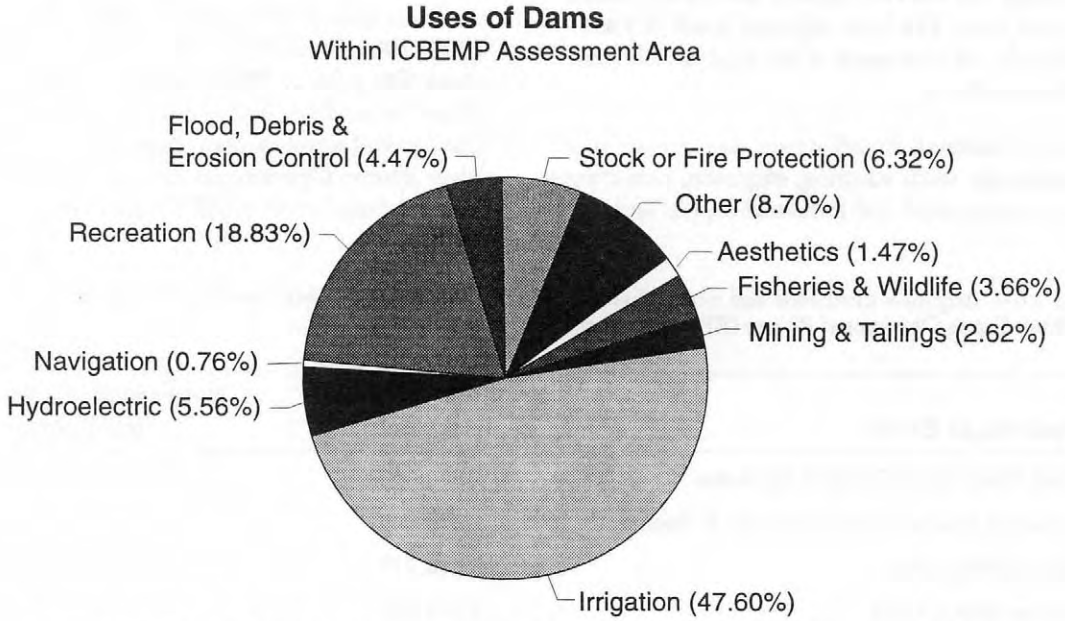


Figure 4.6— Uses of dams in the Basin. Data for dams are maintained and were compiled by State dam inventory databases (Montana and Nevada data was provided by the US Army Corps of Engineers National Inventory of Dams). Not all dam records (2,103) contained "type of use" information. Data quality and completeness varied by State.

Reservoir operation has resulted in long-term changes in downstream water temperatures and the annual discharge of water and sediments. The pattern and timing of the annual hydrograph have been altered in most basins on scales ranging from hours to months and even years. In many instances dams have changed large river systems to isolated fluvial fragments between lakes. In arid parts of the Basin, stream diversions have reduced flows to a trickle.

Regulation of river flows has reduced spring flood flows on the mainstem Columbia River to about 50 percent of the natural levels and has increased fall minimum flows by 10 to 50 percent (Sherwood and others 1990). Prior to regulation, major spring floods (for example, the flood of 1948) occurred when snow melted rapidly and simultaneously throughout the eastern portions of the Basin (Paulson 1949). Although recent spring floods (in 1972 and 1974) produced comparable discharge, the reservoir system prevented natural overland flow. The large regional flood of 1964-1965 only affected parts of the mid- and lower Columbia Basin.

Water withdrawals for off-stream uses include rural domestic use, stock watering, irrigation, public water supply, commercial and industrial supply, and thermoelectric cooling. Agricultural irrigation is by far the dominant off-stream use in the Basin (fig. 4.7). In nine of the 14 subbasins for which data are available, irrigation withdrawals represent more than 80 percent of the total. Overall they account for more than 10 times the combined volumes of water withdrawn by public supply, industry, and thermoelectric power plants (Jackson and Kimerling 1993). Projections for the year 2040 for withdrawal amounts from municipal and irrigation users are discussed in the Economics Assessment chapter (Chapter 6). Projections indicate significant increases in municipal water consumption.

The actual amount of water withdrawn in the Basin is not known because of the large number of irrigation projects and difficulties in assessing return-flow. Estimates for the Columbia River during the early 1980s ranged from seven to 10 percent of the mean annual discharge (Sherwood and others 1990). Simenstad and others (1992) calculated net water consumption in the Columbia River system to be greater than 144 m^3/s in 1900, 200 m^3/s in 1910, 310 m^3/s in 1928, and about 680 m^3/s in 1980. Table 4.6 gives irrigation diversions and net depletions for the 1990-1991 base level of development, from the Columbia River System Operational Review [Bonneville Power Administration (BPA) and others 1995].

Table 4.6— Irrigation diversions and net depletions by hydrologic region. Table reproduced from the *1995 Columbia River System Operational Review* (BPA and others 1995).[1]

Hydrologic Basin	Irrigation Diversion (Hectares)	Net Irrigation Depletion (Hectares)
Clark Fork - Pend Oreille & Spokane	520,849	311,052
Columbia Plateau, East Cascade, & Yakima	2,279,420	1,386,118
Upper Snake River	5,813,718	1,886,331
Central Snake River	3,053,696	1,061,739
Lower Snake River	343,594	215,903
Mid-Columbia	952,101	540,242
Total	12,963,378	5,401,385

[1]Source: USBR/BPA, Columbia River Basin, System Operational Review. Irrigation Depletion Estimate. September 10, 1993, prepared for Bonneville Power Administration by A.G. Crook Company.

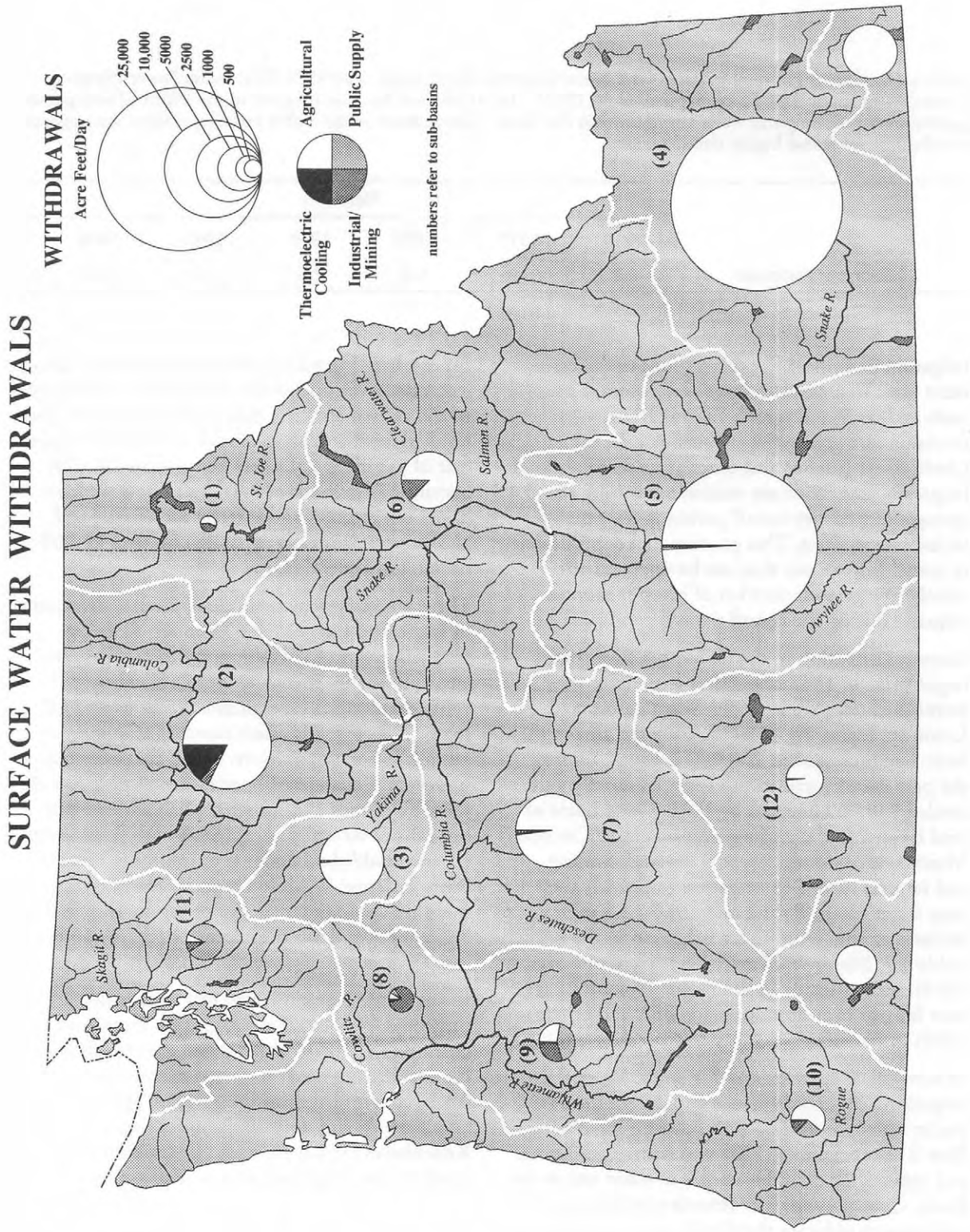


Figure 4.7— Spatial variation of four primary offstream uses of water in the region. From A. Jon Kimerling, Oregon State University, Corvallis, Oregon.

Table 4.7— Changes in total irrigated land in the Columbia River Basin since 1900 (Northwest Power Planning Council-Depletions Task Force, September 30,1993). The increase in hectares irrigated in the 1960s reflects greater groundwater pumping and water storage within the Basin. The decrease in the 1980s probably reflects the response to a drought cycle and higher electrical costs.

	Year					
	1900	1910	1928	1966	1980	1990
Millions of Hectares	0.2	0.9	1.5	2.6	3.0	2.8

Irrigation patterns differ throughout the assessment area. In areas with large water storage reservoirs such as Washington's Yakima River, diversions are greatest in the summer. In the Lemhi River (Idaho) and other areas that use flood irrigation, diversions are maximized during the spring and summer runoff period in the attempt to saturate aquifers. This practice makes it difficult to install fish screens that can be operated efficiently; the greatest number of juvenile salmon migrates during the runoff period.

Intensive irrigation in the Columbia River basin began prior to 1840 at mission settlement sites established near Walla Walla, Washington, and Lewiston, Idaho. By 1890 the irrigated area in the basin had increased to 200,000 hectares. During the next decade, irrigation expanded rapidly and totaled 930,000 hectares by 1910. Great tracts of land located in the arid region east of the Cascade Mountains could not support dryland farming, and farmers turned to irrigation to provide their crop water needs. By the mid 1960s, 2.6 million hectares of land were under irrigation in the Basin (table 4.7; Northwest Power Planning Council 1993). Most streams in the Pacific Northwest are now fully or over-appropriated (BPA and others 1995).

In many areas (particularly the Snake River Plain) irrigation influenced springs return significantly cooler water to streams. This return groundwater flow is beneficial to wildlife and aquatic resources, and typifies the complex nature of water use in the Basin. Cool groundwater returns could be used in arid areas to enhance the distribution of cold water fishes where instream habitat characteristics (pools, instream cover, and under-cut banks) are adequate. In the assessment area, hundreds of reservoirs have resulted from irrigation efforts that put the equivalent of 1.2 meters of water per year on 202,000 hectares. Thousands of hectares of new wetlands have been created, and interest on wildlife and aquatic recreation has expanded on over 81,000 hectares of Federal land.

There are numerous small gravity water diversions in Idaho and Oregon, and although there are fewer diversions in Washington, they often are larger. In Idaho, there are approximately 455 water diversions in the Salmon River basin.[1] Of these, 278 currently affect summer chinook salmon in the Snake River, which are protected under the Endangered Species Act. About 270 of these diversions currently have fish screens, but only about 60 are in compliance with fish passage criteria established under the Columbia River Basin Fish and Wildlife Program. Additionally, there are approximately 250 pump-intakes in the Salmon River Basin that do not have fish protection devices.

In the upper Salmon River, fish are adequately protected from larger diversions on migration corridors, but many small tributaries where spawning and rearing occur have unscreened diversions. These streams historically provided habitat to anadromous and non-anadromous fishes. Keifenheim (1992) indicated that salmon and steelhead no longer use many small streams in the

[1]Personal communication. 1995. Clayton Hawkes, Columbia Basin Fish and Wildlife Authority, Portland, Oregon.

upper Salmon River area because of irrigation withdrawals. Currently instream flow reductions in these streams may result in migration barriers, substantially diminished spawning and rearing habitat, or poor water quality. Although most of these small streams were not likely to have produced large numbers of fish historically, the total loss of spawning and rearing habitat may be significant.

In the current anadromous fish production areas of Oregon above Bonneville Dam, there are approximately 550 water diversions, most of which have fish screens (see footnote 1). However, most (80%) of these screens are several decades old and do not meet current criteria to adequately protect juvenile fish. There are about 55 pump-intakes on the Oregon side of the mainstem Columbia River, most of which were to be screened by the beginning of the 1996 irrigation season, and about 140 screened pump-intakes occur on Columbia River tributaries. Surveys are underway to determine the need for additional pump-intake screens in northeast Oregon.

On the mainstem Columbia and Snake rivers in Washington, there are about 200 pump diversions, most of which were to be screened by the beginning of the 1996 irrigation season. There are approximately 150 gravity diversion fish screens above Bonneville Dam; flows on several of these diversions exceed 28 cubic meters/second. There also are approximately 690 pump-intakes on tributaries in this portion of the Basin, but only about one-fourth have fish screens that currently are in compliance.

Most irrigation diversions on Forest Service and BLM-administered lands are operated by private individuals, but a few of the water rights are held by federal agencies. In subbasins under the jurisdiction of the Wallowa-Whitman National Forest, which include the Hells Canyon National Recreational Area, there are approximately 10 diversions that affect anadromous fish and seven that primarily affect salmonids migrating within fresh waters (Mattson 1993). Less than 10 diversions affecting anadromous fish have been identified on Forest Service lands in mid-Columbia tributaries in Washington.

Irrigation has contributed to the extirpation of salmon and steelhead from many small streams in the Salmon National Forest (Keifenheim 1992). Many streams in the Sawtooth National Recreation Area have inadequate instream flow as a result of irrigation.[2] Seventy-five irrigation diversions occur on Federal lands within the Salmon National Forest, 156 on Federal lands within the Sawtooth National Recreation Area, and 37 on nearby BLM-administered lands. The cumulative loss of spawning and rearing habitat in these tributaries is significant.

Influence of Farming and Grazing

The proportions of land in the Pacific Northwest dedicated to agriculture is relatively small (approximately 16%; see Landscape Dynamics, (Chapter 3). However, agricultural practices can have considerable effects on aquatic resources because the lands are often located on historic flood plains and valley bottoms. The effects of farming on aquatic systems include loss of native vegetation, bank instability, loss of floodplain function, removal of large woody debris sources, changes in sediment supply, changes in hydrology, increases in water temperature, changes in nutrient supply, chemical pollution, channel modification, and habitat simplification (Spence and others 1995). Nutrient and pesticide runoff pollutes many tributaries of the Columbia River, Upper Klamath Basin, and Great Basin. Agricultural herbicides and fertilizers are commonly found in eastern Oregon groundwater samples, and nitrogen is found in concentrations at or above state health advisory levels in five eastern Oregon counties (Vomocil and Hart 1993). The loss of native vegetation extends very near to the stream channel as farmers try to extend the amount of tillable land. Because the landscape alterations are permanent and soil is disturbed several

[2]Personal communication. 1995. M. Moulten, Sawtooth National Recreation Area, Stanley, Idaho.

times a year, negative effects of agricultural development may be more severe than other land uses.

The effects of livestock grazing on aquatic systems are related, in part, to the biophysical attributes of the site (Archer and Smeins 1991). Environmental factors that contribute to the character of an individual watershed include geology, climate, geomorphology, soils, vegetation, and water runoff patterns (Meehan and Platts 1978). Unstable stream conditions often exist as part of the natural conditions of streams; however, grazing can amplify these unstable conditions. In some cases, livestock use may initiate additional instability within a stream system.

Overgrazing by livestock can lead to a reduction of soil structure, soil compaction, and damage or loss of vegetative cover. All of these processes contribute to an increase in the rate and erosive force of surface runoff (Meehan and Platts 1978; Thurow 1991). Resulting increases in soil erosion lead to a loss of stored nutrients in the soil and a decrease in the level of vegetative productivity (Thurow 1991). The degree of soil erosion associated with livestock grazing is related to slope gradient and aspect of the site being grazed, the condition of the soil, type and density of vegetation, and the accessibility of the site to livestock (Meehan and Platts 1978).

Riparian areas maintain stream structure and function through processes such as water filtration, bank stabilization, water storage, groundwater recharge, nutrient retention, regulation of light and temperature, channel shape and pattern (morphology and micro-topography), and dispersal of plants and animals (Cummins and others 1984; Gregory and others 1991; Minshall 1967, 1994; Sullivan and others 1987). Because of the availability of water, forage, and thermal cover, riparian areas are often overgrazed by livestock. Livestock grazing can alter the species composition of stream-side vegetation (Archer and Smeins 1991; Platts 1978; Stebbins 1981; Thurow 1991; Vollmer and Kozel 1993) and diminish vegetative productivity (Archer and Smeins 1991; Horning 1994; Meehan and Platts 1978; Platts 1978; Thurow 1991; Vollmer and Kozel 1993). Grazing alters riparian vegetation by removing deep rooting plant species and decreasing canopy cover and riparian vegetation height (Platts 1991). Grazing has been implicated in the alteration of species composition of vegetative communities and associated fire regimes (Agee 1993; Leopold 1924).

Grazing is a major nonpoint source of channel sedimentation (Dunne and Leopold 1978; MacDonald and others 1991; Meehan 1991; Platts 1991). Grazed watersheds typically have higher stream sediment levels than ungrazed watersheds (Lusby 1970; Platts 1991; Rich and others 1992; Scully and Petrosky 1991). Increased sedimentation is the result of grazing effects on soils (compaction), vegetation (elimination), hydrology (channel incision, overland flow), and bank erosion (sloughing) (Kauffman and others 1983; MacDonald and others 1991; Parsons 1965; Platts 1981a, 1981b; Rhodes and others 1994). Sediment loads that exceed natural background levels can fill pools, silt spawning gravels, decrease channel stability, modify channel morphology, and reduce survival of emerging salmon fry (Burton and others 1993; Everest and others 1987; MacDonald and others 1991; Meehan 1991; Rhodes and others 1994). In addition, runoff contaminated by livestock wastes can cause an increase in potentially harmful bacteria (for example, *Pseudomonas aeruginosa* and *Aeromonas hydrophila*) (Taylor and others 1989; Hall and Amy 1990; Thurow 1991). Compared to ungrazed sites, aquatic insect communities in stream reaches associated with grazing activities often are composed of organisms more tolerant of increased silt levels, increased levels of total alkalinity and mean conductivity, and elevated water temperatures (Rinne 1988).

Influence of Timber Harvest Activities

Timber harvest activities (felling, yarding, skidding, landings, and silviculture) is one of the major land management activities within the assessment area. Timber harvest occurs in forests

in 9 of 13 ERUs within the assessment area (McNab and Avers 1994). These areas include: the yellow pine forests of the Upper Klamath; the lodgepole and ponderosa pine forests of the eastern Cascades ERUs; mixed conifer forests in the Northern Glaciated Mountains, Lower Clark Fork, Blue Mountains, Central Idaho Mountains, and Upper Clark Fork ERUs; and forests within the Snake Headwaters that contain at least 50 percent Douglas-fir.

Anderson (1988), citing a 1986 report of the Montana State Water Quality Bureau, suggested that the single greatest threat to watersheds and aquatic life is timber harvest and associated road building within forests. This threat is due, in part, to the increased level of harvesting timber from steeper, more environmentally sensitive terrain (Anderson 1988; Platts and Megahan 1975). Accelerated surface erosion and increased levels of sedimentation can decrease after initial disturbance but may remain above natural levels for many years (Platts and Megahan 1975; Spencer 1991; Swanson 1981).

The mechanical processes involved in timber harvest and associated road construction, in conjunction with natural conditions, influence the level of disruption or disturbance within watersheds. Negative effects tend to increase when activities occur on environmentally sensitive terrain with steep slopes composed of highly erodible soils that are subject to high climatic stresses (Anderson 1988; Platts and Megahan 1975). Vulnerable watersheds generally have high slope gradients, high levels of potential soil erodibility, soils having moderate to very poor drainage, or soil moisture contents in excess of field capacity for long periods of the year (van Kesteren 1986).

Soil and site disturbance that inevitably occur during timber harvest activities are often responsible for increased rates of erosion and sedimentation (Chamberlain and others 1991; FEMAT 1993; MacDonald and others 1991; Meehan 1991; Reid 1993; Rhodes and others 1994); modification and destruction of terrestrial and aquatic habitats (FEMAT 1993; van Kesteren 1986); changes in water quality and quantity (Bjornn and Reiser 1991; Brooks and others 1992; Chamberlain and others 1991; Rhodes and others 1994); and perturbation of nutrient cycles within aquatic ecosystems (Rowe and others 1992). Physical changes affect runoff events, bank stability, sediment supply, large woody debris retention, and energy relationships involving temperature (Li and Gregory 1995). All of these changes can eventually culminate in the loss of biodiversity within a watershed (FEMAT 1993; Rowe and others 1992).

Increased delivery of sediments, especially fine sediments, is usually associated with timber harvesting and road construction (Eaglin and Hubert 1993; Frissell and Liss 1986; Havis and others 1993; Platts and Megahan 1975). As the deposition of fine sediments in salmonid spawning habitat increases, mortality of embryos, alevins, and fry rises. Erosion potential is greatly increased by reduction in vegetation, compaction of soils, and disruption of natural surface and subsurface drainage patterns (Chamberlain and others 1991; Rhodes and others 1994). Generally, logged slopes contribute sediment to streams based on the amount of bare compacted soils that are exposed to rainfall and runoff. Slope steepness and proximity to channels determine the rate of sediment delivery.

Water quality (for example, water temperature, dissolved oxygen, and nutrients) can be altered by timber harvest activities (Chamberlain and others 1991). Stream temperature is affected by eliminating stream-side shading, disrupted subsurface flows, reduced stream flows, elevated sediments, and morphological shifts toward wider and shallower channels with fewer deep pools (Beschta and others 1987; Chamberlain and others 1991; Everest and others 1985; MacDonald and others 1991; Reid 1993; Rhodes and others 1994). Dissolved oxygen can be reduced by low stream flows, elevated temperatures, increased fine inorganic and organic materials that have infiltrated into stream gravels retarding intergravel flows (Bustard 1986; Chamberlain and others 1991).

Nutrient concentrations may increase following logging but generally return quickly to normal levels (Chamberlain and others 1991).

Because the supply of large woody debris to stream channels is typically a function of the size and number of trees in riparian areas, it can be profoundly altered by timber harvest (Bisson and others 1987; Sedell and others 1988; Robison and Beschta 1990). Shifts in the composition and size of trees within the riparian area affect the recruitment potential and longevity of large woody debris within the stream channel. Large woody debris influences channel morphology, especially in forming pools and instream cover, retention of nutrients, and storage and buffering of sediment. Any reduction in the amount of large woody debris within streams, or within the distance equal to one site-potential tree height from the stream, can reduce instream complexity (Rainville and others 1985; Robison and Beschta 1990). Large woody debris increases the quality of pools, provides hiding cover, slow water refuges, shade, and deep water areas (Rhodes and others 1994). Ralph and others (1994) found instream wood to be significantly smaller and pool depths significantly shallower in intensively logged watersheds. The size of woody debris in a logged watershed in Idaho was smaller than that found in a relatively undisturbed watershed (Overton and others 1993).

Because water is often delivered to lakes via stream channels, we can infer that effects to streams related to timber harvest and road construction may eventually be manifested within lakes. For example, stream erosion and the subsequent increase in sediment and nutrient transport due to land use activities in the Flathead Basin has contributed to lake eutrophication (Flathead Basin Forest Practices Water Quality and Fisheries Cooperative Program 1991). Birch and others (1980) reported that timber harvest activities caused increases in lake sedimentation rate and lake productivity in three of four lakes studied in western Washington, accelerating the rate of change in the trophic status of each lake. Timber harvest activities and road construction, including railroad construction, increased sedimentation rates above natural levels in three lakes of the Flathead Basin (Spencer 1991). Road construction appeared to be the greatest cause of disturbance resulting in enhanced fine sediment deposition in lakes downstream from the construction areas.

Influence of Roads

An assessment of federal roads within the Basin reveals that there are at least 204,333 kilometers of roads on Forest Service and BLM lands (data from Forest and BLM Inventoried Road databases; table 4.8). The majority (77%) are classified for basic maintenance only. Since many roads are not included in the transportation "system," substantial road kilometers are not included in the transportation databases. Therefore, based on discussions with Forest Engineers, we estimate that the magnitude of uninventoried road kilometers is as much as 30-50 percent of the inventoried road kilometers.

Roads contribute more sediment to streams than any other land management activity (Gibbons and Salo 1973; Meehan 1991), but most land management activities, such as mining, timber harvest, grazing, recreation, and water diversions are dependent on roads. The majority of sediment from timber harvest activities is related to roads and road construction (Chamberlain and others 1991; Dunne and Leopold 1978; Furniss and others 1991; Megahan and others 1978; MacDonald and Ritland 1989) and associated increased erosion rates (Beschta 1978; Gardner 1979; Meehan 1991; Reid 1993; Reid and Dunne 1984; Rhodes and others 1994; Swanson and Dyrness 1975; Swanston and Swanson 1976). Serious degradation of fish habitat can result from poorly planned, designed, located, constructed, or maintained roads (Furniss and others 1991; MacDonald and others 1991; Rhodes and others 1994). Roads can also affect water quality through applied road chemicals and toxic spills (Furniss and others 1991; Rhodes and others 1994). The likelihood of toxic spills has increased with the large number of roads paralleling streams.

Table 4.8— Kilometers of Forest Service and BLM roads within the ICBEMP assessment area (from Forest and BLM Inventoried Road databases).

Maintenance Level*	FS Region 1	FS Region 4	FS Region 6	BLM	Total
1	17,718	5,770	22,726	677	46,891
2	22,429	16,283	62,616	9,632	110,960
3	17,714	3,947	12,798	2,450	36,909
4	4,053	526	1,797	1,115	7,491
5	898	197	670	102	1,867
0			70	144	214
Total	**62,811**	**26,723**	**100,678**	**14,120**	**204,333**

* Maintenance Level

1 = Basic custodial care. Closed to 4x4 vehicles 40" wide or wider.

2 = Basic drainage only. High Clearance (4x4) vehicles.

3 = Must meet Highway Standards Act. Normal Clearance vehicles (public).

4 = Must meet Highway Standards Act. Moderate degree of comfort to users.

5 = Must meet Highway Standards Act. High degree of safety and comfort.

0 = Unclassified

NOTE: Many roads not considered as part of the transportation "system" are not included in the transportation databases. Based on discussions with Forest Engineers we estimate that the magnitude of uninventoried road kilometers is as much as 30-50% of the inventoried road kilometers.

Roads directly affect natural sediment and hydrologic regimes by altering streamflow, sediment loading, sediment transport and deposition, channel morphology, channel stability, substrate composition, stream temperatures, water quality, and riparian conditions within a watershed. For example, interruption of hill-slope drainage patterns alters the timing and magnitude of peak flows and changes base stream discharge (Furniss and others 1991; Harr and others 1975) and sub-surface flows (Furniss and others 1991; Megahan 1972). Road-related mass soil movements can continue for decades after the roads have been constructed (Furniss and others 1991). Such habitat alterations can adversely affect all life-stages of fishes, including migration, spawning, incubation, emergence, and rearing (Furniss and others 1991; Henjum and others 1994; MacDonald and others 1991; Rhodes and others 1994).

Poor road location, concentration of surface and sub-surface water by cross slope roads, inadequate road maintenance, undersized culverts, and sidecast materials can all lead to road-related mass movements (Lyons and Beschta 1983; Swanston 1971; Swanston and Swanson 1976; Wolf 1982). Sediment production from logging roads in the Idaho batholith was 770 times higher than in undisturbed areas; approximately 71 percent of the increased sediment production was due to mass erosion (Megahan and Kidd 1972) and 29 percent was due to surface erosion.

In granitic landtypes, sedimentation is directly proportional to the amount of road mileage (Jensen and Finn 1966). For instance, 91 percent (48,900 m^3) of the annual sediment production by land use activities (53,500 m^3) in the South Fork of the Salmon River has been attributed to roads

and skid trails (Arnold and Lundeen 1968). King (1993) determined that roads in the Idaho batholith increased surface erosion by 220 times the natural rates per unit area. Roaded and logged watersheds in the South Fork of the Salmon River drainage also have significantly higher channel bed substrate embeddedness ratings than undeveloped watersheds (Burns 1984).

Roads greatly increase the frequency of landslides, debris flow, and other mass movements (Dunne and Leopold 1978; Furniss and others 1991; Megahan and others 1992). Mass movement in the western Cascade Range in Oregon was 30 to 300 times greater in roaded than in unroaded watersheds (Sidle and others 1985). Megahan and others (1992) found that 88 percent of landslides within Idaho were associated with roads. Roads were considered to be primary factor in accelerated mass movement activity in the Zena Creek drainage (Idaho batholith) following 1964-65 winter storms (Gonsior and Gardner 1971). Out of 89 landslides examined in the South Fork of the Salmon River, 77 percent originated on road hillslopes (Jensen and Cole 1965). Cederholm and others (1981) found that increases (above natural levels) in the percentage of fine sediment in fish spawning habitat occurred when the area of roads exceeded 3.0 percent of the Clearwater River (Washington) basin area. Increased stream channel sedimentation in Oregon and Washington watersheds east of the Cascade Range has also been associated with road density (Anderson and others 1992; McIntosh and others 1995).

Road/stream crossings can also be a major source of sediment to streams resulting from channel fill around culverts and subsequent road crossing failures (Furniss and others 1991). Plugged culverts and fill slope failures are frequent and often lead to catastrophic increases in stream channel sediment, especially on old abandoned or unmaintained roads (Weaver and others 1987). Unnatural channel widths, slope, and stream bed form occur upstream and downstream of stream crossings (Heede 1980), and these alterations in channel morphology may persist for long periods of time. Channelized stream sections resulting from riprapping of roads adjacent to stream channels are directly affected by sediment from side casting, snow removal, and road grading; such activities can trigger fill slope erosion and failures. Because improper culverts can reduce or eliminate fish passage (Belford and Gould 1989), road crossings are a common migration barrier to fishes (Evans and Johnston 1980; Furniss and others 1991; Clancy and Reichmuth 1990).

Influence of Mining Activities

Mining in the assessment area is focused on metals (such as antimony, copper, gold, iron, lead, mercury, molybdenum, silver, and zinc), industrial minerals (such as asbestos, clay, diatomite, dolomite, feldspar, fluorine, gravel, limestone, perlite, phosphate, pumice, sand, silica, talc, and zeolite), gem stones and abrasives (such as garnet), and fuel minerals (such as uranium) (Bryant and others 1980; Jackson and Kimerling 1993). Aluminum is processed in the Basin, but most of the barite and alumina are imported from other countries (Bryant and others 1980); however, there are potential reserves of barite, vanadium, and cobalt in the Basin (Bryant and others 1980). Mining for these materials occurs either as surface mining or underground mining. Although any mining activity may have negative effects on aquatic ecosystems (according to the Pacific States Marine Fisheries Commission 1994, 14,400 kilometers of rivers and streams in the western United States have been polluted by mining), the largest impacts are generally associated with surface mining.

Mining activities can affect aquatic systems in a number of ways: through the addition of large quantities of sediments, the addition of solutions contaminated with metals or acids, the acceleration of erosion, increased bank and streambed instability, and changes in channel formation and stability. Sediments enter streams through erosion of mine tailings (Besser and Rabeni 1987), by direct discharge of mining wastes to aquatic sys-

tems, and through movement of groundwater (Davies-Colley and others 1992). Coarse particles that enter watersheds are likely to settle relatively rapidly (Davies-Colley and others 1992), and therefore, effects on aquatic systems are greatest near mining activities. Fine inorganic particles (like clays) settle slowly and may travel great distances from the point of their introduction and therefore may have a greater effect on water bodies such as lakes further from mining activities. Fine suspended material reduces the amount of light available for benthic algae and plants, and thereby, biomass and primary production are diminished. Fine suspended materials may also reduce the quantity and quality of epilithon (substrate surface biofilm) that serves as food for benthic invertebrates. If suspended sediments damage respiratory structures of benthic invertebrates, their abundance may decline (Davies-Colley and others 1992).

Acidification of surface waters, a process associated with surface mining, mobilizes toxic metals naturally embedded in soils and streambeds. As surface water (including rain) washes through waste piles left (often indefinitely) from mining operations, it is acidified via iron oxidation and then flows into streams where metals are released and converted to forms which are available to aquatic life (Nelson and others 1991). Acidification of surface waters can affect organisms directly, such as salmonids which experience reduced egg viability, fry survival, growth rate, and other ills, or indirectly from toxic metals or substances which can affect growth, reproduction, behavior, and migration of salmonids and production of benthic algae (Spence and others 1995). Ecosystem responses to contaminants are dependent on the chemical, physical, biological, and geological processes at each site (Pascoe and others 1993). Depending on concentration, trace metal toxicity may reduce growth and reproduction or cause death of aquatic organisms (Leland and Kuwabara 1985). Adult stages of mollusks and fish can generally withstand higher concentrations of metals than other organisms (Leland and Kuwabara 1985), but embryonic and larval stages are quite sensitive to heavy metals (Leland and Kuwabara 1985). The combination of some metals may inhibit primary production more than any single metal alone (Wong and others 1978); therefore, when several metals are present, water quality criteria for single metals are insufficient for protecting aquatic life (Borgmann 1980).

Surface mining practices of dredging and placer mining have altered aquatic habitats by destroying riparian vegetation and reworking channels. Gold mining in Idaho's Crooked River forced unnatural meanders in some streams and straightened others (Nelson and others 1991). Some streams, such as the upper reaches of the Grande Ronde River (McIntosh and others 1994a), have been severely altered and now flow underground through rubble dredged from the stream bottoms decades ago.

Common practice for extracting gold today involves heap leach mining, a form of open-pit mining used for low-grade ore deposits. Piles of crushed ore are sprayed with a solution of sodium-cyanide (NaCN) that bonds with gold particles and is deposited in pools from which the gold is recovered. Numerous, small heap leach fields are located in the Basin, primarily in floodplains of rivers or streams which are susceptible to large floods, creating the potential for flood inundation of the toxic leach pools and consequent contamination of river or stream habitats.

Influence of Non-native Fish Species Introductions

The introduction of non-native fishes and aquatic invertebrates has had an important influence on species assemblages and aquatic communities throughout the assessment area. Currently at least 35 species, subspecies, or stocks of fish have been introduced to the Basin or have moved to habitats within the Basin where they did not occur naturally.

Most introductions have been centrarchid (sunfishes and basses), ictalurid (catfishes), cyprinid (minnows), and salmonid fishes, but a few exotic fishes such as the Oriental weatherfish, *Misgurnus anguillicaudatus*, appear to have been introduced through the aquarium trade. At least eight native fish species or subspecies have been transported, some widely within the Basin, outside their historic ranges. This latter group includes Yellowstone, Lahontan, and westslope cutthroat trout; fall chinook salmon; coho salmon; white sturgeon; steelhead; and interior redband (rainbow) trout.

Most introductions have been made with the intent of creating or expanding fishing opportunities and were initiated in earnest as early as the late 1800s (Evermann 1893; Simpson and Wallace 1978). Stocking of mountain lakes with cultured stocks of cutthroat, brook, and rainbow trout has been extensive (Bahls 1992; Liss and others 1995; Rieman and Apperson 1989). Many lakes that were historically barren of fish were capable of sustaining them, but lack of spawning habitat or isolation from colonizing populations prevented natural invasion. A variety of species such as kokanee salmon, chinook salmon, lake trout, brown trout, Atlantic salmon, coho salmon, black bass and other centrarchids, and ictalurids were introduced in these systems to diversify angling opportunities, create trophy fisheries, and to provide forage for potential trophy species. Many ephemeral lakes in the Great Basin have been stocked with crappie, bass, bullheads, and other centrarchids and ictalurids. Cultured strains of rainbow trout have been widely used to sustain put-and-take fisheries in lakes and rivers where angler harvest or habitat degradation is too excessive to rely on natural reproduction. Additional introductions have occurred through illegal transplants, unintentional escape from commercial hatcheries or the aquarium trade, and natural dispersal mechanisms.

Such introductions have led to the elimination of some native populations, while further fragmentation and isolation of other populations have left them more vulnerable to future extirpation. Although introductions have provided increased fishing opportunities and socioeconomic benefits, they have also led to catastrophic failures in some fisheries and expanded costs to management of declining stocks (Bowles and others 1991; Gresswell 1991; Gresswell and Varley 1988; Wydoski and Bennett 1981).

In the assessment area, competition between native and non-native salmonids has resulted in displacement or further isolation of some populations of cutthroat trout (Griffith 1988; Fausch 1988; Rieman and Apperson 1989) and bull trout (Donald and Alger 1992; Rieman and McIntyre 1993). Non-native fishes also threaten native species through hybridization and subsequent loss of the native genome through introgression. Hybridization with introduced trout is one of the most important factors in the decline of Yellowstone and westslope cutthroat trout (Allendorf and Leary 1988; Gresswell 1995; Liknes and Graham 1988; Rieman and Apperson 1989; Varley and Gresswell 1988). Liknes and Graham (1988) reported that genetically unaltered westslope cutthroat trout populations remained in only 2.5 percent of the historic range in Montana, whereas Rieman and Apperson (1989) estimated that less than 4 percent of remaining populations in Idaho were numerically strong and not threatened by hybridization. Hybridization between brook trout and bull trout appears to be common where the species overlap (Adams 1994; Leary and others 1993; Rieman and McIntyre 1993), and elimination or displacement of bull trout can be a common outcome (Leary and others 1993).

Predation by non-native species may have an important influence on some native cyprinids and catostomids (Williams and others 1990), resident trout populations (Griffith 1988; Rieman and Apperson 1989), and on the survival of juvenile anadromous salmonids (Rieman and others 1991). Large numbers of introduced white crappie prey on larval Warner suckers, apparently inhibiting successful recruitment of this threatened species

(Williams and others 1990). Predation by introduced lake trout has been implicated in the dramatic decline of bull trout in the Flathead River Basin,[3] westslope cutthroat trout in Glacier National Park (Marnell 1988), and Yellowstone cutthroat trout in Jackson Lake (Snake River drainage).[4] Predation by introduced fishes is also commonly identified as a major factor in the isolation and decline of native amphibians (Bahls 1992; Bradford and others 1993; Liss and others 1995) and has important effects on local invertebrate faunas as well (Bahls 1992; Liss and others 1995).

Effects of some introductions are unknown and will remain uncertain pending further studies. The Oriental weatherfish, a small species of loach (Cobitidae) native to central and southern Europe, was first collected in the interior Columbia River basin from irrigation canals along the lower Boise River (Courtenay and others 1987). This exotic European fish has now been found in the mainstem Boise River and reported from the lower Powder River Basin in Oregon. The extent of spread and effects associated with this species are unknown.

Consequences of introducing non-native species are not limited to a few interacting species. Effects frequently cascade through entire ecosystems (Winter and Hughes 1995) and compromise structure and ecological function in ways that rarely can be anticipated (Li and Moyle 1981; Magnuson 1976; Moyle and others 1986). The introduction of *Mysis relicta* into Flathead Lake and other large lakes in northern Idaho and Montana, for example, greatly reduced populations of cladocerans (zooplankton), a preferred food of *Mysis* and adult kokanee (Bowles and others 1991). Declines in kokanee abundance and a collapse of recreational fisheries in those systems have followed (Bowles and others 1991; Spencer and others 1991). Ironically, *Mysis* were introduced to provide additional food for kokanee. The shrimp feed on zooplankton in the epilimnion during night and then migrate to deep water (greater than 30 m) during daylight; this vertical migration allows *Mysis* to escape intense predation by kokanee that feed actively only during the day (Bowles and others 1991).

There is growing recognition that biological integrity and not just species diversity (Angermeier 1994; Angermeier and Karr 1994) is an important characteristic of aquatic ecosystem health. The loss or restriction of native species and the dramatic expansion of non-native species leave few systems that are not compromised.

Influence of Hatcheries

Although the cultured stocks of salmonids have been frequently used to mitigate the effects of over-harvest and habitat degradation, there is substantial evidence that this practice has detrimental effects on native populations (Hindar and others 1991; Krueger and May 1991; Marnell 1986; Miller 1954). Offspring of hatchery fish spawning in the wild do not survive as well as the offspring of wild fish (Chilcote and others 1986; Leider and others 1990; Nickelson and others 1986), even if the hatchery stock was developed from wild adults (Reisenbichler and McIntyre 1977). There is unavoidable selection for traits favoring survival in the artificial conditions of egg trays, tanks, raceways, and holding ponds. Hatchery fish thus become genetically distinct from wild fish. If they stray and subsequently spawn with wild fish in natural areas, survival of the offspring is compromised (Chilcote and others 1986).

Despite lower survival, hatchery fish occupy habitat that would otherwise be used by wild fish (Miller 1954). In addition, artificially high densities of fish returning to hatcheries attract intensive fisheries that can over-harvest wild fish (Reisenbichler, in press; Wright 1981, 1993). Increasing harvest rates for Oregon coho salmon, for example, caused a sharp decline in the escape-

[3]Personal communication. 1995. T. Weaver, Montana Department of Fish, Wildlife and Parks, Kalispell, Montana.

[4]Personal communication. 1995. J. Erikson, Wyoming Game and Fish, Jackson, Wyoming.

ment of wild coho in coastal streams and Columbia River tributaries in the late 1960s (Nickelsen and others 1986). To offset the loss, surplus fish at hatcheries were used to supplement spawning in natural habitats, but the problem was exacerbated because the hatchery fish apparently experienced low survival and displaced naturally produced fry.

Many hatcheries located on tributaries of the Columbia River have water intakes upstream of structures designed to divert migrating fish into hatchery ponds. In order to reduce the risk of transmitting diseases to the hatchery via its water intake, adult fish are not passed upstream of the intake barrier at many sites. Protection of hatchery water supplies often prevents natural populations from accessing large tracts of historic spawning and nursery area.

Efforts to protect the investment in hatcheries cause water managers to produce flows for optimizing survival of hatchery fish. Manipulation of flows in the Columbia River to facilitate downstream migration of hatchery fish often precedes the time that naturally produced salmon smolts emigrate (Waples 1991). Where the distribution of hatchery fish overlaps native populations in time and space, the artificially enhanced concentration of fish can aggravate competitive interactions and attract predators (Ames and others, n.d.; Nelson and Soulé 1987; Reisenbichler 1984; Royal 1972; Steward and Bjornn 1990)

Influence of Commercial and Recreational Harvest

Commercial harvest in the Columbia River basin contributed to the decline of spring and summer chinook salmon beginning in the late 1800s (Fulton 1969) and to the decline of fall chinook since 1920 (Lichatowich and Mobrand 1995). Lichatowich and Mobrand (1995) divided the history of the chinook salmon fishery into four phases: initial development (1866-1888), sustained production (1889-1922), resource decline (1923-1958), and maintenance at a depressed level (post 1958). Historical ocean and river harvest rates exceeded 80 percent (Ricker 1959). Prior to 1880, chinook salmon were the primary target of the commercial fishery, but harvest probably shifted to steelhead and other species as chinook salmon runs declined (Mullan and others 1992). Landings of steelhead declined steadily during the 1930s and 1940s as exploitation rates exceeded 60 percent [Northwest Power Planning Council (NWPPC) 1986].

Salmon and steelhead destined for the Columbia River basin are often captured off the coasts of the United States and Canada and in the high seas driftnet fisheries. Ocean harvest may include net, seine, sport, and troll fisheries. The ocean troll fishery began in 1912 (NWPPC 1986). Chapman and others (1994b) reported that 3.5 percent of 3,472 steelhead that were tagged in the mid-Columbia River were recaptured in ocean fisheries off the coasts of Alaska and Canada. Driftnet fisheries for squid operated by Japan, Korea, and Taiwan have contributed to the decline in steelhead by harvesting (illegally or incidentally) from five to 31 percent of the adult steelhead returning to North America (Cooper and Johnson 1992).

Angler harvest directly increases mortality and thereby influences total population abundance, size- and age-structure, and reproductive potential (Ricker 1975). Fishing may lead to substantial declines in abundance, especially in populations that are extremely vulnerable to certain types of gear. Angler harvest of Yellowstone and westslope cutthroat trout, for example, has contributed to substantial declines in abundance of these subspecies (Binns 1977; Gresswell and Varley 1988; Rieman and Apperson 1989; Thurow and others 1988; Varley and Gresswell 1988). Schill and others (1986) estimated that individual Yellowstone cutthroat trout were caught and released an average of 9.7 times during a 108-day angling season, and many were captured two or three times in a single day. Although high catchability may be desirable in sport fisheries, it may lead to substantial declines in abundance and changes in population structure without restrictions (Gresswell 1990; Gresswell and others 1994;

Gresswell and Liss 1995). Chapman and others (1994b) suggested that harvest of steelhead parr could also have significant effects on recruitment of wild steelhead in the mid-Columbia River.

Although management agencies have attempted to reduce or eliminate fishing as a source of mortality, incidental harvest of many sensitive native fish stocks is a problem in the Basin. For example, commercial harvest of steelhead is prohibited, but individuals are incidentally killed in nets set for other species. Chapman and others (1994b) estimated that incidental mortality to A-run steelhead equaled a 4 to 5 percent exploitation rate in 1987-1988 and that this mortality would be additive to harvest rates occurring in tribal fisheries.

Anglers may also affect fish stocks by altering fish habitat through redd trampling and increased bank erosion. Roberts and White (1992) demonstrated that wading on trout redds can cause mortality to eggs and fry. For many years, stream reaches in some states have been closed to angling during salmon spawning season to reduce harassment of spawning fish.

For decades most fish management agencies have supported a maximum sustained yield philosophy that promoted the maximum harvest of surplus fish production (Gresswell 1980; Ricker 1975). Within the past decade, however, many agencies have adopted new philosophies of management that prioritize restoration and management of native fish stocks and their habitats [Idaho Department of Fish and Game (IDFG) 1991] and recognize the non-consumptive values of fish (Botsford 1994; Gresswell 1995). Where habitat for native species remains suitable, fish populations have increased substantially following implementation of restrictive harvest regulations (Gresswell 1990; Varley and Gresswell 1988). For example, the abundance and size structure of Yellowstone and westslope cutthroat trout populations increased dramatically following reductions in angler harvest (Gresswell and Varley 1988; Johnson and Bjornn 1978; Rieman and Apperson 1989; Thurow and Bjornn 1978; Thurow and others 1988). Bull trout numbers and redds also increased in response to decreased harvest (Ratliff 1992).[5] These examples suggest that where populations retain resilience, restoration efforts can be successful.

Influence of General Recreation Activities

Mountain lakes, especially those in national parks and scenic forested areas, may be the most susceptible aquatic systems to the negative effects of recreation. The inherent sensitivity of a lake to pollutants influences its susceptibility to water-quality degradation (Gilliom and others 1980). Sensitivity varies among lake types. Large, deep lakes with a large inflow may be least susceptible to water quality degradation because pollutants are diluted by large volumes of water and settle along with particulate matter (Gilliom and others 1980). Lakes that are small and shallow, or that have a low inflow, are more sensitive to pollutants (Gilliom and others 1980). Likelihood of pollutant-loading increases if soil, geologic, or hydrologic characteristics of a watershed favor the transport of pollutants to the lake (Gilliom and others 1980).

Where visitor use is high, trampling associated with foot traffic can affect vegetation along lakes and streams through direct mechanical action and indirectly through changes in soil (Liddle 1975). Resistance to trampling depends on plant life form; large and broad-leaved plants are most susceptible, and grasses generally are most resistant (Burden and Randerson 1972). Loss of vegetation from shorelines, wetlands, or steep slopes can cause erosion and pollution problems (Burden and Randerson 1972; Gilliom and others 1980).

Effects of recreational use on fish may be more severe during sensitive life history phases. Rafts on the Salmon River were observed to disturb spawning chinook salmon and lead to movement away from redds during low-flow conditions.[6]

[5]Also, personal communication. 1995. J. Stelfox, Alberta Fish and Wildlife Division, Alberta, Canada.

[6]McIntyre, J. 1995. Boise, ID: U.S. Department of Agriculture, Forest Service, Boise, Idaho. Personal communication of unpublished data.

Power boats can have numerous negative effects on lake environments. Resuspension of bed sediments can occur with passage of a single boat (Garrad and Hey 1987). Patterns of suspended sediment have been found to correlate with frequency of boat movements, boat speed, and hull shape. Concomitant high levels of turbidity and reduced light penetration may be a major factor in declining populations of submerged macrophytes. Loss of macrophytes can, in turn, make shorelines more susceptible to erosion from boat wash (Garrad and Hey 1987). Power boats are also associated with the spread of the exotic Eurasian watermilfoil (*Myriophyllum spicatum*). Because it reproduces from seeds, rhizomes, and fragmented stems, this non-native plant is easily transported between water bodies when plant matter becomes entangled on boat propellers or trailers (Reed 1977).

Outboard engines introduce hydrocarbon emissions to the aquatic environment, and emissions have a high phenol content that is quite toxic to aquatic organisms (Wachs and others 1992). Increased lead levels in reservoirs may be attributed to recreational boating and gasoline spills (Cairns and Palmer 1993). Boats, especially larger ones, may also introduce the chemical tributyltin into aquatic environments (Becker and others 1992). Tributyltin is a biocide used in anti-fouling paints, and it is one of the most toxic compounds ever introduced into water (Maguire and others 1986). It has adverse effects on freshwater mollusks at concentrations as low as 0.1 µg/L (Hall and Pinkney 1985).

Effects of off-road recreational vehicle use on aquatic resources are documented only for a few types of natural systems. On sand dunes and shorelines, off-road vehicles can result in significant reductions of vegetation (Anders and Leatherman 1987; Wisheu and Keddy 1991). In dune areas negative effects can occur at rates as low as one vehicle pass per week (Anders and Leatherman 1987). Disturbance associated with off-road vehicle use can alter plant community composition or create openings in cover vegetation on shorelines (Wisheu and Keddy 1991). Partial loss of vegetation from shorelines can result in increased erosion that continues until those shorelines are devoid of vegetation (Wisheu and Keddy 1991). Because seeds tend not to be deeply buried in shoreline wetlands, they may be particularly sensitive to intense disturbance (Wisheu and Keddy 1991), and recovery of disturbed shorelines may be very slow. Use of off-road vehicles may be particularly detrimental in fragile soils or in areas where habitat for sensitive species is limited (Williams 1995). Additionally, off-road vehicle use in streams can result in destruction of redds, eggs, and young.

General Influence of Habitat Fragmentation and Simplification

The physical environment and the natural and human-caused disturbances to that environment profoundly influence the structure, composition, and processes defining aquatic ecosystems. Aquatic habitat fragmentation (impassable obstructions, temperature increases, and water diversion) and simplification (channelization, removal of woody debris, channel bed sedimentation, removal of riparian vegetation, and water flow regulation) have resulted in a loss of diversity within and among native fish populations. The fragmentation of aquatic systems occurs through natural, dynamic processes as well. Over geologic time river basins become connected or isolated. Within the assessment area, river basins have been isolated by geologic processes that influence the distribution of species and subspecies. Natural populations of Yellowstone cutthroat trout, for example, are found almost exclusively within the upper Snake River Basin, and westslope cutthroat trout are restricted to basins outside that area.

Climatic variation and catastrophic events such as fire and flood may change the suitability of, or access to, streams and local habitats, and species distributions expand or contract, often becoming more or less continuous. The distribution of spawning and rearing habitat of bull trout, for example, appears to be strongly influenced by water temperature, and in turn by local climate

(Rieman and McIntyre 1995). Climatic variation will likely lead to changes in the amount of headwater habitat available to bull trout and also to the degree of isolation or connection among those habitats. This natural fragmentation varies with elevation and latitude of streams and tends to be more accentuated on the southern limits of the bull trout range. The fragmentation of habitat available for any species will depend both on these natural processes and on the specific habitat requirements for that species. Bull trout, for example, appear to have a narrower range of suitable habitat than westslope cutthroat trout (Rieman and McIntyre 1993), and even in relatively pristine environments bull trout exhibit a patchy distribution.

The natural patchiness and heterogeneity of habitats represent both problems and benefits for fishes and other aquatic organisms. Theories from population and conservation biology predict that smaller or more isolated populations have an increased risk of extirpation, and that smaller patches of habitat are likely to support less diverse communities (Boyce 1992; Gilpin and Soule 1986; MacArthur and Wilson 1967; Simberloff 1988). There is empirical evidence that these are important issues for many aquatic communities and species (Gilpin and Diamond 1981; Hanksi 1991; Sjogren 1991) including fishes (Rieman and McIntyre 1995; Schlosser 1991; Sheldon 1988). At the same time species and communities that are spatially diverse face lower risks of regional extirpation in highly variable environments (den Boer 1968; Simberloff 1988). Core or source populations that are resistant to disturbance may support populations in other marginal or ephemeral habitats through dispersal (Bowers 1992; Simberloff 1988). The quality and distribution of even a few such key areas may ultimately dominate the dynamics of whole systems (Bowers 1992).

The heterogeneity of habitats for aquatic organisms, and particularly fishes, has been clearly recognized at multiple scales from microhabitat units to entire basins (Sedell and others 1990; Schlosser 1991). This spatial complexity is seen as an important factor influencing species diversity and ecosystem stability (Bowers 1992; Gresswell and others 1994; Schlosser 1991) and results in discontinuous distribution of life stages, populations, metapopulations, or subspecies and species as well. Important habitat types, such as pools or off-channel rearing areas, are discontinuous within stream reaches and influence the distributions and relative abundances of a species or life stages at that scale (Schlosser 1991). At larger watershed scales the distribution among reaches and among streams may be influenced by such things as local climate, stream temperature, stream gradients, the distribution of suitable spawning sites and gravels, and stream size (Fausch and others 1994; McIntyre and Rieman 1995; Rieman and McIntyre 1995). Spawning and rearing of bull trout and westslope and Yellowstone cutthroat trout, for example, may be restricted to smaller, headwater streams both by temperature and stream size even though subadults and adults may move widely throughout entire river basins (Gresswell 1995; McIntyre and Rieman 1995; Rieman and McIntyre 1995). Because spawning salmonids show a strong fidelity to natal habitats (Quinn 1993), even species that disperse widely throughout large river basins are likely structured into a collection of demes or local populations with varying levels of reproductive isolation (Gresswell and others 1994).

Fringe environments that do not support a large abundance of fishes may actually contribute much of the genetic variability to the population and may contribute in a critical way to the persistence of much larger systems (Northcote 1992; Scudder 1989). The connection among spatially diverse and temporally dynamic habitats and populations is likely to be a critical factor to persistence and integrity of aquatic communities.

Fishes, particularly salmonids, exhibit remarkable diversity of life-history strategies (Lichatowich and Mobrand 1995; Rieman and McIntyre 1993; Thorpe 1994) and important dispersal mechanisms for dealing with naturally fragmented and

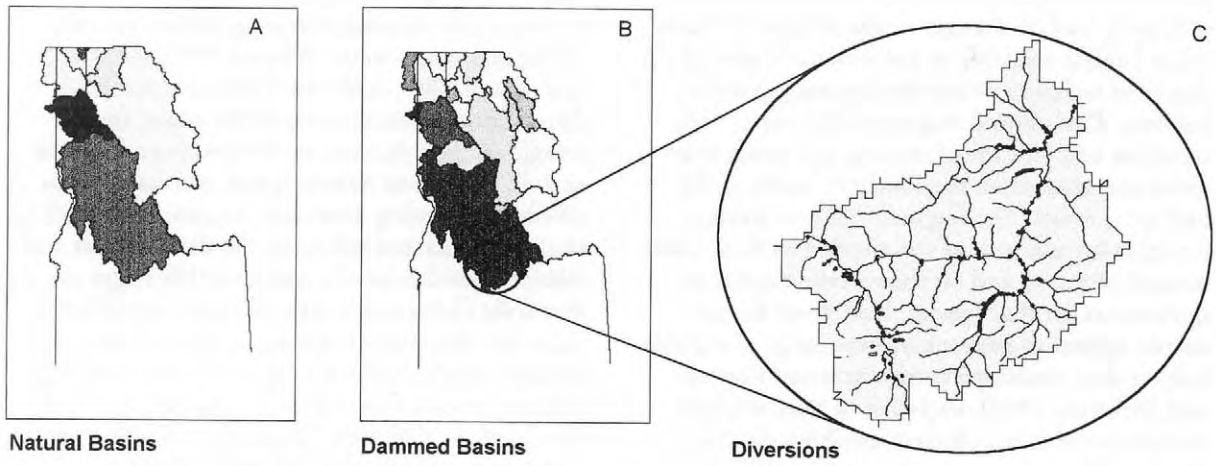


Figure 4.8— Fragmentation of watersheds in northern Idaho and western Montana. 'A' shows basins blocked to upstream movement of fishes by natural barriers. 'B' shows basins blocked to upstream movement by natural barriers and dams. 'C' shows irrigation diversions that may act as partial barriers to upstream and downstream movement within the Upper Salmon River subbasin.

variable environments (Milner and Bailey 1989; Quinn 1993; Thorpe 1994). Migratory life-history forms may be a particularly important mechanism of dispersal and risk aversion in highly variable environments for species like bull and Yellowstone cutthroat trout (Gresswell and others 1994; Rieman and McIntyre 1993).

The loss or degradation of habitats resulting from anthropogenic activities has not occurred in a random or uniformly dispersed fashion. Often lower elevation lands are more accessible, have wider floodplain valleys, and are more easily developed, hence habitat degradation has been greater in lower watersheds or in the lower reaches of larger systems. Dams and water diversions often result in fragmented streams and rivers (fig. 4.8). As a result, watersheds retaining the best remaining habitats are not well dispersed throughout the individual basins; they are often restricted to less productive headwater areas. Small streams in the headwater basins actually represent more extreme or sensitive environments with limited resilience to disturbance, increased synchrony among the populations, and relatively poor potential for dispersal throughout the entire Basin.

Because life-history stages and forms are also distributed in non-uniform or non-random patterns (Lichatowich and Mobrand 1995; Rieman and Apperson 1989; Schlosser 1991), some have been more likely to disappear than others. Within heavily managed areas, disturbance has often been dispersed among watersheds in an effort to minimize damage in any single area. If most watersheds are compromised, there are few local populations with the resilience to persist in the face of major storm or other catastrophic events that eventually test those populations. When high quality habitats are isolated in a system, the loss of migratory life histories, elimination of connecting corridors, or the poor quality of interspersed habitats that may act as "stepping stones" (Gilpin 1987) for dispersal may seriously limit the connectivity among populations. Eventually the ability of populations to refound or support those that are lost is diminished.

Although the importance of protecting hydrologic connectivity and hydraulic continuity of groundwater with surface water is accepted by state agencies throughout the Basin (for example, Washington State Water Resources Act 1971, RCW Chapter 90.54), it has received relatively little management attention. Nonetheless, maintaining connections between surface and subsurface flows can be critical. Many spring-dwelling species in the assessment area, such as the Borax Lake chub and Foskett speckled dace, are dependent upon the integrity of subsurface aquifers. The high degree of hydraulic continuity between groundwater and surface waters in the Methow Valley causes groundwater flows to reverse direction and well volumes to fall in response to flow changes in the river channel (Geo Engineers 1990; Golder Associates 1991). Extensive valley floodplains with alluvial deposits and groundwater flows like those in the Methow Valley have been shown to be extremely important to the ecology of the river. Floodplains having hydraulic connections with channels can support flowing groundwater (hyporheic) habitats that are used by riverine animals. The abundance of animals and nutrients underscore the extreme importance of these subsurface waters to the biological productivity of the channel and riparian ecosystems (Stanford and Ward 1988). These hyporheic systems also serve as a refugia for macroinvertebrate communities during time of drought and thermal stress.

The anticipated effects of human-induced disturbances on aquatic ecosystems throughout the assessment area include the reduced stability of regional aquatic populations and communities and an increased risk of both local and regional extirpations. Even with no further degradation of habitat, local extinctions driven by demographic and environmental variability could continue (Rieman and McIntyre 1993, 1995). The loss of life history expression influences the connectivity and stability among populations, but it also has restricted the full potential for fish production (Lichatowich and Mobrand 1995). The challenge for aquatic ecosystem management will be the maintenance and restoration of spatially diverse, high quality habitats that minimize the risks of extinction (Frissell and others 1993; Reeves and Sedell 1992) and that provide for the full expression of potential life histories (Healey 1994; Lichatowich and Mobrand 1995).

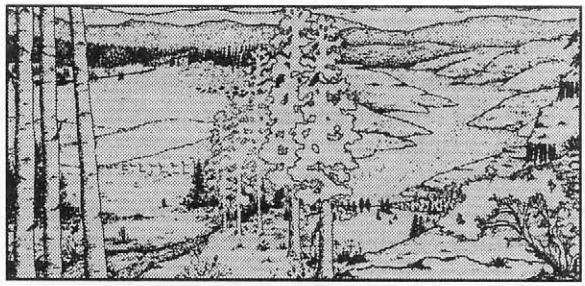
In the following sections, we attempt to assess the condition of key elements of the aquatic ecosystems throughout the assessment area. It is our intent to add to our understanding of the nature and magnitudes of change that have occurred, and to identify the key components that remain. That information can form the basis for the conservation and restoration of the structure and composition of aquatic ecosystems and for linking our understanding with similar problems in terrestrial ecosystems.

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ASSESSMENT OF LAND-USE EFFECTS ON INSTREAM HABITAT CONDITIONS



The effects of land use on aquatic systems are often manifest through substantive changes in hydrology and morphology of streams and rivers. Such changes can have serious ramifications for aquatic organisms. Streams and adjacent environments are generally the most biologically productive areas within watersheds, and are often the sites of greatest conflict in resource management (Thomas 1979). Previous researchers have noted detrimental effects of land management on aquatic habitats (Chamberlin and others 1991; Frissell 1993; Reid 1993), and subsequent effects on aquatic species (Hicks and others 1991; Reeves and others 1993; Williams and others 1989). This has spurred a closer look at the connections between land use, stream-channel characteristics, and habitat conditions.

For decades, various agencies have routinely inventoried streams within their jurisdictions in order to monitor key aspects of stream-channel conditions. These inventories potentially provide a rich source of information for assessing relations between land-management practices and aquatic/riparian habitat conditions—when combined with landscape information not generally measured as part of the stream inventories. Comprehensive comparisons of stream inventory data have been enhanced by the recent adoption of mutually accepted protocols for channel measurements and electronic data storage. Since the late 1980s, standardized stream inventories have been completed within the Basin by the Forest Service, BLM, Oregon Department of Fish and Wildlife, University of Washington Center for Streamside Studies, Oregon State University, and the Confederated Tribes of the Umatilla Reservation.

These extensive inventories allow comparison across broad geophysical settings and among different management regimes, and also permit historical comparisons in some areas. From 1934 to 1945, the Bureau of Commercial Fisheries [now National Marine Fisheries Service (NMFS)] surveyed more than 6,400 kilometers of streams in the Columbia River Basin to determine the condition of freshwater habitat for anadromous salmonids after completion of Grand Coulee and Bonneville Dams (Rich 1948). Many historically surveyed streams throughout the Columbia River Basin were recently resurveyed (McIntosh 1995). Of the 390 streams surveyed by the Bureau of Commercial Fisheries, 120 (30%) were resurveyed, encompassing 2,259 kilometers (35%) of the original survey (6,454 km). The resurveyed streams included a broad range of geologic conditions, land ownerships, and land-use histories (McIntosh 1992, 1995; McIntosh and others 1994b), and were distributed among the Coast Range, North Cascades, West Cascades, Northern Rockies, and the Blue Mountains. McIntosh (1995) examined historical changes in large-pool and deep-pool habitats using the information from the resurveyed streams.

In this section, we summarize the findings of McIntosh (1995), and report on our own analysis of stream inventory data from a wide range of streams. We used stream inventory data in combination with landscape information to address one primary question: can we detect and characterize land-use effects on aquatic habitats, given high natural variability in instream measurements and confounding geophysical, vegetative, and climatic factors? This question is of critical importance to evaluating the potential effects of management and to monitoring the effects of past activities.

Historical Changes in Large-pool and Deep-pool Habitats in the Columbia River Basin

To examine land-use induced changes in fish habitat over time, McIntosh (1995) classified individual streams according to the land management history of the watershed (managed or unmanaged) and looked at the frequency of large (> 20 m^2 area and > 0.8 m depth) and deep (> 20 m^2 area and > 1.6 m depth) pools. Managed watersheds were predominantly multiple-use roaded areas, where timber, grazing, agriculture, or mining production were permitted. Unmanaged watersheds were minimally affected by human disturbance, including wilderness and roadless areas. Although many unmanaged areas historically included grazing and mining, these activities have stopped or been reduced such that they typically affect less of the watershed and are of lower intensity in unmanaged basins relative to managed basins.

Quantifying change within individual streams is problematic (McIntosh 1995). Expressing results (pool increases or decreases) as percentages is confounded by variability in the magnitude of change. For example, streams with infrequent pools show large percentage changes with small actual changes. To overcome this problem, a 95 percent confidence interval around zero was estimated for individual streams in each treatment category (large and deep, managed and unmanaged); only changes (as percentage) that fell outside the respective confidence interval were judged to be significant (fig. 4.9).

One-hundred-four streams in managed areas within the Columbia River Basin were analyzed for changes in large pools. Decreases in the frequency of large pools were observed in 51 percent of the streams; thirty-one percent showed increases, and 18 percent remain unchanged (fig. 4.9b). For unmanaged streams (n = 25), 56 percent of the streams showed an increase in pool frequency, 40 percent experienced no change, and 4 percent decreased (fig. 4.9a).

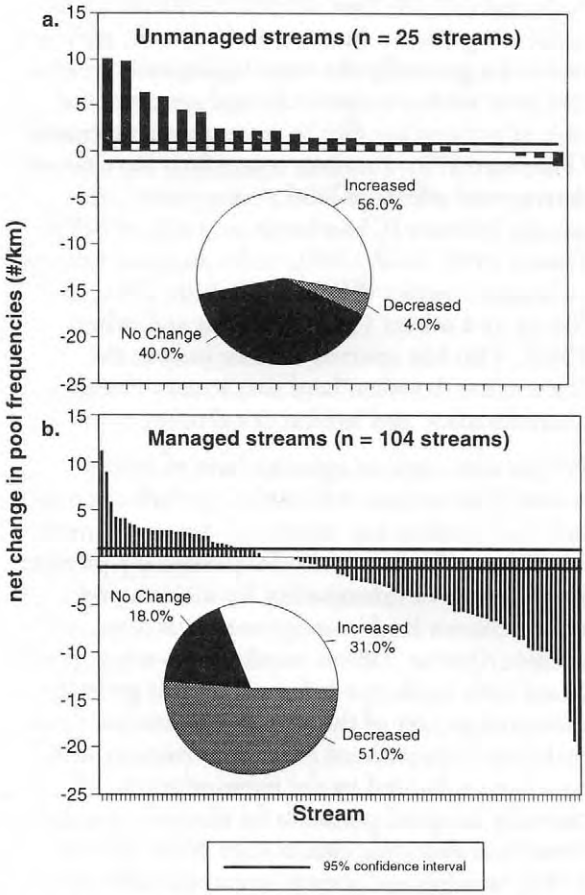


Figure 4.9— Changes in large pools (>20 m^2 and 0.8 m deep) from 1935-1945 to 1991-1994 on Columbia River Basin streams. Stream basins were either (A-upper) in unmanaged condition or (B-lower) under significant active management over the last 50+ years.

Over the last 50 to 60 years, there has been a dramatic loss of deep pools in managed streams throughout the Columbia River Basin. Of managed streams (n = 100), deep pools decreased in 53 percent; only 4 percent increased, and 43 percent measured no change (fig. 4.10b). Approximately 42 percent of the streams which showed no change did not have any deep pools in the historical surveys. Deep pools in about 33 percent of the unmanaged streams (n = 24) increased, 13 percent decreased, and 54 percent showed no change (fig. 4.10a). Of the streams which showed no change, 25 percent had no deep pools in the historic survey.

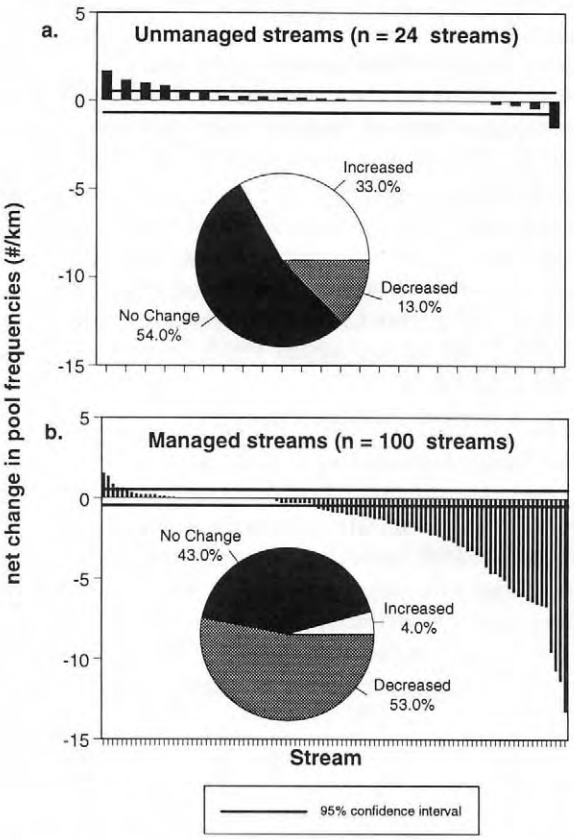


Figure 4.10— Changes in deep pools (>20m² and 1.6m deep) from 1935-1945 to 1991-1994 on Columbia River Basin streams. Stream basins were either (A-upper) in unmanaged condition or (B-lower) under significant active management over the last 50+ years.

Streams from three ERUs (Northern Cascades, Central Idaho Mountains, and Blue Mountains) were included in the analysis. Among these, the Northern Cascades had fewer large pools than either the Central Idaho Mountains or the Blue Mountains, but differences between the Central Idaho Mountains and the Blue Mountains were not significant. There were no statistically significant differences in the frequency of deep pools among ERUs.

A total of 285 kilometers in 20 managed watersheds in the Central Idaho Mountains was surveyed (table 4.9). There was a significant decrease ($p < 0.01$) in large pools from 9.4 pools/kilometer to 5.6 large pools/kilometer (40% decrease). Large pools in 11 unmanaged streams (171 km) in the Salmon River subbasin of the Central Idaho Mountains showed no significant change (from 5.3 to 6.6 large pools/km). There was a significant decrease ($p < 0.05$) in the frequency of deep pools (from 1.2 to 0.3 deep pools/km) in 182 kilometers of 18 managed streams in the Central Idaho Mountains. Deep pools in the 11 unmanaged streams increased significantly ($p < 0.05$) from 0.2 to 0.5 deep pools/kilometer. The data also suggest lower elevation and lower gradient streams had more numerous pools and a more diverse habitat structure.

In the Blue Mountains, 15 managed streams (299 km) and two unmanaged streams (18 km) were surveyed (table 4.9). Managed streams yielded a 58 percent decrease ($p < 0.01$) in large pools (from 5.9 to 2.5 large pools/km). The two unmanaged streams showed no significant change (from 0.0 to 1.3 large pools/km). Deep pools were scarce in the Blue Mountains, and the change from 0.7 to 0.1 deep pools/kilometer in managed streams was not significant. Deep pools in the Umatilla River declined from 4.2 deep pools/kilometer to 0.7 deep pools/kilometer. In the two unmanaged stream reaches on the Tucannon River and Panjab Creek, no deep pools were found in either survey.

In the Northern Cascades, 21 managed streams (479 km) and 10 unmanaged streams (187 km) were surveyed (table 4.9; McIntosh 1995). Large pools in managed streams doubled from 1.9 to 3.8 large pools/kilometer ($p < 0.01$). Unmanaged streams showed an even larger increase in large pools (1.7 to 4.6 pools/km; $p < 0.01$). Neither managed streams nor unmanaged steams showed significant change in deep pools during the 55-year interval between surveys (from 0.9 to 0.6 deep pools/km and from 0.6 to 0.7 deep pools/km for managed and unmanaged streams, respectively). These results may reflect intense grazing at the turn of the century and intact floodplain forests interacting with two large floods in 1948 and 1972 (McIntosh and others 1994b; Wissmar and others 1994a, 1994b).

In summary, in managed streams, roads and accompanying human activities including timber harvest, highway construction, grazing, agricultural practices, and loss of riparian vegetation have combined to create major decreases in pool habitat within the Columbia River Basin. The losses appear to have been the greatest in the lower-gradient, biologically productive areas of river basins most disturbed by humans. The unmanaged streams that were resurveyed generally were in steeper and more highly dissected landforms within the Columbia River Basin, and started with fewer large or deep pools. Most unmanaged streams either have retained pools or have improved pool habitat during the last 55 to 60 years.

Basin-wide Analysis of Stream Inventories

For our analysis, we compiled stream inventory data from electronic databases maintained by Regions 1, 4, and 6 of the Forest Service, the BLM, Oregon Department of Fish and Wildlife, and the Confederated Tribes of the Umatilla Indian Reservation. Stream inventory data were collected using protocols derived from the habitat-based inventory methodology of Hankin and Reeves (1988), which followed that of Bisson and others (1982). For details of the different stream inventory procedures, see Oregon Department of Fish and Wildlife (ODFW 1994), Overton and others (1994), and U.S. Department of Agriculture (USDA 1995).

The sampling unit in these inventories was the reach, identified as a geomorphically homogenous section of stream that is several-to-hundreds of channel widths long. A single reach was generally between major tributary junctions and within a setting of uniform valley slope and morphology (Grant and others 1990; Montgomery and Buffington 1993; USDA 1995). Certain measurements such as slope (channel and valley), valley width, and drainage area were made on an overall reach basis. Most measurements, however, were on individual channel units that were then summarized for the entire reach. Channel units, sometimes termed "habitat units" were portions of the reach that were one to several channel widths long and had distinct morphologic and hydraulic characteristics. Channel units were typically described as pools, riffles, cascades, steps, runs, and rapids (Bisson and others 1982; Grant and others 1990; Hawkins and others 1993; Leopold and others 1964; Montgomery and Buffington 1993).

The final database consisted of summaries of 6,352 reaches covering 17,121 kilometers on 1,982 streams (map 4.4). In total, the summarized reaches contain information from more than 600,000 individual channel units. The reach lengths ranged from 0.2 to 45.6 kilometers, and consisted of 1 to 1,367 channel units. The mean reach length was 2.7 kilometers, and the average number of channel units in each reach was 75.

Distribution and Sampling Issues

The vast majority of inventoried reaches are on federally administered lands, and most of those are on National Forest lands. Because stream inventories are generally motivated by concerns regarding fish habitat, the sampled reaches are

Table 4.9— Comparison of changes in large and deep pools in the Coast Range and western Cascades, by Ecological Reporting Unit. Bureau of Fisheries (BOF) surveys are compared to Pacific Northwest Research Station (PNW) and Intermountain Research Station (INT) surveys.

LARGE POOLS (>20 m² and 0.8 m deep)

MANAGED STREAMS

Stream (n)	km Surveyed	BOF (#/km)	PNW/INT (#/km)	Change (#/km)	Percent Change	Significance	
Coast Range (15)	182	8.2	7.2	-1.0	-12	p>0.05	No Change
Western Cascades (34)	636	10.8	6.9	-4	-37	p<0.01	Decrease
Northern Cascades (21)	479	1.9	3.8	1.9	95	p<0.01	Increase
Blue Mountains (15)	299	5.9	2.5	-3.4	-58	p<0.01	Decrease
Central Idaho Mt. (20)	285	9.4	5.6	-3.8	-40	p<0.01	Decrease
Total (104)	**1881**						

UNMANAGED STREAMS

Stream (n)	km Surveyed	BOF (#/km)	PNW/INT (#/km)	Change (#/km)	Percent Change	Significance	
Coast Range	NO DATA						
Western Cascades (1)	2	2.5	12.5	10	400	p<0.01	Increase
Northern Cascades (10)	187	1.7	4.6	2.9	171	p<0.01	Increase
Blue Mountains (2)	18	0	1.3	1.3		p>0.05	No Change
Central Idaho Mt. (11)	171	5.3	6.6	1.3	25	p>0.05	No Change
Total (25)	**378**						

DEEP POOLS (>20 m² and 1.6 m deep)

MANAGED STREAMS

Stream (n)	km Surveyed	BOF (#/km)	PNW/INT (#/km)	Change (#/km)	Percent Change	Significance	
Coast Range (15)	182	4.6	0.7	-3.9	-85	p<0.01	Decrease
Western Cascades (32)	626	4.4	1.6	-2.8	-63	p<0.01	Decrease
Northern Cascades (21)	479	0.9	0.6	-0.3	-33	p>0.05	No Change
Blue Mountains (14)	299	0.7	0.1	-0.6	-86	p>0.05	No Change
Central Idaho Mt. (18)	182	1.2	0.3	-0.9	-75	p<0.05	Decrease
Total (100)	**1788**						

UNMANAGED STREAMS

Stream (n)	km Surveyed	BOF (#/km)	PNW/INT (#/km)	Change (#/km)	Percent Change	Significance	
Coast Range				NO DATA			
Western Cascades				NO DATA			
Northern Cascades (10)	187	0.6	0.7	0.1	17	p>0.05	No Change
Blue Mountains (2)	18	0	0	0	0	p>0.05	No Change
Central Idaho Mt. (11)	171	0.2	0.5	0.3	150	p<0.05	Increase
Total (24)	**377**						

Map 4.4— Inventoried stream reaches, Ecological Reporting Units (ERUs), and subbasin delineations for the assessment area.

Table 4.10— Number of reaches and total length of inventoried stream in each Ecological Reporting Unit.

Ecological Reporting Unit	Number of Reaches Surveyed	Kilometers Surveyed
Northern Cascades	687	2,064
Southern Cascades	324	916
Upper Klamath	216	522
Northern Great Basin	170	454
Columbia Plateau	172	712
Blue Mountains	1,604	5,108
Northern Glaciated Mountains	757	1,667
Lower Clark Fork	946	3,567
Upper Clark Fork	40	24
Owyhee Uplands	11	16
Central Idaho Mountains	1,442	2,044
Total	**6,369**	**17,094**

not evenly or randomly distributed across the assessment area. The inventories are located primarily in mountainous, headwater, and fish-bearing streams. Eleven of the 13 ERUs contain inventoried reaches, but only seven ERUs contain more than 200 inventoried reaches (table 4.10).

The only basin-wide reference with which to evaluate stream length and stream type sampling coverage is the 1:100,000 hydrography (streams, rivers, lakes, reservoirs, and canals portrayed on 1:100,000 USGS topographic maps). The 1:100,000 hydrography under-represents the total stream network by omitting many small headwater streams, but still provides a relative framework for evaluating sampling coverage. The inventoried streams represent 3 percent of the total stream network in the assessment area as portrayed on the 1:100,000 hydrography. Stream order (Strahler 1957) was assigned to each stream on the 1:100,000 hydrography and to the spatially linked inventoried reaches, allowing us to assess stream order sampling. Strahler's (1957) stream order begins with first-order, representing headwater streams without distinguishable tributaries, and increases with the order of contributing tributaries. For example, two first-order streams join to form a second-order stream, two second-order streams form a third-order stream, and so forth. Basin-wide, the most complete sampling is for the third- and fourth-order streams, where about 10 percent of their lengths were surveyed. Sampling coverage is much less for higher-order streams, which are generally outside federally-administered lands, and for lower-order streams, which are more numerous and typically receive less attention by land management agencies, despite being important habitat for many aquatic species (fig. 4.11).

The stream inventory database contains reaches in 1,052 (14%) of the 7,469 subwatersheds within the Basin. In terms of the 1:100,000 hydrography, the percent by length coverage of the inventoried subwatersheds ranges from 0.06

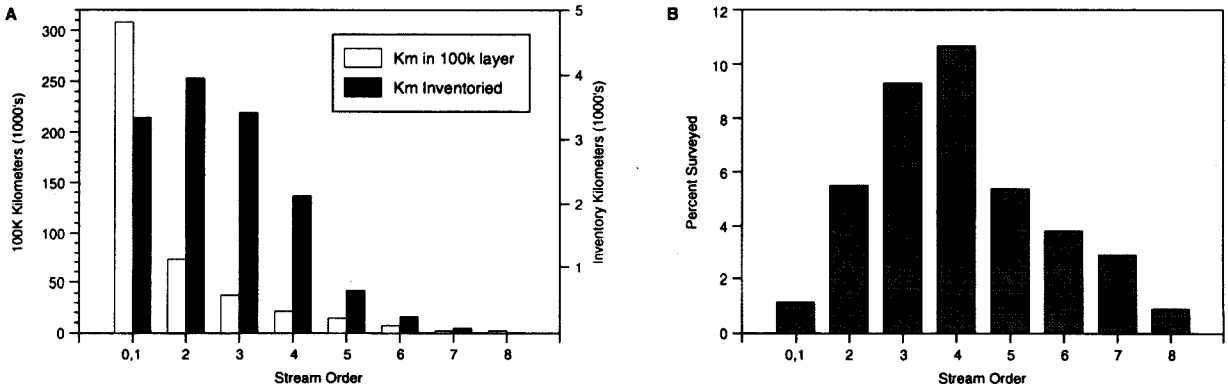


Figure 4.11— Portrayal of stream inventory sampling by stream order. A) The distribution by stream order of all streams and inventoried streams within the assessment area. The lengths are from the 1:100,000 hydrography. The total length of surveyed streams is 13,653 km based on the 1:100,000 hydrography—80 percent of the field-measured length (17,121 km). The difference is the result of channel sinuosity and path complexity not being adequately portrayed on the 1:100,000 hydrography. B) The percent of each stream-order class inventoried, based on lengths from the 1:100,000 hydrography.

percent to over 100 percent. Sampling coverage values greater than 100 percent reflect intensively surveyed streams where there were multiple surveys on individual reaches.

Besides the uneven sampling, there are other considerations and limitations that potentially cloud interpretation and use of the summaries and analyses. During the compilation process, we did not systematically assess the quality of the stream inventory data. Most of the data had undergone some level of prior quality control, but the quality of the data was uneven. Data that had obvious and numerous problems were discarded, but potential erroneous observations and recording errors remain. There also may be errors in spatial location because of the inherent difficulties in precisely locating the inventoried reaches on the 1:100,000 hydrography. Most map locations should be within 0.5 kilometers of the true reach locations. In addition, many stream inventories required channel geometry to be estimated in the field and then corrected by a calibration developed from both measured and estimated channel geometries. The calibration coefficients are generally between 0.9 and 1.1. For this analysis, we used corrected values for all data except for Forest Service Region 6 (eastern Oregon and Washington) stream inventories, where corrections were not applied. Finally, some reaches were surveyed more than once. Multiple inventories of the same reach were not isolated and removed from the database.

Analyzed Channel Features

The choice of stream channel characteristics that can be evaluated for the entire Basin is limited by the different inventory protocols used by the different agencies and administrative regions of the Forest Service. Only the channel geometry measurements (unit width, depth, and length) are directly comparable for most surveys. The choice of summarized variables was further influenced by our understanding of which channel attributes are sensitive to land-use practices and may be important indicators of habitat quality (Overton and others 1993, 1995; Ralph and others 1994; Reid 1993). Moreover, our experience suggests that the channel geometry measurements are least affected by observer error or bias. We identified 13 variables that are suitable for analysis (table 4.11), and chose four variables that have biological implications: *large pool frequency*, *pool frequency*, *R6 wood frequency*, and *surface fines*.

Table 4.11— Thirteen variables and the variable descriptions that were used to characterize stream channels for the entire Columbia River Basin.

Variable	Description
Large pool frequency	Number of pools with maximum depth > 0.8 m and surface area > 20 m^2 per mean reach riffle width.
Pool frequency	Number of pools per mean reach riffle width.
Fraction slow water	Fraction of total reach length consisting of pools and glides.
Mean pool depth/width	The mean of the ratio of maximum depth to width for all pool channel units in a reach. For reaches surveyed with procedures that measured mean depth, but did not measure or report maximum depth, an estimate of the maximum depth was derived by applying the regression equation *maximum pool depth* = 0.19 + 1.504(*mean pool depth*). This regression was developed from a regression relation between mean depth and maximum depth for pools where both measurements were reported (n=3517, r^2=0.59).
Variance pool depth/width	Variance of the ratio of max. depth to width for all pools in a reach. In statistical analysis, standard deviation (s.d. pool depth/width) is evaluated rather than variance.
Mean riffle depth/width	Mean of the depth to width ratio for all riffles in a reach. Mean depth was used to compute the ratio for each riffle except where only max. depth was reported, in which case the max. depth measurement was used without modification.
Variance riffle depth/width	Variance of the ratio of depth to width for all habitat units in a reach. Standard deviation of riffle depth/width was evaluated in the statistical analysis rather than variance.
R6 wood frequency	The number of pieces of wood per average riffle width, surveyed with the Forest Service Region 6 protocol. Tallied wood includes all pieces with diameters greater than 30 cm and lengths greater than 10 m. This includes the "small" and "large" size classifications of the Forest Service Region 6 protocol.
R1/4 wood frequency	The number of single pieces of wood per average riffle width, surveyed with the Forest Sevice Region 1/4 protocol. Tallied wood includes all pieces with diameters greater than 10 cm and lengths that exceed 3 m or two-thirds the channel width.
Wood aggregate frequency	The number of wood aggregates per average riffle width, surveyed with the Forest Service Region 1/4 protocol. Wood aggregates are defined as multiple pieces of wood (>10 cm in diameter, longer than 3 m or two-thirds the channel width) that are touching each other and within the active channel.
Embeddedness	"Yes" or "no" summarization of cobble substrate embeddedness for the reach, surveyed with the Forest Service Region 6 protocol. Substrate is classified as being embedded if 35 percent of the interstices are filled with fine sediment.
Bank stability	Fraction of bank in reach that is estimated as being stable, surveyed with Forest Service Region 1/4 protocol.
Surface fines	Reach mean of the areal fraction of each pool tail and low-gradient riffle covered with sediment < 6 mm in diameter, surveyed with Forest Service Region 1/4 protocol.

Large pool frequency and *pool frequency* measures were available across the Basin. *R6 wood frequency* was measured only within the states of Oregon and Washington. *Surface fines* was measured only within the states of Idaho and Montana.

Landscape Characterization

In order to elucidate relationships between aquatic and terrestrial ecosystems, we developed statistical models that linked landscape features and management activities to stream channel measures (this section) and fish populations (next section). Here, we present our approach to developing a set of variables that describe landscape characteristics and relevant management activities. Many of these variables were taken directly from the data developed by the landscape and spatial teams. The remainder generally were derived from information generated by the landscape team that we modified or summarized, as described below, for our specific purposes. The 30 variables chosen to describe landscape attributes were roughly divided into three broad categories: 1) geophysical variables; 2) terrestrial vegetation; and 3) land ownership and management. The only variable which did not fall within any single category was Ecological Reporting Unit (*eru*), the 13 geographic regions in the Basin that are delineated on the basis of physiographic and vegetative considerations. Variable names for landscape variables used in the analysis of channel morphology and fish populations are identified in table 4.12; *italics* used within the text correspond to variable names identified in the table. Several of these variables, for example, *anadac, dampass,* and *mtemp*, do not describe physical stream features and were only used in addressing the distribution and status of fishes. We include them here for completeness.

Much of the information that went into developing the landscape variables was developed from continuous 90-meter digital elevation data, one-kilometer vegetation data (from satellite imagery), 1:100,000 hydrography, state geologic maps, land ownership and activity maps, and extrapolated landscape characteristics derived from aerial photographic analysis of about 5 percent of the Basin. All variables that describe landscape characteristics were summarized for each of the 7,469 subwatersheds within the Basin. See the Landscape Dynamics and Information System Development chapters in this report for more information regarding derivation of many of these variables.

Physiographic and Geophysical Variables

The physiographic and geophysical variables developed by the Landscape Ecology Team included topographic descriptions such as slope, elevation, and stream length; climatic descriptions such as annual mean temperature, estimated annual precipitation, and average solar radiation; and variables reflecting erosion potential, for example, soil texture, base erosion (susceptibility of bare soil to erosion), and bank erosion. The number and range of variables generated by the Landscape Ecology Team are much broader than the subset that we selected. Our selection was based on an initial screening in which we chose a fairly large number of potential variables that have some plausible relationship with channel morphology or fish. We then calculated Spearman rank correlations (Zar 1984) for all possible pairs of variables and chose a subset which were highly correlated ($|r_s|>0.8$) with the rest of the set, but which were relatively independent of each other. Our objective was to develop a smaller subset of variables that would be easier to manage and interpret, yet still contain much of the information inherent in the larger set.

For the analysis of fish distribution, we developed three additional variables: *anadac*, which indicated whether an area was accessible to anadromous fish; *dampass*, which referred to the number of passable dams between an area and the Columbia River Estuary (used only within the accessible range of anadromous fish); and *hucorder*, which referred to the cumulative number of subwatersheds that contributed hydrologically to a given unit.

Table 4.12— Descriptions of predictor landscape variables used in the stream inventory analysis and the analysis of fish distribution. All values expressed as percents refer to the percent area of the subwatershed.

Variable Name	Description
eru	Ecological Reporting Unit
Physiographic and Geophysical Variables	
slope	area weighted average midslope
slope2	percent of area in slope class 2 (slopes >10%, <30%)
con1	percent weakly consolidated lithologies
con2	percent moderately consolidated lithologies
con3	percent strongly consolidated lithologies
sdt1	percent lithologies that produce coarse-textured weathering products
sdt2	percent lithologies that produce medium-textured weathering products
sdt3	percent lithologies that produce fine-textured weathering products
alsi1	percent felsic lithologies
alsi2	percent intermediate aluminosilicated lithologies
alsi3	percent mafic lithologies
alsi4[1]	percent carbonate lithologies
pprecip	mean annual precipiation (PRISM)
elev	mean elevation (ft)
mtemp[1]	mean annual temperature
solar[1]	mean annual solar radiation
streams[1]	length of 1:100,000 streams in 6th-code hydrologic unit (miles)
drnden	drainage density (mi/mi^2)
anadac[1]	access for anadromous fish (0=no, 1=yes)
dampass[1]	number of intervening dams
hucorder[1]	number of upstream 6th-code hydrologic units
hk	soil texture coefficient
baseero	base erosion index
ero	surface erosion hazard
bank	streambank erosion hazard
Vegetation Indices plus Ownership and Management Variables	
vmf	vegetation amelioration
vegclus	clustered vegetation types
roaddn	road density class
mgclus	management classification

[1]Variable only used in analysis of fish distribution (see section entitled Distribution and Status of Fishes).

Hucorder values ranged from zero for headwater areas that receive no inputs, to several thousand for units spanning the mainstem Columbia River. The majority of subwatersheds had low *hucorder* values; *hucorder* equalled zero for 55 percent of the watersheds, while only 13 percent had values of 20 or more.

We summarized the lithology classifications created by the Landscape Ecology Team according to three different physical qualities. The set of variables we constructed (table 4.13) reflects the degree of consolidation in the parent material (*con1-con3*), the aluminosilicate or carbonate composition (*alsi1-alsi4*), and the size or texture of the weathering products typically produced (*sdt1-sdt3*). Values for each variable were produced for each subwatershed by summing the appropriate lithology variables.

Vegetation Indices

Two measures of current vegetation were used. The first, *vmf*, was the vegetation factor generated by the Landscape Ecology Team to reflect the relative degree to which vegetation ameliorates erosion. It was based on coarse characteristics of the current vegetation. The second, *vegclus*, was derived from a statistical cluster analysis of the current vegetation information provided by the Landscape Ecology Team.

The principal reason for using a cluster analysis was to integrate the relatively complex vegetation information into a simpler metric that would be appropriate for the aquatic analysis. The vegetation data provided by the Landscape Ecology Team identified the amount of area within each subwatershed and classified according to potential vegetation type, structural stage, and cover type. The 13 potential vegetation types, 24 structural stages, and 41 cover types used to characterize vegetation resulted in 205 unique combinations within the Basin. Since many of these 205 vegetative combinations likely have similar effects on aquatic communities, we sought to combine them into a more manageable number of classes. We then used this simpler classification scheme within our cluster analysis.

First, each structural stage and cover class was rated as none, low, medium, or high, depending on the potential of the vegetation within it to grow tall enough to produce shade or large enough to produce woody debris. After rating each structural stage and cover type, a matrix was constructed that combined shade and woody debris potentials into a numerical score (table 4.14). The scores ranged from zero to 10, where zero represented no potential for wood or shade, and 10 represented maximum potential.

These numerical scores were examined for each combination of cover type, structural stage, and potential vegetation type. Structural stages and cover types within potential vegetation groups and with similar ratings were combined. This reduced the 205 combinations to 61 vegetative classes. The new vegetative classes were then ranked according to the amount of the Basin occupied by each class. Vegetative classes covering less than 100,000 hectares (0.12% of total area) were eliminated from further analysis, reducing the number of vegetative classes from 61 to 40 (appendix 4.B). A cluster analysis was performed using the 40 vegetative classes and a disjoint clustering procedure (SAS Institute Inc. 1989) that placed similar subwatersheds into one of 12 clusters. Descriptive names for the clusters were determined by looking at the relative frequency of each vegetation combination within each cluster. Eleven of the twelve clusters were dominated by a small number of combinations, making the descriptions of those clusters straightforward. The twelfth cluster contained a wide variety of combinations, with no dominant theme. This vegetation mix, and the spatial distribution of the twelfth cluster, suggested transitional areas. The 12 clusters were described as: 1) agriculture; 2) moist forest—understory reinitiation; 3) grasslands; 4) desert shrublands; 5) transitions; 6) young, dry forests; 7) aspen stands; 8) young, spruce-fir-lodgepole stands; 9) older, spruce-fir-lodgepole stands; 10) older, dry forest; 11) mountain shrublands; and 12) moist forest—stem exclusion (map 4.5).

Table 4.13— Criteria for classifying mapped lithologies. The 41 mapped lithologies were recast into three sets of variables that reflect sediment texture, aluminosilicate lithology, and degree of consolidation.

Description	Sediment Texture[1]	Aluminosilicate Content[2]	Degree of Consolidation[3]
alluvium	4	5	1
argillite and slate	1	1	2
calc-alkaline meta-volcanic	1	2	3
carbonate		4	4
calc-alkaline volcanoclastic	4	2	3
conglomerate	4	5	2
dune sand	3	1	1
glacial drift	4	5	1
felsic volcanic flow	2	1	2
mafic volcanic flow	2	3	2
granitic gneiss	1	1	3
mafic gneiss	1	3	3
granite	2	1	2
glacial ice	4	5	4
interlayered meta-sedimentary	3	2	2
alkalic intrusive	1	5	2
calc-alkaline intrusive	2	5	2
mafic intrusive	2	3	3
lake sediment and playa	3	5	1
landslide	4	5	1
loess	3	5	1
metamorphosed carbonate and shale	1	4	2
meta-conglomerate	4	5	2
meta-siltstone	1	1	2
mets-sandstone	1	1	3
mafic meta-volcanic	1	3	3
mixed carbonate and shale	1	4	2
mixed eugeosynclinal	1	2	3
mixed miogeosynclinal	1	1	3
felsic pyroclastic	4	1	3
mafic pyroclastic	4	3	3
quartzite	1	1	3
sandstone	4	1	2
mafic schist and greenstone	1	3	3
meta-sedimentary phyllite and schist	3	2	2
shale and mudstone	3	1	2
siltstone	3	1	2
tuff	3	2	2
ultramafic	1	3	3
unclassified	4	5	4
openwater	4	5	4

[1] 1 = Coarse; 2 = Medium; 3 = Fine; 4 = Unknown

[2] 1 = Felsic; 2 = Intermediate; 3 = Mafic; 4 = Carbonate; 5 = unknown

[3] 1 = Weak or None; 2 = Moderate; 3 = Strong; 4 = Other

Table 4.14— Potential production of woody debris and stream shading for vegetation cover classes and structural stages. On a scale of 0 to 10, 0 indicates no potential for wood or shading, 10 indicates maximum potential for wood and shading.

	Structural Stage						
Cover Class	**Other**	**Stand Initiation**	**Multi-Strata**	**Stem Exclusion**	**Understory Reinitiation**	**Old Multi- or Single Strata**	**Tall Shrub**
Other	0						
Englemann Spruce / Subalpine Fir		1	5	8	10	10	
Douglas-fir		1	5	7	9	8	
Lodgepole Pine		1	4	7	10	10	
Whitebark Pine / Alpine Larch		1	1	1	1	1	
Whitebark Pine		1	1	2	2	2	
Aspen		1	1	2	2		
Juniper Woodlands			1		2	2	
Mixed Conifer Woodlands			1	3	3	3	
Grand Fir / White Fir		1	5	7	10	8	
Ponderosa Pine (Interior)		1	5	7	9	8	
Ponderosa Pine (Pacific)			5		9	8	
Sierra Nevada Mixed			5	7	9	8	
Western Juniper / Big Sagebrush			1		2		
Mountain Hemlock		1	5	6	10	10	
Pacific Silver / Mountain Hemlock		1	5	6	10	10	
Red Fir		1	5	7	9	8	
Western Larch		1	4	7	9	8	
Western Redcedar / Western Hemlock		1	5	6	10	10	
Western White Pine		1	5	7	9	8	
Seral Shrub - Regeneration							7
Herbaceous Wetland / Shrub							7
Cottonwood/ Willow			5	9	10	10	
Limber Pine				2	2	2	

Map 4.5— Spatial distribution of 12 vegetation types identified using cluster anlaysis.

Continue

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Mis-scans identified by the software have been corrected;
however, some errors may remain.

Human Factors—Ownership, Management Class, and Roads

We characterized ownership and management using two categorical variables, road density (*roaddn*) and management cluster (*mgclus*). Road density is a categorical classification of each subwatershed based on the estimated length of roads per unit area. Six levels of road density were defined: 0 to 0.02, 0.02 to 0.1, 0.1 to 0.7, 0.7 to 1.7, 1.7 to 4.7, and greater than 4.7 miles of road per square mile. Road density estimates were based on statistical relationships derived from a subsample of roughly 3 percent of the subwatersheds in the Basin; they do not reflect actual measurements and are subject to random errors that can be substantial. Such errors tended to be dampened at larger scales, thus, the estimates should be adequate for interpretation of broad-scale patterns. Further details on the derivation of road density estimates and their limitations are provided in the Information System Development and Documentation chapter of this report. Despite its shortcomings, we used road density because of the numerous direct effects that roads and activities dependent on roads have been shown to have on sediment production and hydrologic regimes (for example, Furniss and others 1991; Reid 1993).

Management cluster (*mgclus*) is a categorical classification of each subwatershed that reflects past and present human use. *Mgclus* was derived from a suite of variables generated by the Landscape Ecology Team that describes various aspects of human activity and ownership. Specifically, these variables describe: 1) life form (categorization of the dominant land use as agriculture, forest, or range); 2) management area classification (unknown, managed grasslands, or forests subject to low, moderate, or high human use); 3) ownership (private, state, tribal, Forest Service, BLM, or National Park Service); 4) percentage grazed; and 5) percentage designated as wilderness. A cluster analysis procedure (SAS Institute Inc. 1989) was used to identify 10 distinctive groupings of subwatersheds with similar properties. A descriptive name and two-letter identifier was attached to each cluster based on the variable means (table 4.15). The distribution of these clusters illustrates the complex pattern of ownership and management found within the Basin (map 4.6).

Results

The simplest way to highlight possible management effects on streams was to array the mean values of stream-channel responses across ownership/management classes and road-density classes (fig. 4.12-4.14). We also constructed similar plots for each ERU (not shown). Despite the relatively coarse nature of this approach, these plots revealed a number of consistent trends. First, *pool frequency* and *large pool frequency* were highest on forested lands predominantly owned by the Forest Service, that are managed as wilderness or moderate use areas (fig. 4.12). The lowest values for pools were found on privately-owned and BLM rangelands. Pools also showed a clear decline with increasing road density.

The effect of road density on wood is less clear. Within the states of Oregon and Washington, where *R6 wood frequency* was measured, *R6 wood frequency* was higher in Forest Service lands managed as wilderness or as moderate use (fig. 4.13). In the Central Idaho Mountains, where *surface fines* was measured, privately owned forests and agricultural lands showed the highest level of surface fines; however, data are limited for these areas (fig. 4.14). The next highest levels were in high-use Forest Service lands. The effect of roads on surface fines is unclear, though the highest mean values were found in the highest road density class.

Examination of spatial patterns in the data identified differences among ERUs. These differences were not specifically related to management effects.

Map 4.6— Spatial distribution of ownership and management classes identified using cluster analysis.

Table 4.15— Management and ownership classification of subwatersheds identified using cluster analysis. Cluster means are for variables used in the analysis; all values refer to percent of area within unit.

Cluster Means															
	Land Type			Management Area Classification					Ownership						
Cluster*	Agric	Forest	Range	Unknown	1+2	3+4	5	6	Private	USFS	BLM	NPS	Tribal	Grazed	Wilderness
TL	20.7	62.9	15.6	98.9	0.2	0.2	0.5	0.2	4.5	0.9	0.3	0.0	93.3	39.8	0.3
PA	77.4	10.0	11.6	95.8	0.4	0.6	1.2	1.9	90.4	1.7	2.4	0.0	1.0	8.2	0.0
PR	14.5	9.0	75.9	76.4	2.4	1.8	5.1	13.3	60.7	5.3	19.4	0.0	1.4	55.8	0.2
FG	8.3	65.1	26.3	6.5	14.5	60.9	8.4	9.6	5.7	88.8	3.4	0.0	0.3	74.6	2.5
NP	1.1	83.4	13.8	95.1	2.6	1.1	1.2	0.0	1.5	5.1	0.0	92.1	0.0	0.9	10.1
PF	14.1	78.9	6.0	77.3	2.2	5.0	14.1	1.2	66.3	20.0	2.7	0.2	0.8	22.3	0.7
FM	2.3	88.1	9.2	9.7	9.2	21.9	58.2	0.2	8.8	88.8	0.4	0.5	0.1	3.7	3.2
BR	4.6	2.6	92.5	15.7	15.2	1.9	3.9	62.5	10.7	4.9	80.0	0.0	0.1	94.1	0.1
FW	2.4	84.2	13.1	1.5	90.9	4.6	2.7	0.1	1.0	98.2	0.1	0.5	0.0	21.6	82.1
FH	6.8	82.9	10.1	13.7	4.2	8.1	72.0	1.9	12.5	82.7	2.6	0.1	0.2	87.1	1.1

*TL = Tribal lands; PA = Private agriculture; PR = Private and BLM rangeland; FG = FS forest and rangeland, moderate impact, grazed; NP = NPS forest land; PF = Private land and FS forest land; FM = FS forest, high-moderate impact, no grazing; BR = BLM rangelands; FW = FS-managed wilderness; FH = Forest Service forest, high impact, grazed.

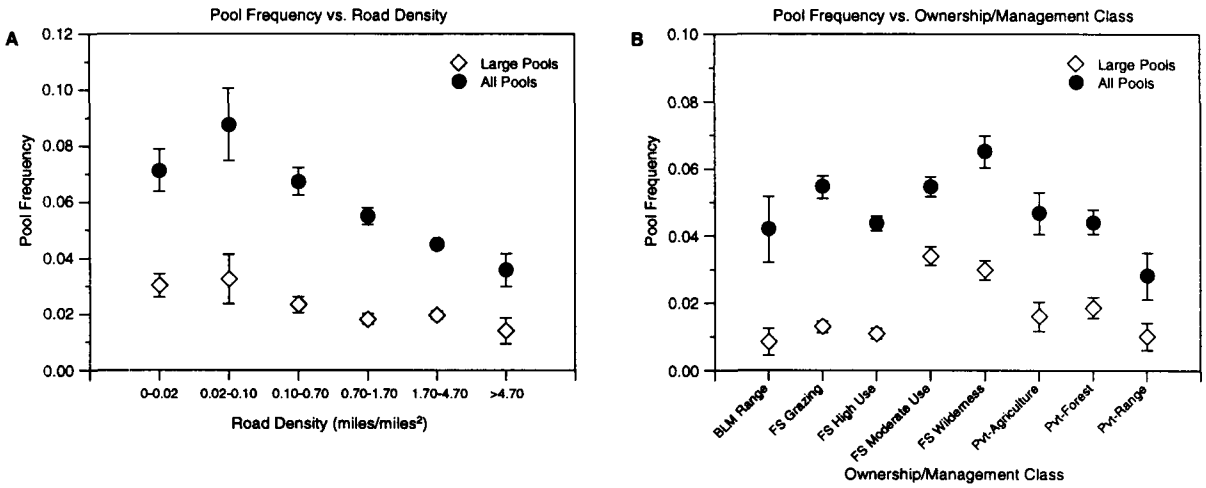


Figure 4.12— Box plots of *pool frequency* and *large pool frequency* for streams with gradients less than 0.02 arrayed by (A) road density classes and (B)ownership/management.

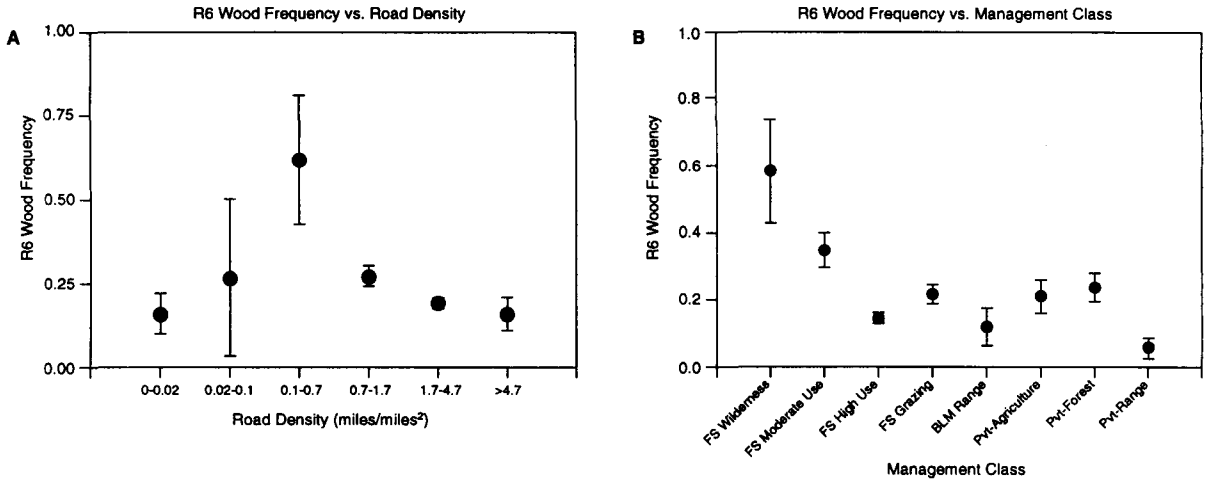


Figure 4.13— Box plots of *R6 wood frequency* for streams with gradients less than 0.02 arrayed by (A) road density classes and (B) ownership/management.

Large pool frequency: The frequency of pools with surface areas greater than 20 square meters and depth greater than 0.8 meters is generally greater in mountainous areas, particularly the Northern Glaciated Mountains, Northern Cascades, and Lower Clark Fork. Compared to other mountainous areas, streams in the Upper Klamath and Blue Mountains ERUs have noticeably fewer large pools.

Pool frequency: The frequency of pools of all sizes is also generally greater in mountainous areas, particularly in the Northern Glaciated Mountains, Upper Clark Fork, and Central Idaho Mountains. Again, *pool frequency* in the Upper Klamath and Blue Mountains ERUs is lower and has values similar to those reported for the Northern Great Basin, Columbia Plateau, and Owyhee Uplands.

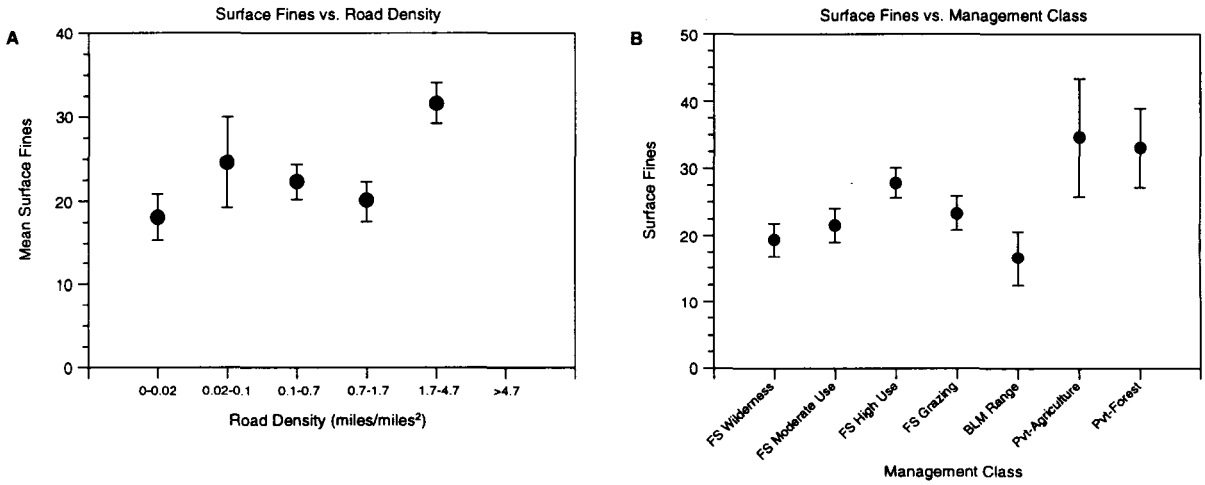


Figure 4.14— Box plots of *surface fines* for streams with gradients less than 0.02 arrayed by (A) road density classes and (B) ownership/management.

R6 wood frequency: Wood is most abundant in Cascade Range streams, where wood frequency is greatest for steep and low-order streams. Median wood frequency values for high-order and low-slope streams in the Northern Cascades and Southern Cascades range from 0.3 to 0.4 pieces per channel width. The lowest values for wood frequency are in the Northern Great Basin, Columbia Plateau, and Blue Mountains, where for high-order and low-slope streams, median values for wood frequency are less than 0.1 pieces per channel width.

R1/4 wood frequency: Streams located in the Central Idaho Mountains apparently have less wood (median values of about 0.2 pieces per channel width) than streams in the Northern Glaciated region, where median values range from 0.3 to 0.7 pieces per channel width. In the Central Idaho Mountains, wood frequency decreases with stream order, a result that contrasts with streams in the Northern and Southern Cascades.

Surface fines: The areal extent of riffles and pool tails covered with fine sediment (clasts with diameters less than 6 mm) was extensively measured only in the Central Idaho Mountains and Lower Clark Fork. For both ERUs, surface-fine coverage was generally greater in the lower slope classes. The Central Idaho Mountains has higher mean values, and median values range from 14 to 35 percent, compared to 5 to 15 percent for the Lower Clark Fork.

Quantitative Analysis

Summarizing the data as we have in figures 4.12-4.14 grossly understates the complexity of interactions between land and streams. We know from examining the data that apparent differences can be found in almost any response variable under a variety of stratification schemes, all of them reasonable. For example, we can show differences in pool frequency due to stream order and slope class. We can also show that responses vary greatly from one ERU to another, or that vegetation and lithology correlate with differences in stream features. None of these results are particularly surprising; each is consistent with a large literature on geomorphological processes. The thorny analytical problem is not distinguishing coarse landscape differences; rather, it is separating the actual response due to management from the variation introduced by a host of confounding factors.

There are several possible approaches for trying to separate management effects. One approach is to stratify the assessment area into more homogeneous units based on geophysical settings. Such a stratification scheme could start with ERUs, and sequentially subdivide smaller and smaller areas based on geomorphic similarities. The problem with this approach is that as the assessment area is divided into progressively smaller units, the amount of data available for use within a given stratum decreases. Since we can make inferences only for those areas where we have data, the areal extent of our inferences would be quite limited. It is not clear how one would reasonably extrapolate to unsampled areas. An alternative approach is to build a statistical model that uses a large set of covariates, both continuous and categorical, to account for the confounding factors. This approach has the usual problems of model specification and selection, and of dealing with potentially large numbers of interactions.

We chose an approach that includes elements of both the stratification scheme and the statistical modeling approach. We used ERU as a broad-scale spatial stratification, and also used stream order and slope class as more physiographic stratifiers to classify all reaches within the Basin. We then constructed a general linear model that allowed us to account for variations induced by geoclimatic and biophysical factors, and test for management effects within a given stratum, depending on the response variable. *Large pool frequency* and *pool frequency* were stratified by slope class and order class, respectively, in two separate, Basin-wide analyses. *Wood frequency* and *surface fines* were examined Basin-wide, and then again by ERU. In each analysis, landscape variables that described geophysical setting and vegetation were entered into the linear model first. Management cluster, then road-density class were entered last, and the procedure was repeated with the order of entry for management cluster and road density reversed. By examining the sequential reduction in unexplained variation, we were able to statistically test the effects of management cluster and road density after adjusting for other factors.

The partial stratification by ERU, stream order, or slope class was necessary because streams from different strata respond differently to environmental conditions and disturbances. Grant and others (1990), Montgomery and Buffington (1993), and Rosgen (1994) proposed various stream classification systems applicable to higher gradient channels. Both the Montgomery and Buffington (1993) and Rosgen (1994) classification systems are essentially considerations of channel confinement. Confined channels are those with boundaries (beds, banks, and floodplains) that are resistant to erosion. They commonly have beds and banks composed of bedrock, colluvium, or relict and relatively immobile alluvium. The bed structure of confined channels generally consists of bedrock outcrops, rapids, cascades, and steps separated by short pools. Confined channels are generally stable, with most introduced sediment flushed rapidly downstream. Bed and bank materials are only mobilized by rare and large events (Grant and others 1990; Lisle 1986). Montgomery and Buffington (1993) referred to these confined channels as "source" or "transport" channels.

Unconfined channels are "authors of their own geometry" (Leopold and Maddock 1953). Unconfined streams commonly have floodplains that are frequently inundated and have alluvial banks and beds that are readily mobilized. Unconfined channels are commonly meandering or braided in planform, and have pool-riffle or plane-bed longitudinal profiles. Unconfined channels, referred to as "response reaches" by Montgomery and Buffington (1993), are more sensitive to disturbance than confined channels and may be particularly sensitive to cumulative effects of upstream processes and disturbances that are rapidly transmitted downstream through confined reaches (Montgomery and Buffington 1993; Rosgen 1994).

Because of the diverse stream inventory protocols within the Basin, it was not possible to use a consistent measure of confinement for all the

reaches. Consequently, channel slope was used as an approximate proxy for confinement and we used slope classes of "low" (gradient <0.02), "medium" (0.02 to <0.04), and "high" (≥0.04). These slope classes generally are consistent with process-based classification systems (Montgomery and Buffington 1993; Rosgen 1994) that distinguish streams of distinct morphology and channel forming processes. Streams with gradients less 0.02 are generally unconfined and have pool-riffle or plane-bed morphologies; streams with slopes ≥0.04 are generally confined and have step-pool or cascade bed structures; and streams with slopes between 0.02 and 0.04 have an intermediate character with pool-riffle, plane-bed, or step-pool bed structures, depending on local conditions. While accurately measured slope probably is a good indicator of stream type, the quality of the slope information associated with the stream inventories is inconsistent. Some slopes were calculated from maps, while some were measured in the field. Field measurements were performed by a variety of techniques, ranging from hand-held clinometer sightings of single channel units to reach-long instrument surveys. Of the 6,352 reaches, 144 could not be classified because there was no slope information.

In part because of the unreliability of the slope measurements, we also classified streams by stream order (Horton 1945; Strahler 1957). Stream order serves as a proxy for drainage area; streams with low-order values within a basin generally have smaller drainage areas than those with larger stream orders. Drainage area has been shown to be an important discriminant in evaluating channel form (Dunne and Leopold 1978; Leopold and others 1964) and responses to human disturbance (Overton and others 1993). Classifying streams solely on the basis of stream order for the purpose of evaluating stream processes has been discouraged (Montgomery and Buffington 1993) because actual and artificial differences in mapped drainage network density and pattern affect the calculated stream order in a manner that probably does not relate to channel form and function. Nevertheless, we established stream-order classes to stratify the analysis because: 1) stream order probably serves as a better indicator of drainage area than slope; 2) we are unsure of the reliability of the measurements used to classify the streams by slope class; 3) every inventoried stream reach can be classified; and 4) the use of stream-order classes in conjunction with the 1:100,000 hydrography offers the only means for assessing sample completeness. Streams were grouped into three classes: order 0 to 1, order 2 to 3, and order greater than or equal to 4. Stream orders of zero refer to intermittent streams or unconnected segments on the 1:100,000 hydrography. Inspection of the 1:100,000 hydrography indicates that most of these zero-order streams on federally administered lands are headwater tributaries, and are appropriately grouped with the first-order streams.

Analytical Results

Despite the aforementioned limitations in the data, the channel morphology variables showed strong and consistent patterns of response to several of the landscape variables for all stream stratifications. Moreover, after accounting for the variance explained by landscape variables, the channel morphology variables displayed significant differences among management clusters and/or road density classifications. Some of the patterns that emerged from this analysis are presented in the following paragraphs.

Differences in *large pool frequency* and *pool frequency* were partially explained by slope, lithology, and vegetation. This was consistent with the obvious and well-established tenet that channel morphology is strongly influenced by local physiography and vegetation (Grant 1990; Hack 1957; Montgomery and Buffington 1993; Rosgen 1994). Commonly, the low-slope and high-order streams (generally the larger and unconfined streams) responded differently (in the opposite direction) than high-slope and low-order streams to slope and lithology variables.

For example, for low-slope and high-order streams, as the average slope of the subwatershed increased, *pool frequency* decreased. The response was distinctly different for steeper and low-order streams, where as average watershed slope increased, *pool frequency* increased.

After accounting for other landscape features, management cluster and road density had significant impacts on *pool frequency* and *large pool frequency* for almost all order and slope classifications. The only exceptions were for *large pool frequency* on medium-slope streams. For streams of order 4 and higher, management cluster and road density accounted for almost 5 percent of the total variance in *pool frequency*. For *large pool frequency* and *pool frequency* in low-slope and order 4 and higher streams, human disturbance factors accounted for twice as much of the variance as they did for the pool frequency variables in steeper and low-order streams. This is consistent with the hypothesis that low-gradient channels are more sensitive to human disturbance (Montgomery and Buffington 1993; Rosgen 1994). In general, reversing the order in which management cluster and road density were entered into the model did not substantially affect the resulting significance levels, indicating that there was little interaction between these two predictor variables.

For five of the seven ERUs in which *R6 wood frequency* was summarized, vegetation (*vegclus*) significantly affected wood frequency. In the Blue Mountains, Upper Klamath, and Columbia Plateau, precipitation had a highly significant effect on wood frequency. *R6 wood frequency* was significantly affected by management cluster and road density in the Northern Cascades, Southern Cascades, Columbia Plateau, Northern Glaciated Mountains, and Blue Mountains. *R6 wood frequency* was not significantly associated with management cluster and road density in the Upper Klamath, and there were insufficient data to evaluate the Northern Great Basin.

Only the Lower Clark Fork and Central Idaho Mountains had sufficient data to construct generalized linear models for *surface fines*. In the Lower Clark Fork, *surface fines* was affected by rock type, but was not significantly affected by management cluster or road density. In the Central Idaho Mountains, *surface fines* was significantly affected by topography, lithology, vegetation, and management/ownership.

Summary

The results of the generalized linear modeling reinforce the general trends portrayed in figures 4.12-4.14 and the historical pool analysis of McIntosh (1995). The evidence is strong; streams within the Basin have been significantly affected by human activities. Most notably, pool frequency (large pools and all pools) is inversely correlated with road density and management intensity. This result is similar to that of other studies of smaller regions west of the Cascade Range (Ralph and others 1994) and in Alaska (Smith and Buffington, in press), where pool frequency has been shown to decline in harvested forests. The negative correlation between pool frequency and management intensity is also corroborated by the repeat surveys of Columbia River Basin streams.

Pools are a fundamental aspect of fish habitat (Bjornn and Reiser 1991). Understanding the sensitivity of pool frequency, especially of large pools, to physical factors and human disturbance is critical to developing management strategies designed to maintain or enhance aquatic conditions. Pools provide rearing habitat for juvenile fish, resting places, overwintering areas, and refugia from floods, drought, and extreme temperatures (Sedell and others 1990). The loss of pools, especially deep pools, substantially and adversely affects fish habitat. Loss of pools in the Basin may be especially critical because of the great extremes of temperature and flow compared to streams west of the Cascade crest (Henjum and others 1994; Wissmar and others 1994a).

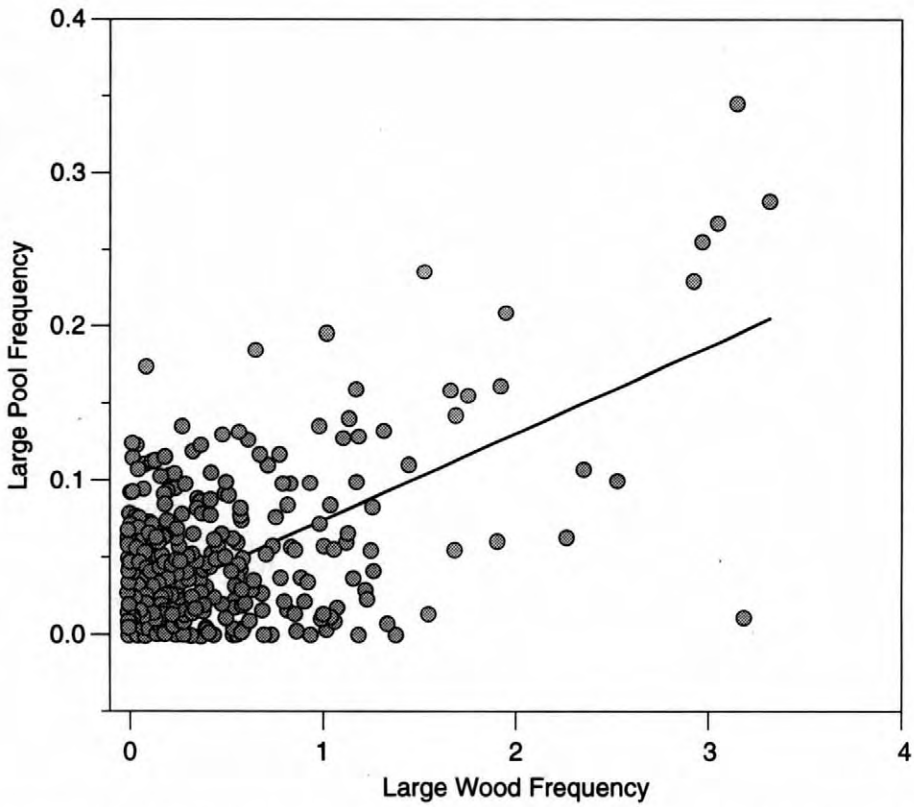


Figure 4.15— Scatter plot of *large-wood frequency* vs. *large pool frequency.* Large wood frequency is the number of large wood pieces measured using the Forest Service Region 6 (Oregon and Washington) protocol per average channel width. Large wood pieces are those with diameters greater than 50 cm and lengths greater than 10.6 m (35 ft). Large pools are those with areas greater than 20 m^2 and depths greater than 0.8 m. The total number of observations (number of reaches) is 646, $r^2 = 0.37$.

A factor likely to be important in controlling pool frequency in the Basin is the abundance of in-stream wood. Wood forms pools by causing hydraulic obstructions and forcing local scour, especially for larger and low-gradient channels (Bilby and Ward 1989; Cordova 1995; Keller and Swanson 1979; Montgomery and others 1995). In the southern portion of the Blue Mountains, 80 percent of large pools in unconstrained reaches are directly associated within stream wood (Cordova 1995). Wood frequency for streams inventoried with the Forest Service Region 6 protocol varies greatly among ERUs, but in mountainous areas, median values range between 0.1 and 0.4, equivalent to 1-2.5 pieces per 10 channel widths, substantially less than wood frequencies in wetter forested regions (Montgomery and others 1995; Ralph and others 1994; Smith and Buffington, in press). Less abundant wood may partly explain why overall large pool frequency is lower in the assessment area relative to streams west of the Cascade crest (McIntosh 1995).

The significant relationship seen in the generalized linear modeling between vegetation factors and pool frequency also points to the importance of wood to pool formation. This observation is further supported by the correlation between wood frequency and pool frequency throughout the assessment area, but most notably between occurrence of large wood and large pools on low-gradient streams (figure 4.15). This is consistent with Cordova's (1995) analysis that showed that in the southern Blue Mountains, wood abun-

dance was important in influencing pool frequency in all types of channels, but especially in unconfined streams.

Wood abundance in streams, in terms of both size and frequency, has been shown to be significantly impacted by many timber harvesting practices (Bilby and Ward 1991; Montgomery and others 1995; Ralph and others 1994). This is also apparently the case in the Columbia River Basin (McIntosh and others 1994b), where wood frequency in high- and moderate-use forests is less than that for wilderness areas, especially in low-gradient streams. Wood is also important for reasons besides pool formation. Wood effectively stabilizes channels, influences sediment routing, and provides a major component of the instream organic matter (Pearsons and others 1992). Wood also provides cover for fish and habitat for some invertebrates, and increases overall channel complexity (Bilby and Ward 1991; Henjum and others 1994). All of these factors call for special attention to protecting sources of instream wood for Columbia basin streams. There is a relatively small amount of wood; it plays a critical role for pool formation and habitat conditions; and wood frequency is sensitive to management practices.

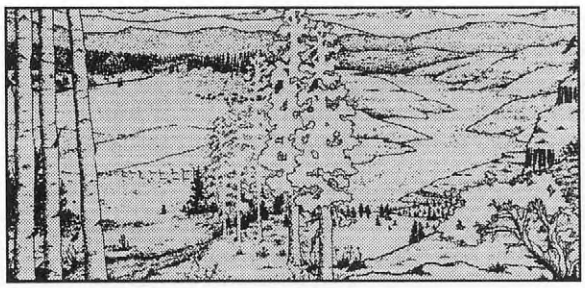
Another important aspect of habitat quality that apparently is influenced by management is the amount of fine sediment (sediment less than 6 mm) on channel beds. Elevated levels of fine sediment adversely affect salmonid embryo survival by impeding intergravel flow and reducing oxygen in redds (Bjornn and Reiser 1991; Chapman 1988; Everest and others 1987). Several studies have shown that forest management practices, especially road building and ground disturbance, can substantially increase sediment flux into streams (reviewed by Everest and others 1991; Furniss and others 1991; Henjum and others 1994; Hicks and others 1991; Reid 1993). Increased sediment loads in streams also cause aggradation, filling of pools, and increased channel widths and width/depth ratios (Madej 1982). Fine sediment has only been consistently measured in the Central Idaho Mountains, where stream sedimentation has been perceived as a problem for several decades (Megahan and Kidd 1972; Platts and Megahan 1975; Platts and others 1989). The results of the generalized linear modeling, where road density significantly affects surface fines, corroborates the link between forest management practices and channel sediment characteristics.

An aspect of channel conditions in the Basin that has not been explicitly evaluated in this analysis is the role of low-frequency disturbance events in controlling channel morphology (Swanston 1991). Low-frequency events such as large floods, mass movements, and fire can profoundly affect stream channels by introducing and/or mobilizing large quantities of sediment, thereby altering bed structure and channel form in manners that can persist for decades or hundreds of years (Baker 1977, Reeves and others 1995). Human activities in watersheds can strongly influence the timing and magnitude of natural events; for example, clearcutting and other watershed disruptions are linked to increased water yields, bedload movement, more frequent flooding and scour events, and channel instability (Rieman and McIntyre 1993). Consequently, streams in similar settings can have very different channel conditions. These differences are the result of varied histories of natural and anthropogenic events. A large portion of the unexplained variance in the general linear models is probably due to the past sequence of natural and human events and their effects on channel morphology. An example is Rapid River, a roadless watershed in central Idaho, where several fires over the last few decades have resulted in rapid wood delivery to the stream—present wood frequency is about 3 pieces per channel width. This wood will continue to affect channel morphology for several decades. We specifically point this out because the dynamic aspect of channels is difficult to evaluate in empirical models such as those presented here. Moreover, potential long-lasting perturbations to channel conditions need to be considered when considering long-term management strategies and evaluating risk to fish and fish habitat on a regional scale.

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DISTRIBUTION AND STATUS OF FISHES

Native fish communities are an integral element in the composition, structure, and function of aquatic ecosystems. Fish typically dominate the aquatic vertebrates. They are sensitive to disturbance, and potentially integrate the effects of landscape and watershed processes over large spatial and temporal scales. Fish have influenced the development, status, and success of human social and economic systems. They also can be important pathways for nutrient and energy flows between aquatic and terrestrial systems. Even in waters historically barren of fish, introduced fishes profoundly influence the structure of aquatic communities (Bahls 1992). In this section, we focus on the distribution, structure, and status of fish assemblages and select, or key, fish species across the assessment area.

Many species of fish and other aquatic biota in the Basin are considered imperiled (Frissell and others 1993, 1995; Moyle and Williams 1990; Nehlsen and others 1991; Williams and others 1989). Presently at least 45 of the Basin's 88 native fish taxa are identified as threatened, endangered, sensitive, or of special concern by state or federal agencies or by the American Fisheries Society. Ten of those fishes are formally listed as threatened or endangered under the Endangered Species Act (ESA) of 1973 (PL 93-205, as amended) (table 4.16) by the National Marine Fisheries Service (NMFS) (anadromous salmonids) or by the U.S. Fish and Wildlife Service (USFWS) (non-anadromous fishes). Two others are designated as Category 1 species by the Federal agencies with listing considered warranted but precluded by other priorities. A single species is under review for listing by NMFS.

Status reviews exist for anadromous salmonids [Columbia Basin Fish and Wildlife Authority (CBFWA) 1990; Chapman and others 1994a, 1994b; Didier and Anderson, in preparation; Howell and others 1985a, 1985b; Huntington and others 1994; Idaho Department of Fish and Game (IDFG) and others 1990; Kostow and others 1994; Nehlsen and others 1991; Northwest Power Planning Council (NWPPC) 1986; Washington Department of Fisheries (WDF) and others 1993] and several non-anadromous salmonids (Liknes 1984; Rieman and Apperson 1989; Thomas 1992; Young 1995). These reviews typically focused on high-profile salmonids in specific geographic areas. Many reviews used different methods with varied resolution, making a synthesis across the Basin difficult. Most reviews summarized known presence and abundance, but provided little information on the absence of species. The lack of detailed inventories limits our understanding of factors affecting the distribution or persistence of many species. Frissell (1993) provided the most complete broad-scale analysis of native fish assemblages within the Pacific Northwest and California. Frissell's analysis provided little resolution below the scale of major river subbasins, however, and

was based primarily on published records of broad, well-documented extinctions of native fishes. We are aware of no attempt to document the distribution or influence of non-native fishes at scales larger than individual watersheds or subbasins.

Our goal was to provide a consistent evaluation of the status and distribution of all fishes throughout the Basin, organized by three primary objectives:

Objective 1—Evaluate the current condition of aquatic ecosystems by summarizing the current distribution of all fishes and the status of select species. Existing reports within the Basin do not adequately reflect the collective (and generally unpublished) knowledge of agencies and individuals familiar with the status and distribution of fishes. Our intent was to capture as much relevant information and understanding as possible. We addressed both complete assemblages (all native and introduced species) and selected several species as indicators of aquatic ecosystem health and integrity.

Objective 2—Identify unique or important areas in terms of fish species diversity and the integrity and composition of fish communities. Ecosystem management includes goals to conserve the structure, function, and resilience of ecosystems by maintaining or restoring processes that influence those characteristics (Grumbine 1994). A starting point may be the conservation of aquatic systems that retain, sensitive species and biological diversity. Recognition of important subbasins and watersheds and the connecting corridors is a first step.

Objective 3—Identify linkages between the status and distribution of fishes and other components of the landscape, including land management and anthropogenic disturbance. We explored the relationships between fish distributions and status and landscape features using information provided by the landscape ecology group. We used the emergent patterns to predict distributions of fish in unsampled areas of the Basin and to identify influential landscape features. We also summarized current knowledge of the physical, biological, and anthropogenic factors or processes that are known to influence population dynamics and distribution patterns of selected species.

Our analysis focused on the distribution and status of native fishes. Most introductions of non-native species or of species native to the Basin but outside their historical ranges (collectively called "introduced" species) were intended to create or expand sport fishing opportunity. Such efforts began in the 1800s (Evermann 1893; Simpson and Wallace 1978). Introduced salmonids, centrarchids and percids now support much, if not most, of the sport-fishing opportunities throughout the Basin. Introduced species are important, and likely permanent, components of the aquatic ecosystems. Their role in sport fisheries implies a large social and economic influence. The widespread occurrence of many introduced species suggests that they are also well adapted to the altered conditions of aquatic environments prevalent throughout the Basin. They tend to be less sensitive to disturbance associated with land management than native fishes, and are more prevalent in waters further removed from the direct effects of change on Federal lands (Marcot and others 1994). Therefore, native fish species provide the more sensitive measure of aquatic ecosystem condition. Management and conservation efforts on Federal lands that maintain or restore the distribution and integrity of native fishes, however, can also benefit desirable non-native species.

A total of 143 fish taxa was reported within the Basin. Table 4.16 lists common and scientific names for each species, subspecies, race or life-history form. In the remainder of this document, we use common names.

Table 4.16—Relative abundance of native and introduced species. The columns "Freq" and "Pct" refer to the frequency reported by watershed and percentage of reported watersheds. Common and scientific names of fishes follow accepted nomenclature of the American Fisheries Society (Robins and others 1991).

ID	Rank	Group rank	Conservation[2] Asc[1]	status	Common name	Freq	Pct	Family name	Scientific name
Native Species									
1	36	24	Y	1,2,3	White sturgeon	141	6.3%	Acipenseridae	*Acipenser transmontanus*
2	50	34	Y		Utah sucker	79	3.6%	Catostomidae	*Catostomus ardens*
3	23	17	Y		Longnose sucker	292	13.1%	Catostomidae	*Catostomus catostomus*
4	14	12	Y		Bridgelip sucker	548	24.7%	Catostomidae	*Catostomus columbianus*
4A[3]	——	——	E		Wood River bridgelip sucker	——	——	Catostomidae	*Catostomus columbianus hubbsi*
5	73	50			Bluehead sucker	22	0.:%	Catostomidae	*Catostomus discobolus*
6	8	6	Y		Largescale sucker	776	34.9%	Catostomidae	*Catostomus macrocheilus*
7	96	69			Sacramento sucker	7	0.3%	Catostomidae	*Catostomus occidentalis*
8	97	70	E	3	Goose Lake sucker	7	0.3%	Catostomidae	*C. occidentalis lacusanserinus*
9	37	25	Y		Mountain sucker	133	5.:%	Catostomidae	*Catostomus platyrhynchus*
10	92	66			Klamath smallscale sucker	8	0.4%	Catostomidae	*Catostomus rimiculus*
11	64	42		3	Klamath largescale sucker	34	1.5%	Catostomidae	*Catostomus snyderi*
12	30	21			Sucker, generic	219	9.9%	Catostomidae	*Catostomus sp.*
13	121	86			Tahoe sucker	1	0.0%	Catostomidae	*Catostomus tahoensis*
14	86	61	E	1,2	Warner sucker	10	0.4%	Catostomidae	*Catostomus warnerensis*
15	74	51	E	1,2	Shortnose sucker	20	0.9%	Catostomidae	*Chasmistes brevirostris*
16	87	62	E	1,2	Lost River sucker	10	0.4%	Catostomidae	*Deltistes luxatus*
17	93	67			Coastrange sculpin	8	0.4%	Cottidae	*Cottus aleuticus*
18	69	46			Prickly sculpin	26	1.2%	Cottidae	*Cottus asper*
19	34	23	Y		Mottled sculpin	154	6.9%	Cottidae	*Cottus bairdi*
20	66	44	E	3	Malheur sculpin	33	1.5%	Cottidae	*Cottus bairdi ssp.*
21	41	29	Y		Paiute sculpin	102	4.6%	Cottidae	*Cottus beldingi*
22	29	20	Y		Slimy sculpin	227	10.2%	Cottidae	*Cottus cognatus*
23	54	37	3		Shorthead sculpin	72	3.2%	Cottidae	*Cottus confusus*
24	111	79	E	3	Shoshone sculpin	3	0.1%	Cottidae	*Cottus greenei*
25	65	43			Riffle sculpin	34	1.5%	Cottidae	*Cottus gulosus*
26	79	55			Marbled sculpin	14	0.6%	Cottidae	*Cottus klamathensis*
27	68	45	E	3	Wood River sculpin	27	1.2%	Cottidae	*Cottus leiopomus*
28	75	52	E	3	Margined sculpin	19	0.9%	Cottidae	*Cottus marginatus*
29	70	47			Reticulate sculpin	24	1.1%	Cottidae	*Cottus perplexus*
30	108	76	E	3	Pit sculpin	4	0.2%	Cottidae	*Cottus pitensis*
31	98	71	E		Klamath Lake sculpin	7	0.3%	Cottidae	*Cottus princeps*
32	46	32	Y	3	Torrent sculpin	90	4.0%	Cottidae	*Cottus rhotheus*
33	89	64	E	3	Slender sculpin	9	0.4%	Cottidae	*Cottus tenuis*
34	2	1			Sculpin, generic	1299	58.4%	Cottidae	*Cottus sp.*
35	76	53			Pacific staghorn sculpin	19	0.9%	Cottidae	*Leptocottus armutus*
36	18	15	Y		Chiselmouth	379	17.0%	Cyprinidae	*Acrocheilus alutaceus*
37	82	58	E	3	Alvord chub	12	0.5%	Cyprinidae	*Gila alvordensis*
38	57	38			Utah chub	62	2.8%	Cyprinidae	*Gila atraria*
39	47	33	Y		Tui chub	88	3.:%	Cyprinidae	*Gila bicolor*
40	106	75	E	3	Sheldon tui chub	5	0.2%	Cyprinidae	*Gila bicolor eurysoma*
41	112	80	E	3	Oregon Lakes tui chub	3	0.1%	Cyprinidae	*Gila bicolor oregonensis*
42	90	65	E	3	Catlow tui chub	9	0.4%	Cyprinidae	*Gila bicolor ssp.*
43	122	87	E	1,2	Hutton tui chub	1	0.0%	Cyprinidae	*Gila bicolor ssp.*
44	113	81	E	3	Summer Basin tui chub	3	0.1%	Cyprinidae	*Gila bicolor ssp.*
45	103	73	E	3	Warner Basin tui chub	6	0.3%	Cyprinidae	*Gila bicolor ssp.*
46	123	88	E	3	XL Spring tui chub	1	0.0%	Cyprinidae	*Gila bicolor ssp.*
47	104	74	E	3	Goose Lake tui chub	6	0.3%	Cyprinidae	*Gila bicolor thallassina*
48	124	89	E	1,2	Borax Lake chub	1	0.0%	Cyprinidae	*Gila boraxobius*
49	99	72			Blue chub	7	0.3%	Cyprinidae	*Gila coerulea*
50	81	57	3		Leatherside chub	13	0.6%	Cyprinidae	*Gila copei*
51	83	59	3		Northern roach	12	0.5%	Cyprinidae	*Hesperoleucus symmetricus mitrulus*
52	24	18	Y		Peamouth	291	13.1%	Cyprinidae	*Mylocheilus caurinus*
53	7	5	Y		Northern squawfish	801	36.0%	Cyprinidae	*Ptychocheilus oregonensis*
54	116	82			Umpqua squawfish	2	0.1%	Cyprinidae	*Ptychocheilus umpquae*

Table 4.16 (continued).

ID	Rank	Group rank	Conservation[2] Asc[1]	status	Common name	Freq	Pct	Family name	Scientific name
55	15	13	Y		Longnose dace	531	23.9%	Cyprinidae	*Rhinichthys cataractae*
56	71	48			Leopard dace	23	1.0%	Cyprinidae	*Rhinichthys falcatus*
57	11	9	Y		Speckled dace	665	29.9%	Cyprinidae	*Rhinichthys osculus*
58	109	77	E		Klamath speckled dace	4	0.2%	Cyprinidae	*Rhinichthys osculus klamathensis*
59	125	90	E	1,2	Foskett speckled dace	1	0.0%	Cyprinidae	*Rhinichthys osculus ssp.*
60	12	10			Dace, generic	663	29.8%	Cyprinidae	*Rhinichthys sp.*
61	6	4	YD		Redside shiner	962	43.3%	Cyprinidae	*Richardsonius balteatus*
62	117	83			Lahontan redside	2	0.1%	Cyprinidae	*Richardsonius egregius*
63	40	28	Y		Shiner perch	107	4.8%	Embiotocidae	*Cymatogaster aggregata*
64	53	36		2	Burbot	74	3.3%	Gadidae	*Lota lota*
65	61	40			Threespine stickleback	45	2.0%	Gasterosteidae	*Gasterosteus aculeatus*
66	77	54	E	3	Sand roller	17	0.8%	Percopsidae	*Percopsis transmontana*
67	126	91			River lamprey	1	0.0%	Petromyzontidae	*Lampetra ayresi*
68	80	56			Pit-Klamath brook lamprey	14	0.6%	Petromyzontidae	*Lampetra lethophaga*
69	118	84	E		Miller Lake lamprey	2	0.1%	Petromyzontidae	*Lampetra minima*
70	63	41			Western brook lamprey	42	1.9%	Petromyzontidae	*Lampetra richardsoni*
71	85	60	E		Klamath lamprey	11	0.5%	Petromyzontidae	*Lampetra similis*
72	38	26	Y	2	Pacific lamprey	128	5.8%	Petromyzontidae	*Lampetra tridentata*
73	119	85	E	3	Goose Lake lamprey	2	0.1%	Petromyzontidae	*Lampetra tridentata ssp.*
74	32	22	YD	3	Yellowstone cutthroat trout	188	8.5%	Salmonidae	*Oncorhynchus clarki bouvieri*
75	60	39		3	Coastal cutthroat trout	48	2.2%	Salmonidae	*Oncorhynchus clarki clarki*
76	39	27	Y	1,2	Lahontan cutthroat trout	111	4.:%	Salmonidae	*Oncorhynchus clarki henshawi*
77	10	8	YD	3	Westslope cutthroat trout	737	33.2%	Salmonidae	*Oncorhynchus clarki lewisi*
78	28	19			Cutthroat trout, generic	242	10.9%	Salmonidae	*Oncorhynchus clarki spp.*
79	94	68		3	Chum salmon	8	0.4%	Salmonidae	*Oncorhynchus keta*
80	51	35	Y	3	Coho salmon	79	3.6%	Salmonidae	*Oncorhynchus kisutch*
81	3	2	Y	3	Interior redband trout	1244	55.:%	Salmonidae	*Oncorhynchus mykiss gibbsi*
82	13	11	Y	3	Summer steelhead	649	29.2%	Salmonidae	*Oncorhynchus mykiss mykiss*
83	42	30	Y	3	Winter steelhead	102	4.6%	Salmonidae	*Oncorhynchus mykiss mykiss*
84	110	78		3	Catlow Valley redband trout	4	0.2%	Salmonidae	*Oncorhynchus mykiss ssp.*
85	88	63		3	Warner Valley redband trout	10	0.4%	Salmonidae	*Oncorhynchus mykiss ssp.*
86	22	16	Y	1,2	Sockeye (kokanee) salmon	294	13.2%	Salmonidae	*Oncorhynchus nerka*
87	43	31	Y	1,2	Ocean-type chinook salmon	100	4.5%	Salmonidae	*Oncorhynchus tshawytscha*
88	17	14	Y	1,2	Stream-type chinook salmon	444	19.:%	Salmonidae	*Oncorhynchus tshawytscha*
89	72	49		3	Pygmy whitefish	23	1.0%	Salmonidae	*Prosopium coulteri*
90	5	3	YD		Mountain whitefish	1063	47.8%	Salmonidae	*Prosopium williamsoni*
91	9	7	Y	3	Bull trout	752	33.8%	Salmonidae	*Salvelinus confluentus*
Introduced Species									
92	107	32			White sucker	5	0.2%	Catostomidae	*Catostomus commersoni*
93	84	25			Green sunfish	12	0.5%	Centrarchidae	*Lepomis cyanellus*
94	26	8	Y		Pumpkinseed	261	11.7%	Centrarchidae	*Lepomis gibbosus*
95	105	31			Warmouth	6	0.3%	Centrarchidae	*Lepomis gulosus*
96	33	11	Y		Bluegill	186	8.4%	Centrarchidae	*Lepomis macrochirus*
97	19	4	Y		Smallmouth bass	379	17.0%	Centrarchidae	*Micropterus dolomieu*
98	20	5	Y		Largemouth bass	359	16.1%	Centrarchidae	*Micropterus salmoides*
99	49	16	Y		White crappie	84	3.8%	Centrarchidae	*Pomoxis annularis*
100	31	10	Y		Black crappie	207	9.3%	Centrarchidae	*Pomoxis nigromaculatus*
101	52	17			American shad	76	3.4%	Clupeidae	*Alosa sapidissima*
102	62	22			Goldfish	45	2.0%	Cyprinidae	*Carassius auratus*
103	120	35			Finescale dace	2	0.1%	Cyprinidae	*Phoxinus neogaeus*
104	27	9	Y		Carp	259	11.7%	Cyprinidae	*Cyprinus carpio*
105	114	33			Spottail shiner	3	0.1%	Cyprinidae	*Notropis hudsonius*
106	95	27			Fathead minnow	8	0.4%	Cyprinidae	*Pimephales promelas*
107	59	21			Tench	54	2.4%	Cyprinidae	*Tinca tinca*
108	48	15	Y		Northern pike	87	3.9%	Esocidae	*Esox lucius*
109	45	14	Y		Black bullhead	95	4.3%	Ictaluridae	*Ameiurus melas*
110	58	20			Yellow bullhead	62	2.8%	Ictaluridae	*Ameiurus natalis*
111	25	7	Y		Brown bullhead	280	12.6%	Ictaluridae	*Ameiurus nebulosus*
112	35	12	Y		Channel catfish	142	6.4%	Ictaluridae	*Ictalurus punctatus*

Table 4.16 (continued).

ID	Rank	Group rank	Asc[1]	Conservation[2] status	Common name	Freq	Pct	Family name	Scientific name
113	100	28			Tadpole madtom	7	0.3%	Ictaluridae	*Noturus gyrinus*
114	91	26			Flathead catfish	9	0.4%	Ictaluridae	*Pylodictis olivaris*
115	21	6	Y		Yellow perch	340	15.3%	Percidae	*Perca flavescens*
116	55	18			Walleye	71	3.2%	Percidae	*Stizostedion vitreum vitreum*
117	115	34			Southern platyfish	3	0.1%	Poeciliidae	*Xiphophorus maculatus*
118	56	19			Lake whitefish	71	3.2%	Salmonidae	*Coregonus clupeaformis*
119	101	29			Golden trout	7	0.3%	Salmonidae	*Oncorhynchus aguabonita*
120	1	1	Y		Rainbow trout	1726	77.6%	Salmonidae	*Oncorhynchus mykiss*
121	102	30			Kamloops trout	7	0.3%	Salmonidae	*Oncorhynchus mykiss mykiss*
122	78	24			Atlantic salmon	17	0.8%	Salmonidae	*Salmo salar*
123	16	3	Y		Brown trout	517	23.3%	Salmonidae	*Salmo trutta*
124	127	36			Sunapee char	1	0.0%	Salmonidae	*Salvelinus alpinus oquassa*
125	4	2	Y		Brook trout	1106	49.8%	Salmonidae	*Salvelinus fontinalis*
126	44	13	Y		Lake trout	96	4.3%	Salmonidae	*Salvelinus namaycush*
127	67	23			Arctic grayling	28	1.3%	Salmonidae	*Thymallus arcticus*
The following introduced species were reported by subbasin.									
128					Shortnose sucker			Catostomidae	*Chasmistes stomias*
129					Rock bass			Centrarchidae	*Ambloplites rupestris*
130					Sacramento perch			Centrarchidae	*Archoplites interruptus*
131					Redear sunfish			Centrarchidae	*Lepomis microlophus*
132					Tambaqui			Characidae	*Colossoma macropomum*
133					Convict cichlid			Cichlidae	*Cichlasoma nigrofasciatum*
134					Tilapia			Cichlidae	*Cichlidae sp.*
135					Oriental weatherfish			Cobitidae	*Misgurnus anguillicaudatus*
136					Loach			Cobitidae	*Misgurnus mizolepis*
137					Grass carp			Cyprinidae	*Ctenopharyngodon idella*
138					Tiger barb			Cyprinidae	*Puntius tetrazona*
139					Grass pickerel			Esocidae	*Esox americanus*
140					Gar			Lepisosteidae	*Lepisosteus sp.*
141					Striped bass			Percichthyidae	*Morone saxatilis*
142					Rainbow smelt			Osmeridae	*Osmerus mordax*
143					Saddleback gunnel			Pholidae	*Pholis ornata*
144					Mosquitofish			Poeciliidae	*Gambusia affinis*
145					Green swordtail			Poeciliidae	*Xiphophorus helleri*
146					Shortfin molly			Poeciliidae	*Poecilia mexicana*
147					Guppy			Poeciliidae	*Poecilia reticulata*
148					Arctic char			Salmonidae	*Salvelinus alpinus*
The following composite species groups were used in the assemblage analysis:									
			Y		Suckers	1324	59.6%		
			YD		Dace	1392	62.6%		
			Y		Sculpins	1676	75.4%		
			Y		Shiners	963	43.3%		
			Y		Chubs	188	8.5%		
			Y		Crappie	224	10.1%		
			YD		Bullheads	339	15.2%		
			Y		Lampreys	170	7.6%		
			Y		Cutthroat	1029	46.3%		
			Y		Trout	2167	97.5%		
			Y		Whitefish	1075	48.4%		
			YD		Steelhead	659	29.6%		
			YD		Rainbow (all)	1972	88.7%		
			YD		Chinook	454	20.4%		
			YD		Sunfish	331	14.9%		

[1] Asc codes: Y=species used in the association analysis; YD=divisor species; E=narrowly distributed endemics.

[2] Conservation status codes: 1=Federally listed as endangered or threatened; 2=State or American Fisheries Society listed as endangered, threatened, sensitive, or of special concern; 3= Federal candidate and/or sensitive species.

[3] The Wood River, Idaho supports a distinct subspecies of bridgelip sucker. We found the taxonomic description of this subspecies after the association analysis was completed.

Overview of Approach and Data Sources

We considered the fishes at three levels of detail:

1) **Fish Species Assemblages**—We summarized the known occurrence of all fish taxa, native and introduced, across the Basin. Species assemblages were defined by species composition and mapped by watershed across the Basin. Species richness and diversity indices were calculated for each species assemblage.

2) **Sensitive Native Species**—We compiled information for 38 taxa considered sensitive, threatened, endangered, or of special concern. We summarized current knowledge regarding fish status relative to the known historical range, biology and life history, and important threats to persistence. We used composite distributions of the most sensitive or narrowly distributed of these species to indicate sensitive or otherwise important watersheds.

3) **Key Salmonids**—We considered seven select salmonids in the greatest detail: bull, westslope cutthroat, Yellowstone cutthroat, and redband trout; steelhead; and ocean-type (age-0 migrant) and stream-type (age-1 migrant) chinook salmon. We summarized the presence, absence, and status in subwatersheds that supported spawning and rearing habitats for each species or life history. Because existing information describing the occurrence and status of these salmonids is incomplete, we used classification trees to analyze patterns in the known distributions and to predict the occurrence and status in watersheds lacking such information. We also briefly considered the distribution of several introduced salmonids.

There are several reasons for focusing on these salmonids, other than their obvious social and cultural values. First, we know more about them, and are more likely to discern important environmental relationships. Second, they are or were widely distributed, which allows for broad-scale comparisons. Third, salmonids act as predators, competitors, and prey for a variety of other aquatic and terrestrial taxa. Thus, they are likely to influence the structure and function of aquatic ecosystems and may serve as critical links with energy and nutrient flows to terrestrial systems (Henjum and others 1994; Willson and Halupka 1995). Finally, the salmonids potentially are more sensitive to disturbance than other groups (Marcot and others 1994). Different species and life stages often use widely divergent habitats, exposing individual populations and native assemblages to a wide variety of environmental and habitat disturbances. Salmonids may therefore integrate the cumulative effects of environmental change over broad areas.

We developed two primary databases, one that summarizes the current status of the selected "key" salmonids, and a second that summarizes the reported presence of all native or introduced fish taxa. As part of each database, we also summarized the historical distributions for each key salmonid and species recognized as sensitive, threatened, endangered, or of special concern by state or federal agencies.

Key Salmonids Current-Status Database

The seven key salmonids include both distinct species and life-history forms. Bull, westslope cutthroat, and Yellowstone cutthroat trout are taxonomically and geographically distinct. Redband trout and chinook salmon, however, are each represented by two distinct life-history forms. Non-anadromous redband trout and anadromous steelhead are commonly recognized as interior rainbow trout, and occur both together in sympatry and in isolation from each other (allopatry) throughout a major portion of the Basin. For purposes of this analysis, redband trout designates the non-anadromous form. We adopted Gilbert (1912 cited by Matthews and Waples 1991) and Healeys' (1991) characterization of chinook salmon that migrate seaward primarily at age-1 as "stream-type" and that migrate primarily at age-0 as "ocean-type."

The current-status database was developed through the classification of subwatersheds by private, agency, and tribal fishery biologists working throughout the Basin. The data were augmented with information from existing electronic databases maintained by state and federal agencies, and other sources (appendix 4C).

Biologists were asked to summarize the status of each of the key salmonids from existing data. We used a series of workshops to train facilitators who then trained or worked with other biologists from the study area. Each participant was responsible for an area familiar to them, where they either generated or maintained information or had access to the available data and expertise. Biologists worked in teams and incorporated information from other federal, state, private and tribal biologists and inventories. More than 150 biologists contributed to the project (appendix 4C).

Our sample units were 6th-field watersheds, also termed subwatersheds. Biologists classified the status of naturally reproducing populations only. If populations were supported solely by hatchery-reared fish, naturally spawning fish were considered absent. Biologists classified units where fish were present as follows: spawning and rearing habitat; overwintering and migratory-corridor habitat; or present but of unknown status. Subwatersheds supporting spawning and rearing habitat were further classified as strong or depressed. We asked biologists to judge strong or depressed status based on population characteristics, including life-history forms, recent trends in abundance, and current abundance. Status should not have been inferred from surrounding landscape characteristics or the occurrence or other species (for example, habitat condition or presence of introduced fishes). The following criteria guided classification:

Present, strong—Strong subwatersheds include those with the following characteristics: 1) all major life histories (for example: stream resident or migratory) that historically occurred within the watershed are present; 2) numbers are stable or increasing, and the local population is likely to be at half or more of its historical size or density; and 3) the population or metapopulation within the subwatershed, or within a larger region of which the subwatershed is a part, probably contains at least 5,000 individuals or 500 adults.

Present, depressed—Depressed watersheds include those with at least one of the following characteristics: 1) a major life-history component (for example, a migratory or resident form of westslope cutthroat trout) has been eliminated; 2) numbers within the subwatershed are declining, or the salmonid occurs in less than half of its historical habitat, or numbers are less than half of what the watershed supported historically; if historical information is unavailable, densities are less than half of what is found in comparable streams in an undisturbed condition where the species is well distributed; in cases with relatively strong numbers, but where a population was seriously hybridized with an introduced species or subspecies, the population representing the pure native species/subspecies was considered depressed; or 3) total abundance for the population or metapopulation within the subwatershed, or the larger region of which this subwatershed is a part, is less than 5,000 total fish or 500 adults; the fish within the subwatershed are isolated by distance or natural barriers from other populations that would collectively exceed these numbers.

Absent—The key salmonid is not present in this subwatershed. It is either extinct or it never occupied the subwatershed. The subwatershed is located within the natural range of the species and colonization of the subwatershed was historically possible even though habitat or other environmental conditions might make the habitat unsuitable.

Present, unknown—The key salmonid is present, but there is no reliable information to determine current status.

Present, migration corridor—Migration corridors are habitats that do not support spawning or rearing, and function solely as routes or staging and wintering areas for migrating fish. If spawning or rearing are known to occur, the population

status is judged as present-depressed, present-strong, or present-unknown. Many salmonids may disperse widely from natal habitats prior to maturation. Where a distinction could be made between areas that serve as initial rearing areas prior to migration and those that support transient or subadult fish (for example, mainstem rivers or lakes for bull trout), we considered the latter to be corridor habitat.

Unknown—No information exists regarding the current presence or absence of the species. Subwatersheds that were unclassified were considered unknown.

All status classifications were done by color coding maps of the subwatersheds. Data were entered into the current-status database and proofed against the original maps and against preexisting databases (appendix 4C). We accepted classifications of absent from the preexisting databases only when sampling was documented. Subwatersheds where the current and preexisting databases conflicted regarding the known presence or absence of a species were classified as unknown. Rules employed for merging data sets and treatment of conflicting information are detailed in appendix 4C.

Species-assemblage Database

The species-assemblage database was developed at the same time as the current-status database. For this database the sample units were 5th-field watersheds. The biologists recorded the known presence of all potential fish species in each watershed. They used a master list of all taxa (that is, native and introduced) expected within the Basin, with a unique numeric code for each taxa. Biologists characterized watersheds where they were knowledgable about all species, but they were also asked to use professional judgement to provide as complete a classification as possible. For example, where available data indicated a common species complex in some watersheds but data were limited in other watersheds, biologists were encouraged to extrapolate species occurrence to similar, adjacent waters. Where sampling, records, or personal experience where too limited to include all likely species, watersheds were classified as unknown even though some species were known present. The assemblage database was proofed in the same manner as the current-status database. We compared our database with the preexisting databases maintained by each state and the Oregon State University collection records. If any database included a species as present, it was included as present in the final assemblage database. Additional records of introduced species were added at the subbasin level using data provided by the National Biological Service's Southeastern Biological Science Center.

Historical Ranges

Historical ranges were defined for the seven key salmonids and, whenever possible, for all species, subspecies, or races recognized as sensitive, threatened, endangered or otherwise of special concern. We defined historical as prior to European settlement whenever such inference was possible. Ranges were characterized from the historical distributions in the preexisting databases and augmented through published and anecdotal accounts. We did not accept all accounts as correct, but reviewed and revised distributions whenever possible. The Wilderness Society (1993) distribution of several salmon species, for example, was based on the range of contiguous waters that were historically accessible and not on specific species accounts.

For many fish species, the historical ranges remain speculative and more accurately represent the potential range rather than an actual historical distribution. Few records are available with which to ascertain the historical range of steelhead and salmon throughout the Bruneau River subbasin, for example, because access was blocked early in the century and prior to any detailed population survey. Some species like bull trout are also unlikely to occupy all reaches or all accessible streams within the watersheds of the historical range. Distributions may be restricted by elevation, temperature, and local channel features. Because

we mapped historical ranges at the watershed scale, the entire watershed was included in the historical range, even where species may have occurred in only part of a watershed. In some cases, the historical range may be overestimated because of the loss of resolution.

The historical ranges of redband trout and steelhead are ambiguous where the two co-occur (see species narrative for redband trout). Although all native non-anadromous rainbow trout were considered redband trout in our summary, we believe that populations isolated from steelhead in recent geologic history may represent evolutionarily distinct subgroups of the species. Such isolation may result in substantial genetic divergence between groups, representing important genetic variability for the species. For this reason, we identified two historical ranges for redband trout, those isolated from (allopatric) and those contiguous with (sympatric) the historical distribution of steelhead.

Historical ranges were merged with the current-status and species-assemblage databases. A summary and documentation of the defined historical ranges are presented in appendix 4D.

Current Fishes

Like many portions of western North America, the Basin includes a moderately sized, but locally diverse fish fauna. The native fish fauna of the Columbia River Basin is unusual in that it clearly is not a single faunal unit, but is rather comprised of several subbasin faunas with limited species overlap among subbasins.

Ichthyological Provinces

Based on local endemism and common relationships to nearby basins, McPhail and Lindsey (1986) described five ichthyological provinces within the Columbia River Basin: Upper Snake, Wood River, Glaciated Columbia, Middle Columbia, and Lower Columbia. The Snake River was an independent drainage until the Early Pleistocene, and the Upper Snake remains isolated by Shoshone Falls in south central Idaho. The fishes of the Upper Snake are more closely related to those of the Bonneville Basin than to the remainder of the Columbia Basin.[1] Eighteen fish species present in the Snake River below Shoshone Falls are not found above; however, 10 of 12 species that occur in the Snake River above and below the Falls also occur in the Bonneville system. Exchanges of fish faunas between the Upper Snake and Bonneville systems probably occurred during Pleistocene spillovers of pluvial Lake Bonneville into the Upper Snake (McPhail and Lindsey 1986; Wheeler and Cook 1954). Recognition of the Wood River drainage as a separate province is supported by the presence of Wood River sculpins and a unique subspecies of bridgelip sucker (McPhail and Lindsey 1986), both of which are endemic to the Wood River, and the Shoshone sculpin, which is endemic to the Snake River near the confluence of the Wood River.

The glaciated portion of the Basin includes roughly the northern third, which is characterized as mountainous, heavily forested, and with cold, high-gradient streams. Pygmy whitefish, lake chub, longnose sucker, burbot, and slimy sculpin are confined to glaciated areas and the southern edges of their ranges coincide with the limits of glaciation. One species, the margined sculpin, is restricted to the Middle Columbia, which flows through an arid plateau region. In contrast, streams in the Lower Columbia are well connected and contain 12 species; nine of which are euryhaline, tolerant of higher salinities, or anadromous species (McPhail and Lindsey 1986). Some of these latter species are not included within the Basin because waters most influenced by ocean conditions are located to the west of the crest of the Cascades.

Portions of the Klamath and Great Basin drainages also occur in the area considered in this assessment. The Upper Klamath Basin is dominated by Upper Klamath and Agency lakes, which harbor a

[1]Personal communication. 1995. W. Minckley, Arizona State University, Tempe, Arizona.

diverse assemblage of specialized catostomid fishes (Andreasen 1975b). The Great Basin is characterized by a series of isolated subbasins, each with a largely or wholly closed drainage pattern and resulting depauperate, but highly endemic, fish assemblages (Sigler and Sigler 1987). The distinctive native fishes of both the Upper Klamath and Great Basin bear little resemblance to those of the Columbia River Basin.

With some notable exceptions, the Ecological Reporting Units (ERUs) correspond well to the ichthyological provinces described above (see map 4.1). The Upper Snake province of McPhail and Lindsey (1986) includes the Upper Snake and Snake Headwaters. The Wood River province is problematic in that it is rather evenly split between the Central Idaho Mountains and Owyhee Uplands ERUs. The Glaciated Columbia province includes three ERUs, as follows: the Northern Glaciated Mountains; the Lower Clark Fork; and the Upper Clark Fork. The Middle Columbia province includes four ERUs, as follows: first, the Columbia Plateau; second, the Blue Mountains; third, the Owyhee Uplands; and fourth, the Central Idaho Mountains. The Blue Mountains ERU includes the Silvies subbasin, which is part of the Harney Basin (Bisson and Bond 1971) and is therefore more correctly associated with the Great Basin than the Columbia River system. The Goose Lake Basin is placed with the Upper Klamath, but more appropriately should be associated with the Northern Great Basin or treated separately in addition to the Great Basin. Except for the ubiquitous speckled dace and tui chub, there is no overlap of species between the fish faunas of the Goose Lake subbasin and the Upper Klamath basin (Moyle and Daniels 1982).

Species List and Relative Abundance

The fish communities found in the Basin reflect broad-scale differences in ichthylogical provinces, environmental gradients from headwater streams to major rivers, and the myriad changes that post-European settlement has wrought through altered habitat, harvest, and introduced species. To understand the joint distributions of numerous species, both native and introduced, we summarized the available information using community analysis techniques, specifically, diversity indices and association analysis.

As explained in the subsection on "Overview of Approach and Data Sources," we were restricted to presence or absence information. This is misleading, in that the information referred not so much to "presence" or "absence" as to "reported" or "not reported." Strictly speaking, "not reported" does not necessarily mean "absent." Based on verification of the data, we believe that more errors of omission (not reporting species that were present), than commission (reporting species that were not present) were committed. We use the term relative abundance to refer to the frequency with which a species is reported as present, rather than as a measure of numerical abundance *per se*. Thus, bull trout will have a higher relative abundance than speckled dace because they were more frequently reported, not because they are more numerically abundant.

A total of 143 recognized species, subspecies, or races was reported within the Basin (table 4.16). There were 88 native taxa (61%) reported, and 55 taxa (39%) that have been introduced from outside areas. Of the total, 124 were reported by watershed. The remaining 19 taxa were introduced species that could only be recorded by subbasins. We also recorded the occurrence of four "generic" taxa that were used when species or subspecies designations were unknown (cutthroat, dace, sculpins, and suckers) at the watershed level and two generic taxa (gar and tilapia) that were used at the subbasin level.

A brief examination of the species list in table 4.16 provides some perspective. Although our list of 88 native fishes may seem like high species richness, it includes only 10 families, 21 genera, and 66 species. By comparison, the Rio Grande River system has 154 native species in 29 families (Smith and Miller 1986), and the western Mississippi River system has 235 native species in 33 families (Cross and others 1986). Compared with these systems,

species richness within the Basin is low. The Basin more closely resembles the Sacramento-San Joaquin system, with 55 native species in 13 families (Moyle 1976). The lower diversity of western rivers likely reflects a relatively young geologic age, and greater zoogeographic isolation. Also, fewer marine species invade the Columbia River than the Mississippi River (Cross and others 1986).

Major disruptive events that have shaped a dynamic Basin landscape have undoubtedly influenced fish communities as well (Li and others 1987). The native species fall into two groups. The first group is comprised of 15 to 20 species that are widely distributed throughout the Basin and/or reported in 20 percent or more of the watersheds. The second, larger group of roughly 60 species is the narrowly distributed species that have restricted ranges or are infrequently reported (less than 5% of the watersheds).

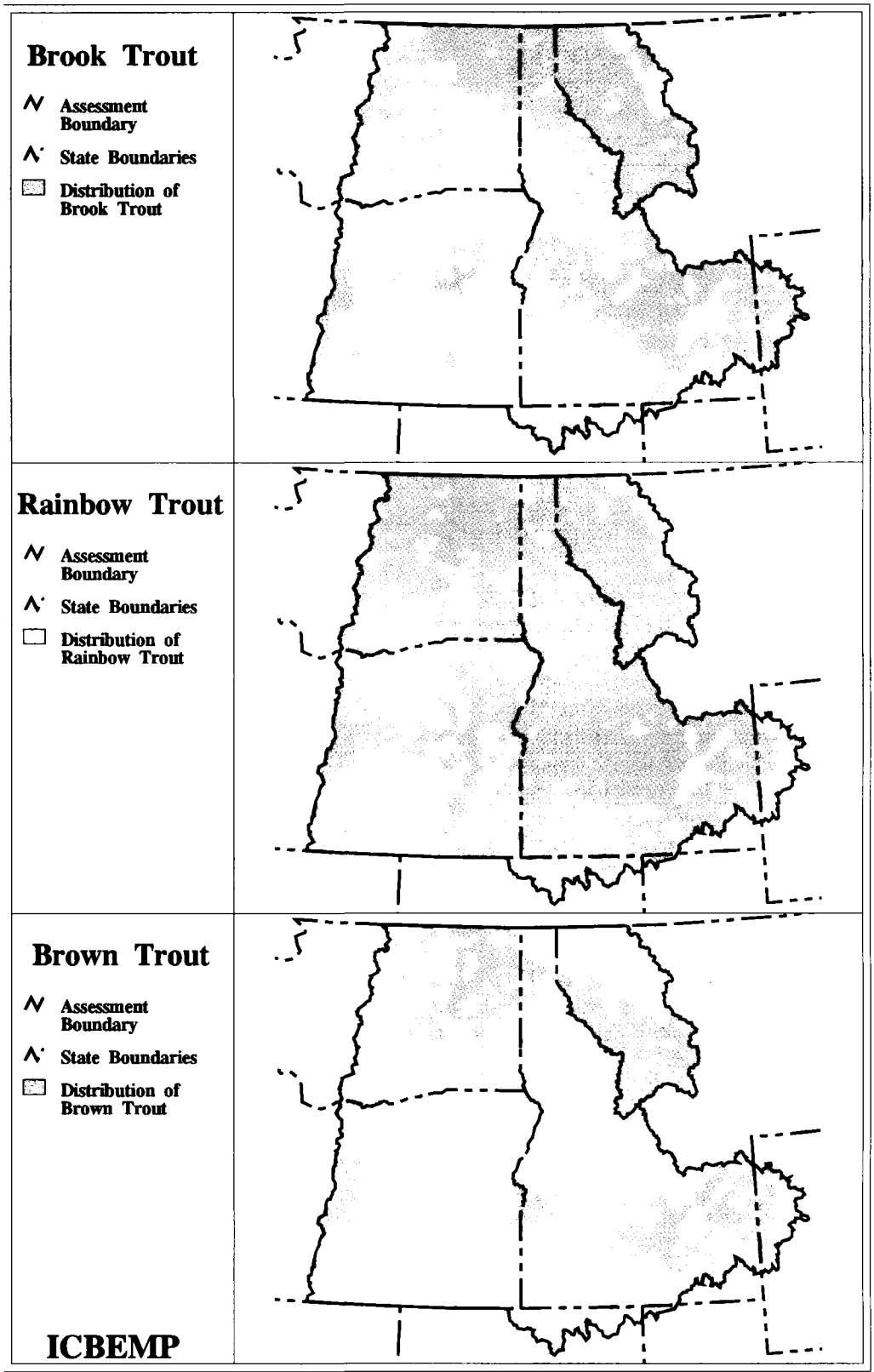
Clearly, introduced species are a major component of the current icthyofauna. The most frequently reported species was introduced rainbow trout, occurring in 78 percent of the Basin (map 4.7). Introduced brook trout were reported in 50 percent of the watersheds (map 4.7). The majority of introduced species are game fishes that were purposefully introduced by fishery management agencies and private individuals to provide fishing opportunities; sixteen (32%) of the 50 most-reported species are introduced game fishes. In addition, fishing practices likely contributed a number of bait-bucket introductions of non-native fish, as well. More unusual occurrences likely resulted from aquaria releases. For example, Amazonian tambaqui were reported in the Snake River, and oriental weatherfish were reported in the Boise River.

Species Assemblages

Species lists and individual species distributions provide limited information. A more complete understanding of ecological processes can be gained from analysis of aquatic communities or assemblages. Following Fauth and others (1996) we define a community to include all species occurring together at the same time, and use the more restrictive term, assemblage, to refer to phylogenetically related species within a given community. There are several ecological principles at play within an aquatic community or assemblage of fishes. First, for any given species there generally are several other species that have similar habitat or resource requirements (Liem 1984). Second, there may be complex predator-prey relationships or competitive interactions where the presence of one species influences the presence of another (Chesson and Rosenzweig 1991; Sredl and Collins 1992; Winston 1995). Finally, the distribution of fish assemblages within stream networks is determined not only by environmental gradients in habitat features (Beecher and others 1988; Li and others 1987; Schlosser 1990, 1991), but also by temporal variability (Poff and Allan 1995; Schlosser 1990). Collectively, these interacting principles make analysis of fish assemblages both interesting and challenging.

Analytical Approach

The first step in our analysis was to identify distinct fish assemblages using the species presence/absence data collected at the watershed level. Association analysis was used, which is a monothetic, divisive, hierarchial scheme (Ludwig and Reynolds 1988). Association analysis is monothetic in that the presence/absence of single species is used to separate adjacent groups, divisive in that all units begin as a single group that is successively partitioned, and hierarchical in that lower level groups are exclusive subsets of parent groups at higher levels. Association analysis arose from the vegetation classification work of Goodall (1953). In the conventional application, one implicitly assumes that certain species are more sensitive to environmental factors controlling community structure. These species form the basis for the classification scheme (Coetzee and Werger 1975). We did not make this assumption. Instead, we looked for those species that had the highest level of association with other species, both positive



Map 4.7—Current distribution of brook, introduced rainbow, and brown trout by watershed, based on the assemblages database.

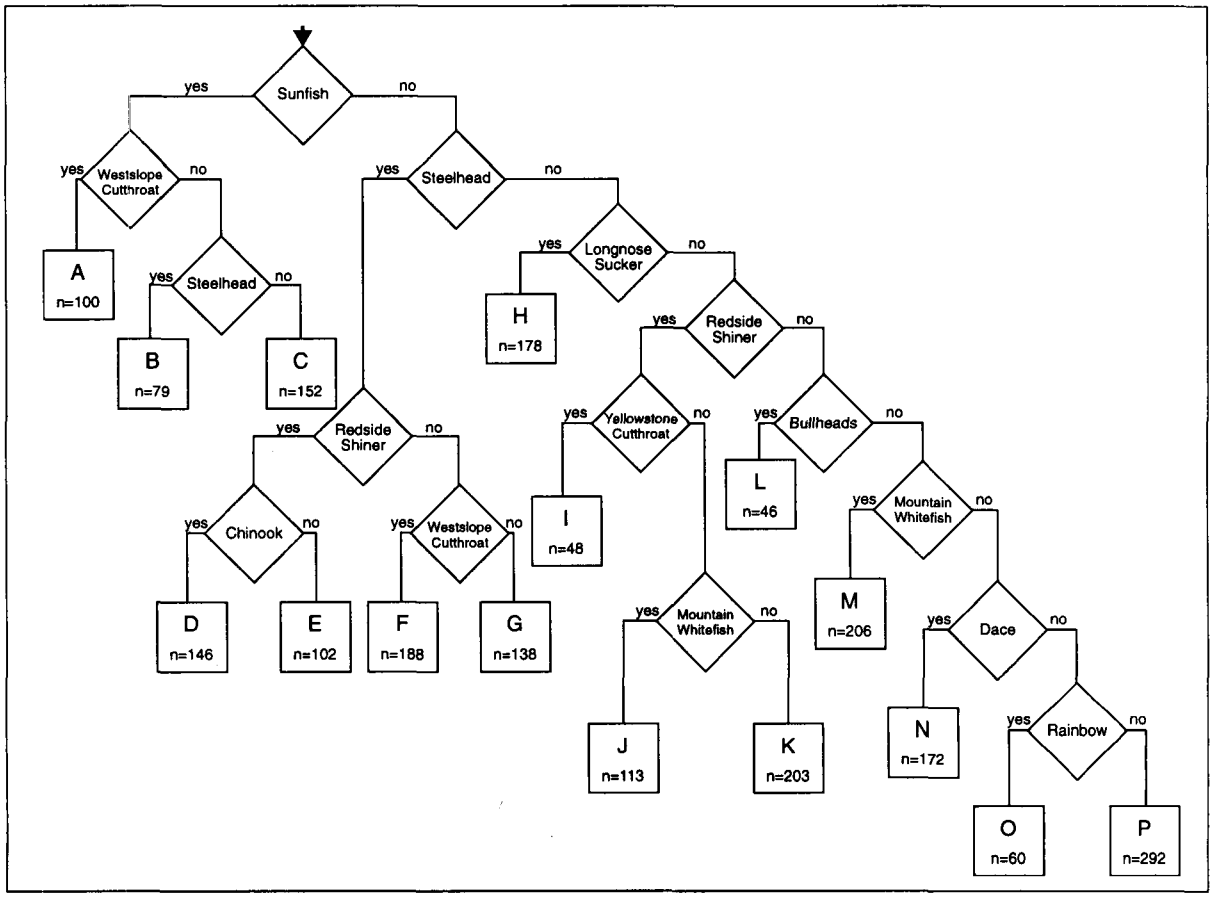


Figure 4.16. Dichotomous rule set for grouping observations based on the presence/absence of select taxa (diamonds) with the highest degree of association with other taxa. Assemblages (squares) are identified by alphabetic notation and described further in the text.

and negative, and used these associations to group watersheds. Our hope was that the resultant groupings of watersheds would suggest meaningful ecological patterns.

The 47 most frequently reported species and 15 composite groups composed of combinations of species (table 4.16) were used in the association analysis. We followed Ludwig and Reynolds (1988), except that we terminated the subdivisions at levels considerably above any of the alternative stopping rules proposed by Ludwig and Reynolds. Our intent was to keep a manageable number of species assemblages that would highlight important differences in species composition and distribution of assemblages. Thus, we did not subdivide groups of less than 150 observations, or where the maximum chi-square statistic for two potential groups was less than 500. All watersheds with at least two species reported were used, giving an initial sample size of 2,223 watersheds. The association analysis grouped the observations into 16 classes, which we identified with the letters A through P, using the dichotomous rule set illustrated in fig. 4.16.

Table 4.17—Summary statistics for 16 species assemblages identified in the association analysis

	Assemblage:															
Sample statistics	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**P**
sample size	100	79	152	146	102	188	138	178	48	113	203	46	206	172	60	292
mean number of taxa	19.9	26.2	16.6	14.9	10.5	9.0	8.1	12.1	11.9	11.0	7.4	10.5	7.0	5.0	2.8	3.6
mean number of groups	9.3	11.1	8.0	9.4	7.5	6.8	6.1	6.9	8.0	7.2	5.3	6.0	5.2	4.1	2.4	2.9
mean number of native tx.	10.5	13.7	7.6	11.7	8.8	6.9	6.0	9.0	8.3	7.8	5.7	6.2	4.8	3.6	2.2	1.6
mean number of exotic tx.	9.4	12.5	9.0	3.2	1.7	2.1	2.1	3.1	3.5	3.2	1.7	4.4	2.2	1.5	0.6	2.0
min taxa	8	12	2	7	4	3	2	7	7	5	2	2	2	2	2	2
max taxa	46	46	31	25	20	16	20	22	17	20	21	20	17	13	7	9
min groups	5	7	1	3	4	3	2	6	6	5	2	2	3	2	1	2
max groups	14	14	12	11	10	9	10	9	11	10	10	9	8	7	4	5
min native	1	4	0.0	5	4	2	2	4	4	5	1	0.0	2	1	1	0.0
max native	21	27	16	18	16	14	14	16	11	12	12	14	9	9	6	6
min exotic	3	4	1	0.0	0.0	0.0	0.0	1	1	0.0	0.0	1	0.0	0.0	0.0	0.0
max exotic	25	25	17	10	8	6	13	7	9	9	9	11	9	4	2	6
Diversity and Evenness*:																
total taxa	69	70	92	54	45	37	53	50	35	58	58	65	55	70	46	57
abundant taxa (T1)	36	48	41	29	23	16	25	23	21	27	23	40	21	24	25	14
very abundant taxa (T2)	30	42	32	23	18	13	18	19	17	20	16	27	14	15	16	8
taxa evenness	0.82	0.86	0.79	0.79	0.77	0.78	0.69	0.80	0.83	0.73	0.68	0.68	0.66	0.58	0.62	0.52
total native species	42	45	64	39	31	29	36	32	22	41	43	51	41	60	42	42
abundant native (N1)	20	30	24	23	18	14	19	17	13	19	17	34	17	21	24	13
very abundant native (N2)	17	25	18	19	15	11	14	14	12	14	12	25	11	12	15	7
native ratio (N1/T1)	0.56	0.62	0.59	0.80	0.81	0.85	0.75	0.73	0.64	0.69	0.72	0.85	0.79	0.85	0.96	0.94
native species evenness	0.81	0.84	0.73	0.81	0.80	0.76	0.73	0.82	0.86	0.74	0.69	0.71	0.65	0.53	0.62	0.47
composite index (Z)	0.71	0.81	0.66	1.00	1.0	1.0	0.85	0.92	0.85	0.79	0.77	0.94	0.79	0.70	0.93	0.68

* Reference: Hill, M.O. 1973. Diversity and evenness: a unifying notation and its consequences. Ecology. 54: 427-432.

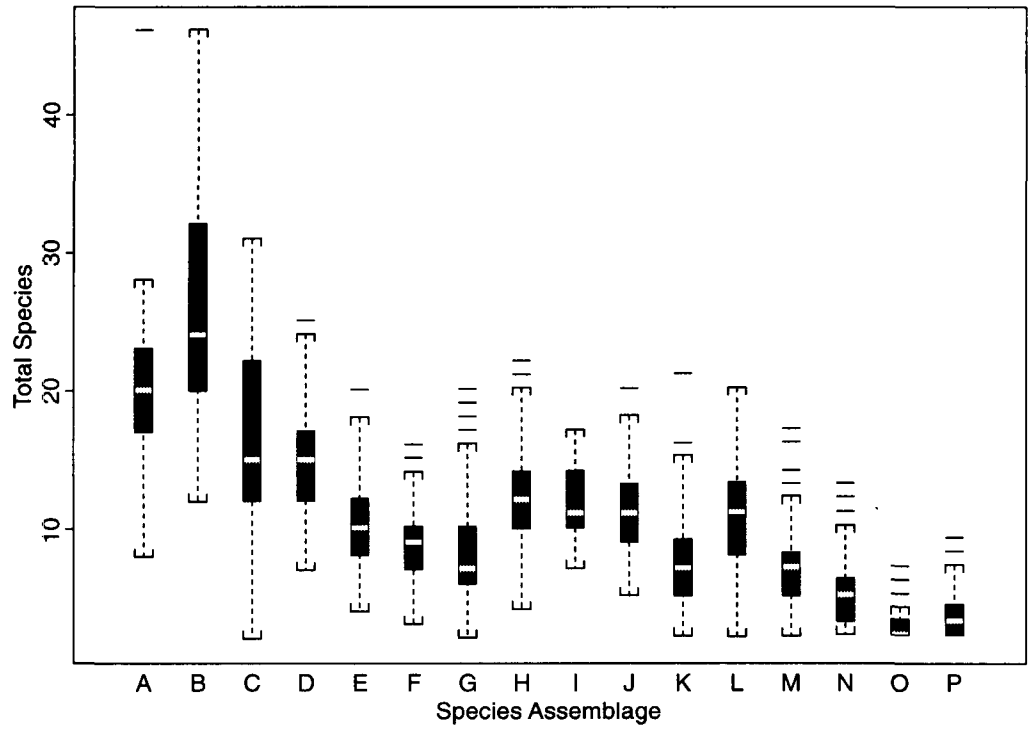


Figure 4.17—Box and whisker plots illustrating the distribution of total species across watersheds grouped according to the rules developed in the association analysis. The horizontal line in the interior of the box represents the median, the box height equals the interquartile distance, and the dotted lines extend to the extreme values of the data. Data points outside the dotted lines may be outliers and are indicated by horizontal lines.

The full complement of species information was summarized for each fish assemblage in a number of ways. First, we calculated basic summary statistics for all species, composite groups, native species, and introduced species (table 4.17), and plotted the distribution of total species per sample within each assemblage (fig. 4.17). Diversity indices were calculated by treating the total sample for each assemblage as a single observation and using the frequency counts as abundance measures, adapting Hill's (1973) approach as presented in Ludwig and Reynolds (1988) (see also Alatalo 1981; Peet 1974). Though unconventional, this approach was consistent with the view of diversity indices as simple, comparative measures that attempt to incorporate both richness and evenness into a single value. For comparative purposes, we also devised a single composite index from the measures of abundant taxa (T1), abundant natives (N1), and very abundant natives (N2). Our index (Z) is defined as

$$Z' = (N1/T1) * (N2-1)/(N1-1),$$

$$\text{then } Z = Z' / Z'max,$$

which is the ratio of abundant native species to abundant taxa, times native evenness, scaled by the maximum observed value (Z'max) of the intermediate product (Z'). This index incorporates elements of native species abundance relative to non-natives, and evenness, that is, uniformity in distribution, among native species. The intermediate product, Z', approaches one as T1, N1, and N2 become more similar. Dominant species and groups, that is, those reported in 80 percent or

Table 4.18—Dominant taxa found within 16 species assemblages identified in the association analysis.

Assemblage	A	B	C	D	E	F	G	H
Species:	Largescale sucker	Chiselmouth	Rainbow	Sculpin, generic	Redside shiner	Sculpin, generic	Interior redband	Longnose sucker
	Northern squawfish	Northern squawfish	Northern squawfish	Interior redband	Westslope cutthroat	Summer steelhead	Largescale sucker	
	Redside shiner	Summer steelhead	Redside shiner	Summer steelhead	Rainbow	Westslope cutthroat		
	Westslope cutthroat	Mountain whitefish	Interior redband	Summer steelhead	Rainbow			
	Rainbow	Bluegill	Summer steelhead	Stream-type chinook	Mountain whitefish			
	Mountain whitefish	Smallmouth bass	Stream-type chinook	Bull trout	Brook trout			
	Pumpkinseed	Largemouth bass	Mountain whitefish					
	Largemouth bass	Carp						
	Yellow perch							
	Brook trout							
Groups:	Suckers	Suckers	Suckers	Suckers	Suckers	Sculpins	Trout	Suckers
	Sculpins	Dace	Sculpins	Dace	Dace	Cutthroat	Steelhead	Sculpins
	Shiners	Sculpins	Bullheads	Sculpins	Sculpins	Trout	Rainbow (all)	Cutthroat
	Cutthroat	Trout	Trout	Shiners	Shiners	Steelhead	Trout	
	Trout	*Whitefish*	*Rainbow (all)*	*Trout*	*Trout*	*Rainbow (all)*	*Whitefish*	
	Whitefish	Steelhead	Sunfish	Whitefish	Steelhead	Chinook	Rainbow (all)	
	Rainbow (all)	Rainbow (all)	Steelhead	Rainbow (all)				
	Sunfish	Chinook	Rainbow (all)					
	Sunfish	Chinook						

Assemblage	I	J	K	L	M	N	O	P
Species:	Utah sucker	Redside shiner	Redside shiner	Rainbow	Mountain whitefish	none	none	Rainbow
	Speckled dace	Rainbow	Brown bullhead					
	Redside shiner	Mountain whitefish						
	Yellowstone cutthroat							
	Brook trout							
Groups:	Suckers	Suckers	Dace	Bullheads	Sculpins	Dace	none	Trout
	Dace	Dace	Shiners	Trout	Trout	Trout		Rainbow (all)
	Sculpins	Sculpins	Trout	Rainbow (all)	Whitefish			
	Shiners	Shiners						
	Cutthroat	Trout						
	Trout	Whitefish						
	Rainbow (all)							

more watersheds, were also identified for each assemblage (table 4.18). Species assemblages were spatially mapped (map 4.8) and cross-referenced with ERU.

One of the more interesting summaries generated was a plot of native species versus non-native species for each assemblage (fig. 4.18). Each point in figure 4.18 corresponds to an individual watershed. The diagonal line corresponds to points where the number of native species equals the number of non-native species. Points above the diagonal correspond to areas where native species outnumber non-native species; points below the line are areas where the reverse is true. Assemblages exhibiting a majority of points well above the diagonal indicate areas of relatively high native-species integrity.

Characterizations

Data generated by the association analysis provide a rather formidable array of information (table 4.18). To help summarize this information, we provide a brief characterizations of each assemblage.

Assemblage A—These watersheds are found primarily in the Northern Glaciated Mountains, the Lower Clark Fork and Upper Clark Fork, outside the range of anadromous fishes. The watersheds generally contain a high number of fish species, many of them non-native. Species composition consistently includes fish with a wide range of temperature tolerances, suggesting a mix of larger rivers and reservoirs with smaller, cold-water streams.

Assemblage B—These watersheds are found primarily in the Columbia Plateau, Blue Mountains, and Northern Glaciated Mountains, within the range of anadromous fish. The watersheds display the highest taxa diversity and evenness and generally contain many species—many of which are non-native. Dominant species include anadromous steelhead and chinook salmon, several warm-water gamefish, and carp, suggesting that these are larger rivers, and perhaps migration corridors for anadromous fish.

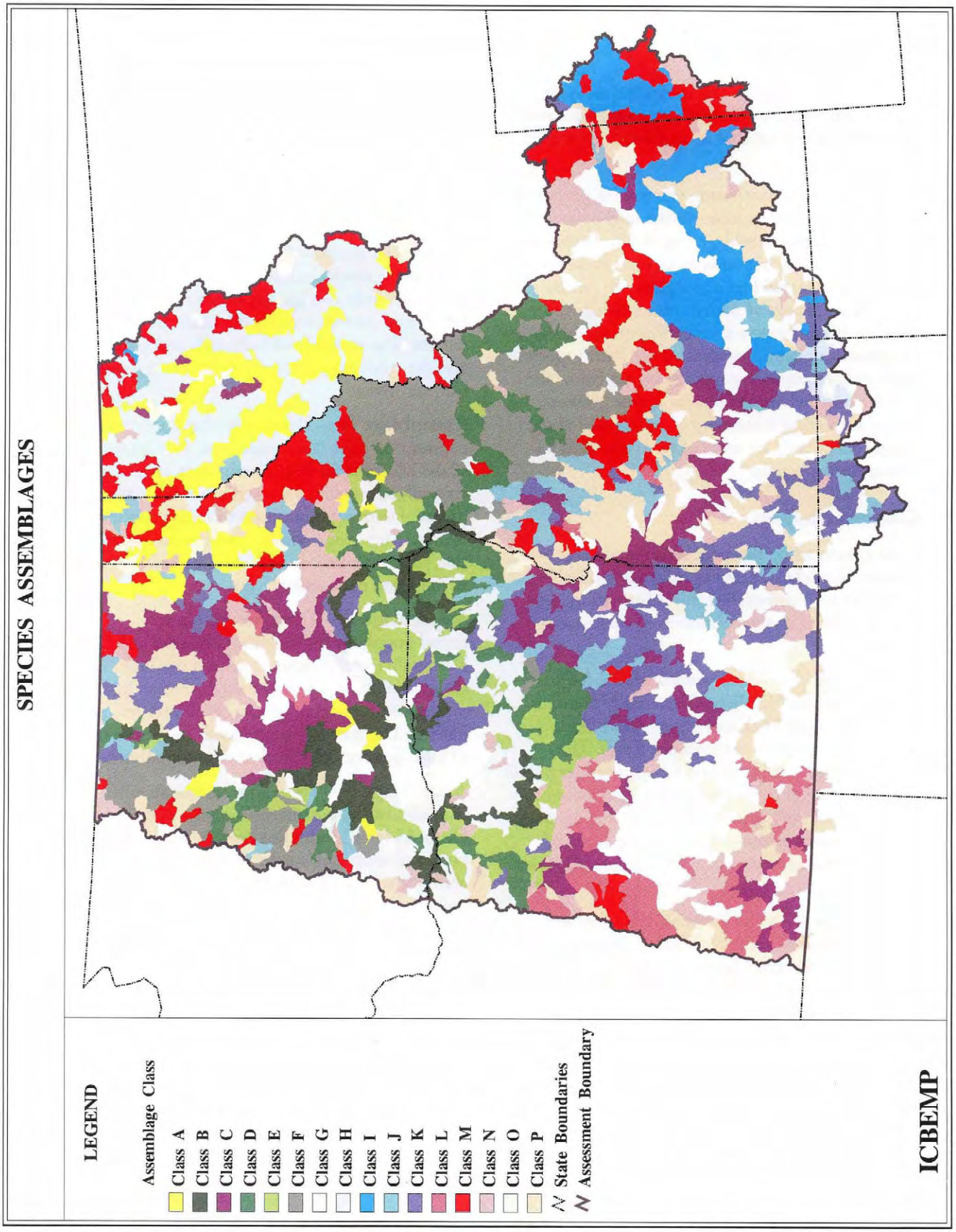
Assemblage C —These watersheds are scattered throughout the Basin, but are most common in the Columbia Plateau, Northern Glaciated Mountains, and the Owyhee Uplands generally outside the range of anadromous fish. The watersheds include the highest total taxa and show high taxa diversity, yet have only one dominant species (introduced rainbow trout) and relatively few dominant groups. In addition, these watersheds are one of only two groups where the mean number of non-natives exceeds the mean number of natives. The presence of bullheads and sunfish, and the relative absence of native trouts suggests warmer rivers.

Assemblage D—These watersheds are most common in Blue Mountains and the Central Idaho Mountains, and contain both steelhead and chinook salmon. The watersheds exhibit high diversity with high numbers of native species and relatively few non-natives. The species' composition suggests a mix of high-quality, cold-water streams and cool-water rivers.

Assemblage E—These watersheds are found mainly in the Columbia Plateau and Blue Mountains, and contain steelhead but lack chinook salmon. The watersheds tend to have moderate numbers of species, with very few non-natives. The species' composition suggests a mix of high-quality, cold- and cool-water habitats.

Assemblage F—These watersheds are most common in the Northern Cascades and the Central Idaho Mountains, within the overlapping ranges of westslope cutthroat trout, steelhead, chinook salmon, and bull trout. The watersheds include predominately native species, mostly salmonids and sculpins that are typical of cold-water habitats, with relatively low diversity.

Assemblage G—These watersheds are scattered through the Northern Cascades, Southern Cascades, Columbia Plateau, Blue Mountains, and Central Idaho Mountains. The watersheds include the fewest total species and highest percentage of non-natives among the cooler-water assemblages that contain steelhead. Redband trout and steelhead are the only dominant species.



Map 4.8—Spatial distribution of the 16 species assemblages identified in the association analysis by watershed.

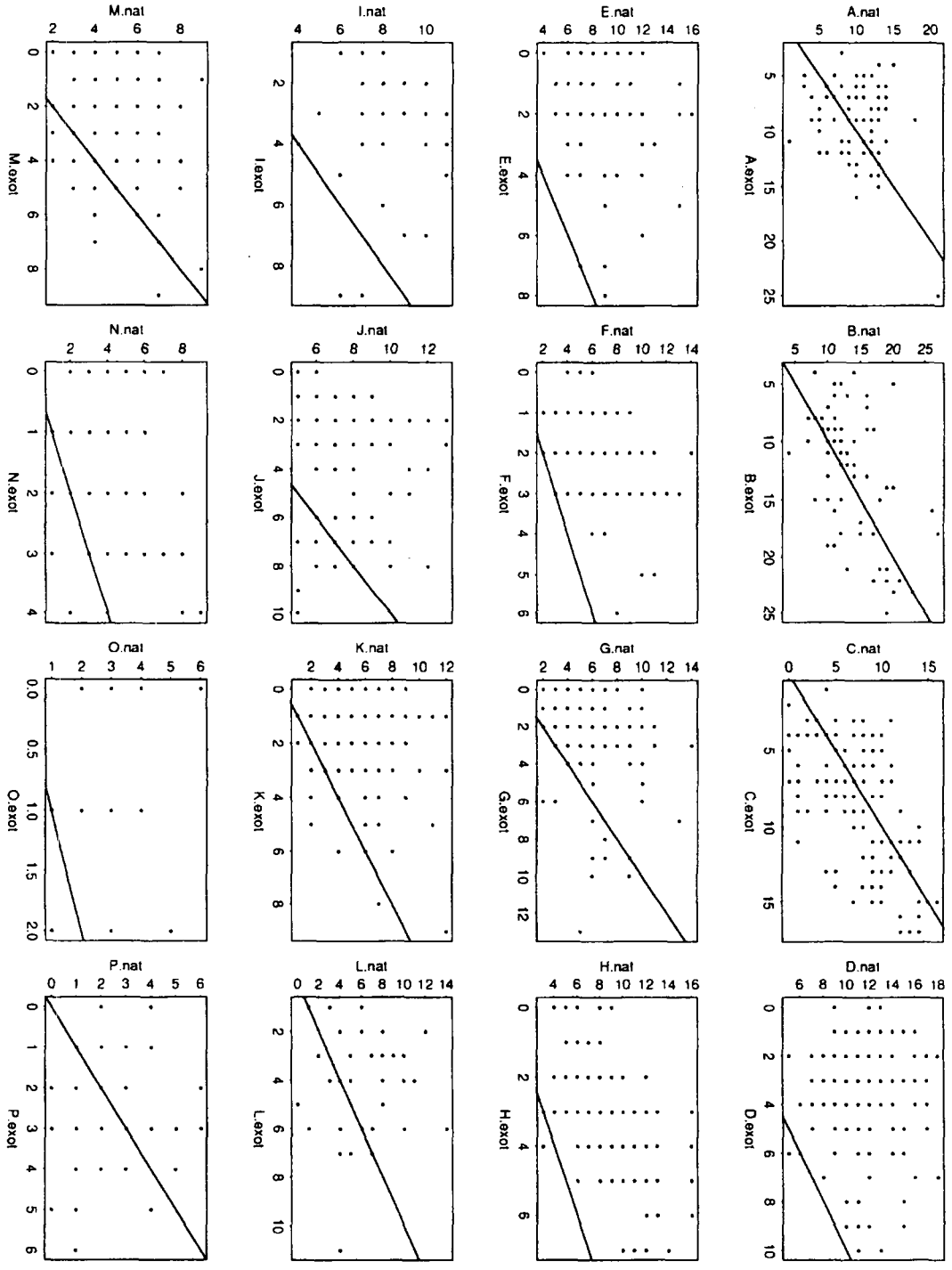


Figure 4.18—Plots of native species versus introduced species for each watershed within each of the 16 species assemblages. The diagonal line corresponds to points where the number of natives equals the number of introduced species.

Assemblage H—These watersheds are found primarily in the Northern Glaciated Mountains, the Lower Clark Fork, and the Upper Clark Fork, outside the range of anadromous fish. They are distinguished by the presence of longnose suckers. They exhibit moderate numbers of species, predominately natives, though introduced rainbow and brook trout are common. The species mix and spatial distribution suggest mid- to higher-elevation, cold- and cool-water streams.

Assemblage I—These watersheds are found in the Upper Snake and Snake Headwaters, within the range of Yellowstone cutthroat trout. The watersheds contain moderate numbers of species, mostly natives, but a relatively high ratio of non-natives for the given species mix.

Assemblage J—These watersheds are scattered throughout the Basin, excluded only from the Southern Cascades and Upper Klamath. The watersheds exhibit moderate numbers of species and diversity, with a fair number of introduced fishes. Dominant species include redside shiners, mountain whitefish, and introduced rainbow trout, suggesting cool-water rivers or transitional areas.

Assemblage K—These watersheds are found most commonly in the Owyhee Upland, and scattered throughout the rest of the Basin. The watersheds exhibit high variability in species counts that are lower than average. Numbers of non-natives are low, but occasionally exceed native counts. Assemblage K is distinguished from Assemblage J by lack of mountain whitefish.

Assemblage L—These watersheds are found in the Southern Cascades, Upper Klamath, Northern Great Basin, and Columbia Plateau. The two dominant species are non-native bullhead and introduced rainbow trout. Non-native species often outnumber native species. Despite this apparent contradiction, the watersheds are very high in native species diversity and native ratio, suggesting a relatively diverse native fauna and fewer, but widespread non-native species.

Assemblage M- These watersheds are found mainly in the Northern Glaciated Mountains, the Snake Headwaters, and the Central Idaho Mountains, but are scattered throughout other ERUs. The watersheds have low species counts, low diversity, and widespread non-natives. Mountain whitefish is the only dominant species, and is generally found in combination with trout and sculpins.

Assemblage N—These watersheds are scattered throughout the Basin, most commonly in the Columbia Plateau, and are excluded only from the Upper Clark Fork. Collectively, the watersheds contain a high total number of species, most of which occur only rarely. Mean counts and diversity are low. Trout and dace are the dominant groups, suggesting smaller, cold-water streams.

Assemblage O—These watersheds are scattered throughout the Basin and have very few species, averaging less than three per watershed. Given the distribution of this assemblage, it probably reflects areas that were incompletely sampled.

Assemblage P—The most abundant and widespread of all assemblages, other than unclassified, these are areas where introduced rainbow trout are known present but, in general, few other species were reported. Reported non-native species generally outnumber native species, though the ratio of abundant natives to abundant taxa is high. Low evenness suggests unequal distribution of species.

Rare and Sensitive Fishes

We prepared summary narratives for 39 rare or sensitive fish species in the Basin (next section). These fishes included federally listed endangered or threatened species, Category 1 Candidate species for Federal protection (the U.S. Fish and Wildlife Service deleted all Category 2 Candidate species from candidates for listing under the Endangered Species Act), taxa recognized for special protection by the states of Oregon, Washington, Idaho, Nevada, or Montana, taxa managed as sensitive species by the Forest Service and/or Bureau of Land Management,

and taxa recognized by the American Fisheries Society (Williams and others 1989) as warranting special management status because of rarity. Also included are coastal cutthroat trout and chum and coho salmon, which are regionally important but occupy only a small portion of the Basin, and Sunapee char, an introduced species that is extinct within its native range.

Our special status list includes white sturgeon (Acipenseridae), five lampreys (Petromyzontidae), sockeye, chum and coho salmon (Salmonidae), coastal and Lahontan cutthroat trout (Salmonidae), pygmy whitefish (Salmonidae), burbot (Gadidae), 11 minnows (Cyprinidae), six suckers (Catostomidae), and eight sculpins (Cottidae). Twenty-two of these taxa occur in the Great Basin and Klamath Basin portions of the assessment area. The Great Basin harbors 11 of these taxa, six occur in the Klamath Basin (excluding the Goose Lake Basin), and four in the Goose Lake Basin. Within the interior Columbia River Basin, eight taxa occur entirely or primarily in the mainstem Columbia River, four are restricted to the upper Snake River (including the Wood River), two are restricted to the Northern Glaciated Mountains, two occupy streams in the middle and upper Columbia River Basin, and one is restricted to the Blue Mountains of the middle Columbia River.

The problems facing these special-status fishes are similar to those facing most native fishes, but may be more acute because of their limited distributions and abundances (table 4.19). Hydroelectric development has disrupted movements of migratory forms. Irrigation diversions, water withdrawal, and the loss of wetlands, marshes, and interconnected waterways have radically altered habitats for many species, especially in arid regions. Timber harvest, mining, grazing, and urbanization have degraded the habitat of others through siltation, and increased temperatures, and eutrophication. Especially threatened are those species dependent on springs, such as the Foskett speckled dace, Hutton tui chub, and Shoshone sculpin. Introduced species are a prevalent threat, due to competition, predation, or hybridization.

Management of many special-status fishes may be hindered by a lack of even basic information on life history and habitat requirements. In many cases, we cannot be certain of the species' distribution, much less appreciate life history and habitat characteristics. Our most complete information is for the salmonids, or for a few select species that have attracted the attention of researchers.

Key Salmonids

In this section we summarize the current distribution, status, and biology of selected salmonids. We also consider the factors known to influence each species or form. Our knowledge of these species is necessarily limited to areas that have been sampled and recorded by biologists working throughout the basin. In an attempt to generate the most complete possible picture of the current distribution of these fishes we used the emergent patterns in distribution associated with landscape features to predict occurrence and status for unsampled areas.

Analysis Using Classification Trees

The relationships between the status and distribution of the seven key salmonids, the biophysical environment, and land management were explored quantitatively. We produced a set of predictions that reflect the likelihood of a species presence, or alternatively, the likely status of the population within a subwatershed. The predictions arose from statistical models, called classification trees, that elucidate the relationship between a set of predictor variables and a single response variable. In this section, we discuss the following: 1) the nature of the classification problem and classification trees 2) an example classification analysis of stream-type chinook salmon; 3) application and results for all seven species; and 4) a brief validation of results based on new information not used in the original analysis. We conclude this section with a general discussion of insights gained from the analysis.

Table 4.19—Key factors influencing status for rare and sensitive fish in the Basin.

	Key Risk Factors									
Species	Dams	Water quality	Water quantity	Harvest	Mining	Livestock	Forestry practices	Hatchery	Non-native interactions	Limited distribution
White sturgeon	X			X						
Klamath River lamprey	X		X							
River lamprey	X									
Pacific lamprey	X	X		X			X			
Goose Lake lamprey			X			X				
Pit-Klamath brook lamprey		X				X	X			
Sockeye salmon	X		X	X						
Chum salmon	X	X		X			X			
Coho salmon	X	X	X	X			X	X		
Coastal cutthroat trout				X			X	X	X	
Lahontan cutthroat trout		X	X			X			X	
Pygmy whitefish		X					X			
Burbot	X									
Sand roller		X							X	
Pit roach		X	X						X	
Alvord chub			X			X			X	
Borax Lake chub		X	X			X				X
Catlow tui chub			X			X				X
Oregon Lakes tui chub			X			X			X	
Summer Basin tui chub			X			X			X	X
Sheldon tui chub						X				X
Hutton tui chub		X				X				X
Leatherside chub			X		X	X	X			
Foskett speckled dace						X				X
Lost River sucker	X	X				X	X		X	
Wood River bridgelip sucker	X	X							X	
Warner sucker	X		X			X			X	
Goose Lake sucker	X	X	X			X	X			
Shortnose sucker	X	X				X	X		X	
Klamath largescale sucker	X	X	X			X	X		X	
Torrent sculpin		X	X			X	X			
Shorthead sculpin		X				X	X			
Pit sculpin		X				X	X			X
Slender sculpin		X							X	X
Margined sculpin		X				X	X			
Wood River sculpin		X	X			X			X	
Shoshone sculpin		X	X							X
Malheur sculpin		X				X	X		X	

Our primary objective in this analysis was to accurately predict fish presence or status using landscape features and management history. Ideally, this prediction should be based on a formal model that was developed in a rigorous and repeatable manner and that is accessible for review and validation. Better still, the model should rely on empirical data and provide a quantitative measure of the confidence that can be placed in our predictions.

We began by stating the problem in statistical terms, and for simplicity, considered the problem simply as one of predicting the presence of a species based on a set of predictor variables. We let y denote the response variable, presence, which could assume the values, P for present, or A for absent. Let $x_1, x_2, ..., x_k$ denote the set of k predictor variables, which are undefined for now, but which may include both continuous and discrete measures. Thus, we sought a model that can be expressed as:

$$\text{Prob}(y = P) = \text{fn}(x_1, x_2, , ..., x_k),$$

which reads as, "the probability that y equals P is a function, fn, of predictor variables x_1, x_2, through x_k. By definition, Prob(y = A) = 1 - Prob(y = P)." The function, fn(x), might assume a variety of forms, for example, simple constants, linear or nonlinear functions, or complex rule sets.

There are a variety of statistical approaches that might be suitable. Logistic regression is perhaps the more familiar approach (for example, Hosmer and Lemeshow 1989), but assumes a specific functional form of the model that requires the predictor variables to enter the model in a linear, or additive fashion. Furthermore, finding the best subset of predictors from a large set of potential predictor variables or incorporating multiple interactions is problematic. The limitations of logistic regression are more acute as the number of levels in the response variable increases. Logistic regression and other log-linear models have the advantage, however, of a large literature on the procedures and statistical inference for such models.

Tree-based models are one alternative to linear models that offer certain advantages (see Breiman and others 1984, Clark and Pregibon 1992, Crawford and Fung 1992, and Taylor and Silverman 1993; the following explanation is based principally on Clark and Pregibon 1992). First, where the set of predictor variables includes both continuous and discrete variables, tree-based models may be easier to interpret. Second, tree-based models are insensitive to monotonic transformations of the predictor variables, relying solely on the rank ordering of variables. Third, tree-based models are more adept at capturing non-additive behavior. The disadvantage of classification trees is that they are of limited utility for drawing statistical inferences. Thus, their primary uses are for building predictive models or data exploration, rather than testing of specific hypotheses.

For categorical response variables, tree-based models result in classification trees, so named because of the branching diagrams used to display the models which resemble inverted trees. To build a classification tree, one generates a dichotomous rule set through a process of recursive partitioning. Recursive partitioning involves sequentially splitting the data set into more homogeneous units, relative to the response variable, until a predefined measure of homogeneity is reached or no further subdivision is desired or feasible. Data are split at each juncture based on a single predictor variable that produces the greatest differences between the two resultant groups of observations. Predictor variables can be reused again at subsequent splits. The objective of the classification algorithm is to derive a terminal set of nodes, each containing a subset of the original data, where the distribution of the response variable is independent of the predictor variables to the greatest extent possible.

Details of the algorithm used to build the classification trees can be found in Clark and Pregibon (1992) and Statistical Sciences (1993).

Example Classification Tree Analysis—The process of developing a suitable classification tree requires several iterative steps. Some steps require professional judgement, beginning with the selection of the variables to include in the analysis. For previous analysis the derivation of meaningful response measures and a useful set of predictor variables was presented. Here, we describe our classification tree analysis using data on stream-type chinook salmon to illustrate the general procedure that we followed for each species.

Building a Classification Tree—All analyses involving classification trees were performed using the Splus®[2] programming language, following the procedures outlined in Clark and Pregibon (1992). Status of stream-type chinook salmon *(stc)*, was used as the response. Four possible values indicated whether the species was absent (A), present at depressed levels (D), present at strong levels (S), or used the subwatershed as a migration corridor (M). Twenty-nine of the potential predictor variables were made available to the model; *anadac* was excluded since the analysis was restricted to only those subwatersheds accessible to anadromous fish (see table 4.12).

The tree-fitting routine produced a full model that used 22 of the 29 potential predictors available to it. Excluded from the model were *alsi2*, *alsi4*, *bank*, *baseero*, *con2*, *drnden*, *hk*, *roaddn*, and *slope*. The model had 64 terminal nodes and an overall misclassification rate of 11.7 percent; predicted values did not match observed values for 147 of the 1,262 observations used to fit the model. While misclassification rate makes intuitive sense, statisticians generally prefer deviance as a measure of model performance and as a criterion for splitting nodes. Simply stated, deviance refers to the degree of homogeneity within a node. A set of identical observations, for example, would have zero deviance.

Cross-validation and Pruning—Many nodes near the termini of the full tree added little to change the predictions or reduce the deviance. This is typical of an over-fitted tree, which is produced intentionally. The next step was to prune the tree by removing the least important nodes. One consideration in tree pruning was to make a fairly robust tree, that is, one that performed well in making predictions using data not used to fit the tree. This posed something of a dilemma. We had limited data, and we wanted our tree to reflect the full expression of relationships found in all available data. Thus by holding out a subset of data for testing the model, we risked missing an important relationship that might exist in the subset, but is not reflected in the sample used for fitting.

To address this problem, Breiman and others (1984) developed a process of cross-validation which uses the full set of observations to build the full model, and mutually exclusive subsets of the data iteratively to prune and test the tree. Cross-validation produces a plot of the residual deviance of a successive set of trees of different sizes. The optimal tree size (minimum deviance) is suggested by the low point on the graph. This is the tree size that shows the highest out-of-sample prediction rate. For our example using stream-type chinook salmon, a tree with 26 nodes seemed appropriate. A smaller tree may predict responses equally well, but we chose to keep the additional nodes for the insight they provide. Sometimes, a higher residual deviance may be preferable if the larger tree adds to interpretation, or better discriminates between particular responses of interest such as distinguishing strong and depressed populations.

The reduced or pruned tree is presented in table 4.20. Figure 4.19 displays the rule set as an inverted tree. The letter within each node reflects the predicted value at that node. Part A of table 4.20 lists the variables used in the reduced tree and summarizes overall performance. Note that decreasing the size of the tree increased the overall misclassification rate to 16.7 percent. Part B of table 4.20 provides a complete listing of the tree structure and identifies each node, the variables and ranges defining each split, the number of observations, the deviance, the modal response, and the relative frequencies of each response level

[2]Splus is a registered trademark of Statistical Sciences Inc.

Table 4.20—The pruned classification tree relating status of stream-type chinook salmon to landscape variables.

A. Summary

Variables actually used in tree construction:

hucorder	pprecip	dampass	streams	mtemp	eru
mngclus	alsi1	solar	alsi3	con3	

Number of terminal nodes: 26

Residual mean deviance: 0.8282 Misclassification error rate: 0.1672 = 211 / 1262

B. Tree structure

Node) Split criterion	Sample size	Deviance	Mode	Relative Frequencies Absent	Depressed	Migration	Strong
1) root	1262	2718.00	A	0.43900	0.36450	0.190200	0.006339
2) hucorder < 30	991	1652.00	A	0.54990	0.41370	0.028250	0.008073
4) hucorder = 0	500	622.40	A	0.75800	0.22200	0.020000	0.000000
8) pprecip < 601	145	93.04	A	0.92410	0.03448	0.041380	0.000000 *
9) pprecip > 601	355	473.80	A	0.69010	0.29860	0.011270	0.000000
18) dampass < 4	23	13.59	D	0.08696	0.91300	0.000000	0.000000 *
19) dampass > 3	332	418.60	A	0.73190	0.25600	0.012050	0.000000
38) streams < 23	145	112.40	A	0.88280	0.11030	0.006897	0.000000 *
39) streams > 23	187	274.20	A	0.61500	0.36900	0.016040	0.000000
78) mtemp < 6.9	158	242.70	A	0.54430	0.43670	0.018990	0.000000
156) streams < 43.6	122	177.00	A	0.63110	0.35250	0.016390	0.000000
312) pprecip < 960.7	52	50.68	A	0.84620	0.13460	0.019230	0.000000 *
313) pprecip > 960.7	70	106.00	D	0.47140	0.51430	0.014290	0.000000 *
157) streams > 43.6	36	49.04	D	0.25000	0.72220	0.027780	0.000000
314) streams < 64.1	31	32.40	D	0.12900	0.83870	0.032260	0.000000 *
315) streams > 64.1	5	0.00	A	1.00000	0.00000	0.000000	0.000000 *
79) mtemp > 6.9	29	0.00	A	1.00000	0.00000	0.000000	0.000000 *
5) hucorder > 0	491	841.50	D	0.33810	0.60900	0.036660	0.016290
10) eru: 5,7	116	117.80	A	0.81900	0.17240	0.008621	0.000000
20) mngclus: BR,PA,PF,PR	106	85.95	A	0.87740	0.11320	0.009434	0.000000
40) alsi1 < 1.56	77	18.55	A	0.97400	0.02597	0.000000	0.000000 *
41) alsi1 > 1.56	29	45.20	A	0.62070	0.34480	0.034480	0.000000 *
21) mngclus: FG,FH,FM,TL	10	10.01	D	0.20000	0.80000	0.000000	0.000000 *
11) eru: 1,2,6,13	375	568.10	D	0.18930	0.74400	0.045330	0.021330
22) mngclus :BR,PA,PR	68	129.60	A	0.45590	0.44120	0.102900	0.000000
44) mtemp < 10.54	62	94.79	A	0.50000	0.48390	0.016130	0.000000 *
45) mtemp > 10.54	6	0.00	M	0.00000	0.00000	1.000000	0.000000 *
23) mngclus: FG,FH,FM,FW,PF,TL	307	394.20	D	0.13030	0.81110	0.032570	0.026060
46) dampass < 4	56	82.10	D	0.10710	0.75000	0.000000	0.142900
92) solar< 330.6	30	8.77	D	0.03333	0.96670	0.000000	0.000000 *
93) solar > 330.6	26	53.37	D	0.19230	0.50000	0.000000	0.307700
186) pprecip < 535.2	10	13.86	A	0.50000	0.50000	0.000000	0.000000 *
187) pprecip > 535.2	16	22.18	D	0.00000	0.50000	0.000000	0.500000 *
47) dampass > 4	251	280.20	D	0.13550	0.82470	0.039840	0.000000
94) hucorder <4	130	149.20	D	0.22310	0.76920	0.007692	0.000000 *
95) hucorder > 3	121	105.00	D	0.04132	0.88430	0.074380	0.000000
190) mngclus: FG,FM	51	0.00	D	0.00000	1.00000	0.000000	0.000000*
191) mngclus: FH,FW,PF	70	88.31	D	0.07143	0.80000	0.128600	0.000000*
3) hucorder > 29	271	334.40	M	0.03321	0.18450	0.782300	0.000000
6) hucorder < 58	74	138.00	M	0.09459	0.39190	0.513500	0.000000
12) eru: 5,7	10	12.22	A	0.70000	0.00000	0.300000	0.000000 *
13) eru: 1,6,13	64	88.16	M	0.00000	0.45310	0.546900	0.000000
26) alsi3 < 59.7	52	65.73	M	0.00000	0.32690	0.673100	0.000000
52) alsi1 < 0.37	9	6.28	D	0.00000	0.88890	0.111100	0.000000 *
53) alsi1 > 0.37	43	44.12	M	0.00000	0.20930	0.790700	0.000000 *
27) alsi3 > 59.7	12	0.00	D	0.00000	1.00000	0.000000	0.000000 *
7) hucorder > 57	197	155.60	M	0.01015	0.10660	0.883200	0.000000
14) dampass < 3	16	19.87	D	0.00000	0.68750	0.312500	0.000000*
15) dampass > 2	181	99.13	M	0.01105	0.05525	0.933700	0.000000
30) con3 < 0.49	90	19.18	M	0.02222	0.00000	0.977800	0.000000*
31) con3 > 0.49	91	63.00	M	0.00000	0.10990	0.890100	0.000000*

* denotes terminal node

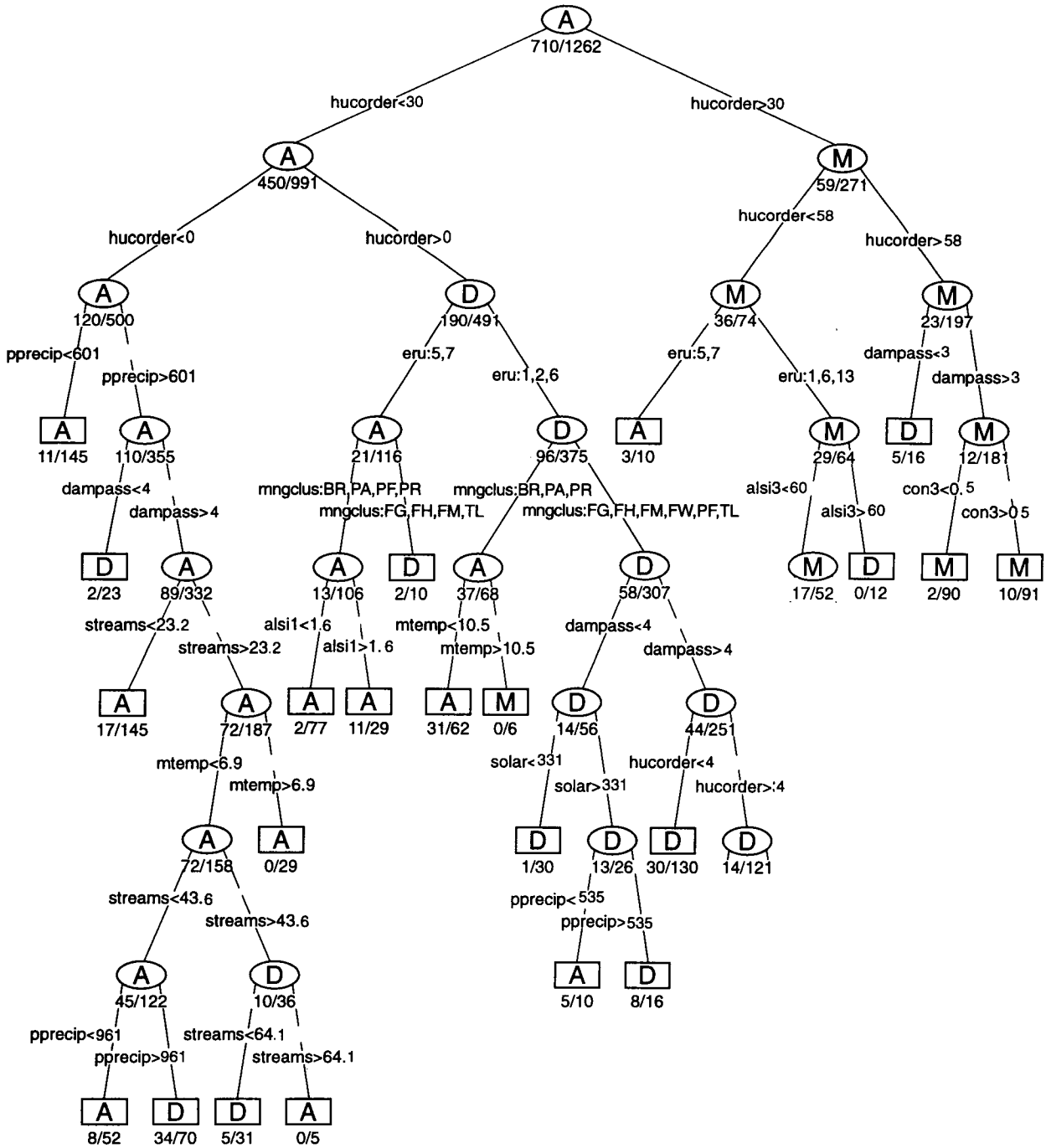


Figure 4.19—Graphical representation of pruned classification tree for stream-type chinook salmon. Each split is labeled with the appropriate predictor variable and splitting values. Letter designations within each node indicate the modal value at that node. The misclassification rate is shown under each node.

at that node. When used in a predictive fashion, these frequencies are equivalent to a probability of a given response. Normally, the modal response is equivalent to the predicted value. With the status data, however, three of the responses indicate different levels of presence, in contrast to a single absent value. Thus, we choose to predict absence only when the relative frequency was greater than or equal to 0.5. Otherwise, the predicted response was M, D, or S, whichever had the highest probability. The probability of presence was defined as one minus the probability of absence.

Prediction and Accuracy—Table 4.21 presents a cross-classification table of our predicted responses versus the observed response for all 1,694 observations in the data set. (Note that the 432 observations judged present-unknown or unknown were not used to build the tree.) The table shows both the accuracy of the predictions and the direction of the errors. Of primary interest are the diagonal cells of the top four rows, beginning in the upper left corner. For the diagonals, the row percentage indicates what percentage of the true values that were correctly predicted. Similarly, the column percentages indicate what fraction of our predictions was actually true. Row and column percentages can be quite different within a given cell. Which of these is more important depends on how the model is used. For predictive purposes, the column percentages perhaps are more mean-

Table 4.21—Cross-classification table of predicted versus observed values for stream-type chinook salmon. There are two or three values in each cell. The top value is the frequency, the second value is the row percentage, and the third is the column percentage for the top four rows.

	Frequency Row pct Column pct	Predicted Values				
		Absent	**Migration Corridor**	**Present - Depressed**	**Present - Strong**	**Total**
Observed Values	**Absent**	440 79.4% 89.4%	2 0.4% 0.9%	112 20.2% 20.7%	0 0.0% .	554 43.9%
	Migration Corridor	12 5.0% 2.4%	209 87.1% 90.9%	19 7.9% 3.5%	0 0.0% .	240 19.0%
	Present - Depressed	40 8.7% 8.1%	19 4.1% 8.3%	401 87.2% 74.3%	0 0.0% .	460 36.5%
	Present - Strong	0.0 0.0% 0.0%	0.0 0.0% 0.0%	8 100.0% 1.5%	0 0.0% .	8 0.6%
	Present - Unknown	198 68.0%	3 1.0%	90 30.9%	0 0.0%	291
	Unknown	67 47.5%	1 0.7%	73 51.8%	0 0.0%	141
	Total	757 44.7%	234 13.8%	703 41.5%	0 0.0%	1694

ingful because they indicate the probability that predictions are correct. For identifying relationships, row percentages may be more useful because they show the percentage of known observations that were correctly predicted by the model.

In the example using stream-type chinook salmon, the model does an excellent job of predicting all but present-strong responses within the data used to build the tree. Given that there were only eight (0.6%) present-strong responses in the complete data set, we would not expect the model to distinguish them easily. Yet, looking closely at node 187 in table 4.20 B reveals that all eight strong responses fell within a single node. For node 187, the probability of strong is 0.5. These observations are predicted to be depressed because the rules were set to choose "depressed" in case of a tie between strong and depressed. A second alternative would be to add a further split at this node that separates depressed from strong.

Application to the Seven Key Salmonids— The model building exercise outlined above for stream-type chinook salmon was repeated for ocean-type chinook salmon and steelhead. For the non-anadromous species, several modifications were made. *Dampass* was replaced in the list of potential predictors by *anadac*, indicating if an area was accessible to anadromous fish (which could have positive or negative consequences for resident fish) (see table 4.12). Two separate classification trees were built for each non-anadromous species. In the first analysis, migration corridors were combined with absent calls and a model built to predict status (A, D, or S) in only spawning and rearing areas. In the second analysis, migration corridors, present-depressed, and present-strong were combined into a single prediction, present. A model was then built using the binomial response, present or absent. In neither case were the present-unknown calls used in model building.

The resulting trees, following cross-validation and pruning, are summarized in table 4.22; further details are provided in appendix 4E. The trees ranged in size from 57 nodes for bull trout status, to 9 nodes for predicting Yellowstone cutthroat trout presence only. The size of the trees was roughly proportional to the areal extent of the species range, and thus to the degree of complexity expressed throughout the range. Yellowstone cutthroat trout and ocean-type chinook salmon had the most limited ranges and showed excellent fits with rather small trees. Redband and bull trout, which had much larger ranges, were more difficult to fit accurately, and showed the highest misclassification rates and residual mean deviances.

Cross-classification tables of status calls versus predicted status provide further insight into both the accuracy of the models, and landscape-fish relationships. For the anadromous species (table 4.23), the models did a good job of distinguishing absence, migration corridors, present-depressed, and present-strong. Errors followed a reasonable pattern. For example, absent was often confused with depressed and rarely confused with strong; strong was confused primarily with depressed. Note that the models recognized no ordinal relationships among the responses, *a priori*. Thus, to see reasonable patterns in the errors reinforces the conclusion that the models identified meaningful relationships.

Similar patterns were observed in the status predictions for non-anadromous species (table 4.24). Since migration corridors were grouped with the absent calls in model fitting, migration corridors should have been identified as absent. This pattern held true where significant numbers of migration calls existed, namely for bull and redband trout. While the overall success rates were favorable, increased inaccuracies occurred with the non-anadromous predictions. Localized factors such as hatchery stocking, fishing, or predation, and factors outside the watershed were not reflected in the predictor variables.

We also evaluated the predictive success by examining the mean probability of presence resulting from each model, calculated for each response level (table 4.25). For the anadromous species, the probabilities of presence were the sums of probabilities for migration corridor, present-depressed,

Table 4.22—Summaries of the classification trees developed for seven key salmonids.

Model	Bull trout			Westslope cutthroat			Yellowstone cutthroat			Redband trout		
Status												
Predictor Variables	*mtemp*	*con3*	*con1*	*eru*	*mtemp*	*solar*	*eru*	*solar*	*drnden*	*mngclus*	*mtemp*	*streams*
	roaddn	*elev*	*streams*	*mngclus*	*alsi1*	*pprecip*	*mtemp*	*hk*	*pprecip*	*slope*	*alsi3*	*elev*
	hucorder	*slope*	*alsi1*	*roaddn*	*elev*	*vmf*	*hucorder*	*ero*	*sdt1*	*bank*	*anadac*	*solar*
	vegclus	*bank*	*mngclus*	*hk*	*drnden*	*vegclus*				*vmf*	*vegclus*	*baseero*
	solar	*eru*	*slope2x*	*bank*	*sdt3*	*sdt1*				*hucorder*	*con3*	*ero*
	alsi3	*baseero*	*con2*	*alsi4*	*con2*	*hucorder*				*eru*	*pprecip*	*drnden*
	ero	*pprecip*	*vmf*	*sdt2*	*slope*						*con1*	
Terminal Nodes		57			37			11			35	
Residual Mean Deviance		0.83			1.00			0.79			1.14	
Misclassification Error Rate	0.184 = 500 / 2717			0.197 = 323 / 1640			0.1501 = 59 / 393			0.2426 = 435 / 1793		
Presence/Absence												
Predictor Variables	*slope*	*baseero*	*vegclus*	*eru*	*con2*	*bank*	*mtemp*	*hk*	*hucorder*	*pprecip*	*hucorder*	*anadac*
	hucorder	*bank*	*con3*	*slope2x*	*vegclus*	*drnden*	*solar*	*ero*	*con1*	*baseero*	*slope*	*drnden*
	elev	*alsi2*	*streams*	*sdt3*	*slope*	*streams*			*alsi3*	*eru*	*solar*	*sdt2*
	pprecip	*slope2x*	*drnden*	*mngclus*	*hk*	*hucorder*				*mtemp*	*alsi3*	*slope2x*
	eru	*mtemp*	*hk*	*elev*	*anadac*	*mtemp*				*bank*	*mngclus*	*streams*
	ero	*con1*	*anadac*	*ero*	*pprecip*					*hk*		
		con2										
Terminal Nodes		42			24			9			20	
Residual Mean Deviance		0.74			0.42			0.17			0.78	
Misclassification Error Rate	0.167 = 454 / 2717			0.075 = 123 / 1640			0.0204 = 8 / 393			0.086 = 155 / 1793		

Model	Steelhead			Ocean-type chinook			Stream-type chinook		
Status									
Predictor Variables	*hucorder*	*pprecip*	*sdt2*	*hucorder*	*ero*	*pprecip*	*hucorder*	*solar*	*mtemp*
	eru	*drnden*	*streams*	*vmf*	*elev*	*slope*	*pprecip*	*alsi3*	*eru*
	vmf	*vegclus*	*elev*	*dampass*			*dampass*	*con3*	*mngclus*
	slope	*alsi3*	*bank*				*streams*		*alsi1*
	baseero	*mngclus*	*con1*						
	solar	*hk*	*dampass*						
Terminal Nodes		35			12			26	
Residual Mean Deviance		0.58			0.43			0.83	
Misclassification Error Rate	0.114 = 154 / 1355			0.076 = 17 / 224			0.167 = 211 / 1262		

Table 4.23—Cross-classification of the observed status calls with the predicted values for three anadromous taxa. There are two or three values in each cell. The top value is the frequency, the second value is the row percentage, and the third is the column percentage for the top four rows.

	Frequency Row pct Col pct	Steelhead Predicted Values A	M	D	S	Total	Ocean-type chinook Predicted Values A	M	D	S	Total	Stream-type chinook Predicted Values A	M	D	S	Total
Observed Values	**Absent (A)**	124	1	53	0	178	89	1	2	1	93	440	2	112	0	554
		70%	1%	30%	0%		96%	1%	2%	1%		79%	0%	20%	0%	
		79%	0%	6%	0%	13.1%	93%	2%	4%	5%	41.5%	89%	1%	21%	.	44%
	Migration Corridor (M)	2	196	28	0	226	2	54	1	2	59	12	209	19	0	240
		1%	87%	12%	0%		3%	92%	2%	3%		5%	87%	8%	0%	
		1%	87%	3%	0%	16.7%	2%	96%	2%	10%	26.3%	2%	91%	4%	.	19%
	Present - Depressed (D)	30	29	870	2	931	5	0	47	0	52	40	19	401	0	460
		3%	3%	93%	0%		10%	0%	90%	0%		9%	4%	87%	0%	
		19%	13%	91%	15%	68.7%	5%	0%	90%	0%	23.2%	8%	8%	74%	.	36%
	Present - Strong (S)	0	0	9	11	20	0	1	2	17	20	0	0	8	0	8
		0%	0%	45%	55%		0%	5%	10%	85%		0%	0%	100%	0%	
		0%	0%	1%	85%	1.5%	0%	2%	4%	85%	8.9%	0%	0%	1%	.	1%
	Present - Unknown	61	8	210	0	279	9	3	3	1	16	67	1	73	0	141
		22%	3%	75%	0%		56%	19%	19%	6%		48%	1%	52%	0%	
	Unknown	68	8	191	0	267	44	2	2	3	51	198	3	90	0	291
		25%	3%	72%	0%		86%	4%	4%	6%		68%	1%	31%	0%	
	Total	285	242	1361	13	1901	149	61	57	24	291	757	234	703	0	1694
		15%	13%	72%	1%		51%	21%	20%	8%		45%	14%	41%	0%	

Table 4.24—Cross-classification of the observed status calls with the predicted values in spawning and rearing areas for four non-anadromous salmonids. Migration corridors were grouped with absent calls in building the models, but are separated here to demonstrate classification patterns. (For example, most migration corridors are predicted as absent for spawning and rearing bull trout.)

	Frequency Row pct Col pct	Bull trout Predicted Values A	D	S	Total	Westslope cutthroat Predicted Values A	D	S	Total	Yellowstone cutthroat Predicted Values A	D	S	Total	Redband trout Predicted Values A	D	S	Total
Observed Values	**Absent (A)**	1445	81	28	1554	165	84	22	271	97	3	1	101	685	132	8	825
		93%	5%	2%		61%	31%	8%		96%	3%	1%		83%	16%	1%	
		69%	17%	19%	57.2%	67%	8%	7%	16.5%	92%	2%	1%	25.7%	82%	18%	4%	46%
	Present - Depressed (D)	267	335	22	624	33	896	59	988	9	96	11	116	117	525	70	712
		43%	54%	4%		3%	91%	6%		8%	83%	9%		16%	74%	10%	
		13%	70%	15%	23.0%	13%	82%	20%	60.2%	8%	73%	7%	29.5%	14%	72%	31%	40%
	Present - Strong (S)	31	48	90	169	9	103	218	330	0	29	141	170	32	73	145	250
		18%	28%	53%		3%	31%	66%		0%	17%	83%		13%	29%	58%	
		1%	10%	61%	6.2%	4%	9%	73%	20.1%	0%	22%	91%	43.3%	4%	10%	65%	14%
	Migration Corridor (M)	344	18	8	370	38	12	1	51	0	4	2	6	3	2	1	6
		93%	5%	2%		75%	24%	2%		0%	67%	33%		50%	33%	17%	
		16%	4%	5%	13.6%	16%	1%	0%	3.1%	0%	3%	1%	1.5%	0%	0%	0%	0%
	Present - Unknown	322	71	45	438	106	272	193	571	45	26	12	83	807	761	449	2017
		74%	16%	10%		19%	48%	34%		54%	31%	14%		40%	38%	22%	
	Unknown	1065	116	56	1237	140	222	62	424	76	29	22	127	864	586	116	1566
		86%	9%	5%		33%	52%	15%		60%	23%	17%		55%	37%	7%	
	Total	3474	669	249	4392	491	1589	555	2635	227	187	189	603	2508	2079	789	5376
		79%	15%	6%		19%	60%	21%		38%	31%	31%		47%	39%	15%	

Table 4.25—Sample size (N) and estimated probability of presence for seven key salmonids, cross-referenced with observed status.

	Bull trout		Westslope cutthroat		Yellowstone cutthroat		Redband trout		Steelhead		Ocean-type chinook		Stream-type chinook	
Status call	N	Prob.	N	Prob.	N	Prob.	N	Prob.	N	Prob.	N	Prob.	N	Prob.
absent	1554	0.202	271	0.074	101	0.356	825	0.276	178	0.341	93	0.098	554	0.208
migration corrider	370	0.775	51	0.992	6	0.890	6	0.851	226	0.987	59	0.943	240	0.942
present - depressed	624	0.691	988	0.957	116	0.931	712	0.750	931	0.939	52	0.897	460	0.780
present - strong	169	0.771	330	0.986	170	0.933	250	0.806	20	0.980	20	0.980	8	1.000
present - unknown	438	0.554	571	0.363	83	0.809	2017	0.637	279	0.755	16	0.462	141	0.475
unknown	1237	0.303	424	0.413	127	0.660	1566	0.467	267	0.697	51	0.196	291	0.290

and present-strong from the status model. For non-anadromous species, the probabilities of presence were derived from the present/absent models. Again, the model results were consistent; the highest probabilities generally occurred with the present-strong calls and there was strong separation between the absent calls and any of the present calls. Migration corridors were also well defined, exhibiting the highest probability of presence for four of the seven species.

The predicted status and probability of presence where the status calls were present-unknown or unknown both have a lower overall likelihood of supporting populations than areas where we know that the species are present and their status. The fact that the mean probabilities of presence in present-unknown areas are consistently low across non-anadromous species may have more onerous implications. Model results suggest that these areas generally are less likely to support populations than areas where better information is available. Stated another way, unidentified, major population strongholds within the Basin are unlikely; if fish are there in abundance, we generally know of their presence. The predicted probabilities of presence are even less for the totally unknown areas. Other than for steelhead and Yellowstone cutthroat trout, unknown areas tend to resemble areas that do not support fish populations. Naturally, there are exceptions. Where unknown areas are expected to have strong populations of some species (for example, westslope cutthroat trout within the northern Cascades), these areas tend to be in proximity to areas where known populations are strong.

The classification trees were used to predict the status for each of the key salmonids in watersheds where the biologists' classifications were unknown or present-unknown. In the following section we summarize both the known and predicted occurrence and status for each of the seven salmonids. Some watersheds within the historical range of each fish do not have predictions, either because of missing landscape information or corrections in the original status call based on information obtained after predictions were made. The omissions include 14 watersheds for bull trout, 50 for Yellowstone cutthroat trout, five for westslope cutthroat trout, 127 for redband trout, 22 for steelhead, 8 for stream-type chinook salmon and 4 for ocean-type chinook salmon.

Interpretation of Classification Trees—We leave specific interpretations of tree structures to the species narratives that follow. There are two general issues to consider when examining the models. First, the models were not designed to draw strong inferences about linkages between specific watershed characteristics and species status. Our intent was to develop predictive models that would allow us fully to map the distribution and status of the key salmonids and to identify apparent relationships within the data, not test specific hypotheses. Other methods more conducive to testing hypotheses may be pursued in the future.

Second, although predictive variables were limited to a subset not strongly correlated throughout the Basin, spatially driven correlations were still present and may have been strengthened as the classification routine limited observations to smaller regions. Exploration of individual models demonstrated that several variables could often provide nearly equal power in discrimination. The first split in the bull trout model, for example, was based on mean temperature, although elevation, management cluster, and vegetation cluster performed nearly as well. Correlation in the predictive variables is likely because all tend to describe colder, higher-elevation, and steeper settings. Which variable or set of variables provide the more meaningful ecological interpretation is a subjective judgement. Rather than select the more interpretable variables from a subset of likely candidates at each node, we used the statistically optimal choice. This means that the relationships were not always easy to interpret.

The suite of predictor variables that emerged in the models can be broadly grouped into three categories as follows: 1) causal variables, such as solar radiation and road density, where one might

postulate a direct causal link between the variables and fish response; 2) correlative variables, such as the erosion index, that likely are responding to similar environmental drivers as fish; and, 3) serendipitous variables, those which show up unexpectedly as good predictors without an apparent ecological mechanism. The serendipitous relationships may represent a fruitful area for hypothesis generation and future research.

Overall, the patterns suggested by the classification trees were consistent with our understanding of salmonid biology and habitat use. Variables related to temperature, stream size, slope, vegetative cover and solar radiation commonly provided important discrimination in the analyses. Cooler temperatures, for example, generally suggested a higher likelihood of finding salmonids; the differences in splitting temperatures associated with bull trout (5.1° C), Yellowstone cutthroat trout (6.1° C), and redband trout (8°-10° C) are also consistent with differences in thermal preferences or tolerances suggested for these species from other work (for example, Mullan and others 1992). As a second example, the classification trees associated the distributions of steelhead and redband trout with steeper slopes, higher elevation, and higher solar radiation. Although redband trout are a cold-water salmonid, they exhibit higher temperature tolerances than others and, within limits, have shown increased production and abundance associated with canopy openings and increased solar radiation. Redband trout have also been found to use steeper gradient channels (Kunkel 1976).

The preponderance of physiographic and geophysical predictor variables within the models suggest that biophysical setting is an important determinant of species distributions and habitat suitability. Variables potentially reflecting the degree of human disturbance within watersheds (roads, management cluster, dams) were important in the distributions of bull trout, westslope cutthroat trout, steelhead, and both chinook salmon. *In no instances could increased disturbance of natural landscapes be interpreted as a positive effect.* The number of mainstem dams in the migratory corridor showed a consistent, negative impact on chinook salmon. Management cluster and road density, however, did not always produce better predictions for all species and no species were excluded from more intensively managed landscapes. However, the relative difficulty in distinguishing status, particularly between strong and depressed, indicates that other effects acting at different scales are important as well. For example, sampling and classification error potentially influenced model results, and many potentially important effects simply could not be represented in the analysis. We could not incorporate the potential effects of fishing, poaching, introduced species, or pollutants other than as surrogates tied to the intensity of land use. We could not incorporate information reflecting the size or spatial patterns in habitat patches that might influence the degree of fragmentation or connectivity among local populations.

The lack of a consistently strong influence of disturbance related variables in the classification trees cannot be construed as evidence that human related activities are not important for some species. A more refined analysis is necessary to explore the relative significance and covariance among the potentially important variables. The resolution in the summary of data may also mask some relationships. The loss of resolution in summarizing information at a subwatershed scale may mask important processes which occur primarily at finer scales characteristic of individual streams or stream reaches. Roughly 30% of all the subwatersheds defined in the Basin are not true watersheds, but represent composites including small tributaries and higher-order reaches of a mainstem stream or river. Because land disturbing activities are likely to be integrated across true watersheds (that is, the entire area drained above a point of interest), the characterization of disturbance within the higher-order watersheds that do not include the headwaters may not reflect the conditions that directly influence habitats and fish.

Validation—Additional fish-survey data became available after the analysis and predictions were completed. Rather than update the databases and redo the analysis, we used the new information as a simple check of the status calls and classification-tree predictions. The new data were made available from fish surveys conducted by the Plum Creek Timber Co. on streams draining their lands in Washington, Idaho, and Montana; from recent updates of the Washington Streams and Lakes database maintained by the Washington Department of Fish and Wildlife; and from fish surveys by the Oregon Department of Fish and Wildlife in the Klamath River basin. We summarized observations by subwatershed as in the original classification and we compared the summary directly with the model predictions for each subwatershed. Observations were available for 1,377 combinations of species and subwatersheds where we had existing status classifications, and 203 species-subwatershed combinations with unknown status. New information was available for all of the key salmonids except Yellowstone cutthroat trout.

Classification success can be judged by the relative frequency with which new data agreed with the status calls or predictions (table 4.26). Three patterns emerged. First, the new data agreed with the status calls more frequently than with the predictions. That pattern is expected simply from the error in predictions resulting from the inherent variability in distributions. Second, the agreement between the new data and status calls or predictions were consistently better for known absent or predicted absent than for known present or predicted present. That is, our models did a better job of anticipating where fish would not be found than where they would be found. Third, the lowest agreement rates occurred with known or predicted presence of the more rare taxa, specifically the anadromous species and bull trout. There are several possible interpretations. One is that these fish are simply less abundant or widespread than we estimate. Alternatively, it may be an artifact of sampling that was inadequate to detect species that were present, but in low abundance.

This comparison of our status classifications and predictions does not meet the standards of a rigorous validation, in that it was not applied systematically across the Basin. Nor are we confident that the new data fully reflect the species status of each subwatershed. Regardless, the general conclusion from this limited exercise is that there are likely errors in our distribution maps of key salmonids, but these errors are not so large as to compromise our general assessment. Errors are most likely in the model predictions, as with any model. Because predictions are probabilistic and based on the broad patterns of occurrence for each species, analysis of broad scale patterns summarized by ERU or subbasin will be little influenced by the errors. Results in subwatersheds, however, will vary. We emphasize our caution that local validation should always accompany the application of any of the distribution and status information in watershed or subwatershed-scale analysis, planning, and management.

Discussion of Key Salmonids Status, Distribution and Management

In this section we summarize the distribution and status of the seven key salmonids. Although we briefly review the biology and life history of each species, we focus on information relevant to the current condition of remaining populations and the factors influencing those populations.

Each species may exhibit a complex set of life-history patterns that include varying age-at-maturity, frequency and timing of spawning, age and seasonal timing and pattern of migration, longevity, habitat selection and a host of other characteristics. We have already noted major differences associated with the life histories of redband trout and steelhead, and chinook salmon. In the following discussion of each species we highlight important life-history characteristics but repeatedly recognize the variation in migratory patterns as a particularly important and well-known phenomenon. In the remaining portion of this chapter we use the nomenclature of anadromous, non-anadromous to refer to salmonids that do and do

Table 4.26—Cross-classification table of status calls (known present and known absent) and model predictions (predicted present and predicted absent) versus recently obtained data from three sources. Numbers refer to subwatersheds where fish were found or not found during sampling. Percentages refer to the agreement or disagreement between the new data and each staus call or prediction (for example, bull trout were found in 64.8% of sampled subwatersheds with previously known bull trout presence). Shaded cells highlight points of agreement.

Species		Data Source[1]	Known Present	Predicted Present	Known Absent	Predicted Absent
Bull Trout	found	WSL	78	0	2	7
		PC	21	1	0	1
		OK	54	0	0	0
		total	153	1	2	8
			64.8%	12.5%	2.6%	11.8%
	not found	WSL	28	1	17	29
		PC	15	2	16	11
		OK	40	4	41	20
		total	83	7	74	60
			35.2%	87.5%	97.4%	88.2%
Westslope Cutthroat Trout	found	WSL	67	3	4	2
		PC	50	4	1	0
		OK	17	0	0	0
		total	134	7	5	2
			71.3%	46.7%	50.0%	28.6%
	not found	WSL	43	6	5	5
		PC	11	1	0	0
		OK	0	1	0	0
		total	54	8	5	5
			28.7%	53.3%	50.0%	71.4%
Redband Trout	found	WSL	99	6	2	11
		PC	9	0	0	2
		OK	218	16	3	2
		total	326	22	5	15
			79.5%	56.4%	50.0%	53.6%
	not found	WSL	38	2	2	4
		PC	6	4	2	5
		OK	40	11	1	4
		total	84	17	5	13
			20.5%	43.6%	50.0%	46.4%
Steelhead	found	WSL	12	1	0	0
			12.8%	9.1%	0.0%	0.0%
	not found	WSL	82	10	36	2
			87.2%	90.9%	100.0%	100.0%
Ocean-type Chinook Salmon	found	WSL	4	0	2	2
			25.0%		10.0%	33.3%
	not found	WSL	12	0	18	4
			75.0%		90.0%	66.7%
Stream-type Chinook Salmon	found	WSL	23	0	2	2
		OK	38	0	1	0
		total	61	0	3	2
			40.1%	0.0%	2.3%	15.4%
	not found	WSL	48	4	45	3
		OK	43	2	83	8
		total	91	6	128	11
			59.9%	100.0%	97.7%	84.6%

[1]WSL=Washington streams and lakes database; PC=Plum Creek Timber Co. surveys for Washington, Idaho, and Montana; OK=Oregon Department of Fish and Wildlife surveys for the Klamath River Basin.

not migrate to and from the ocean, respectively. We recognize non-anadromous forms as resident or migratory.

Migratory populations include fluvial fish that migrate from larger streams into smaller tributaries to spawn and adfluvial fish that migrate from lentic waters to spawn in inlet or outlet tributaries.

Bull Trout (*Salvelinus confluentus*)—Bull trout are recognized as a species of special concern by state management agencies (Rieman and McIntyre 1993) and the American Fisheries Society (Williams and others 1989), and as a sensitive species by the Forest Service. Concern regarding the species' status is evident with their classification as a Category 1, Candidate Species, under the Endangered Species Act (listing warranted but precluded because of other species management priorities) [Federal Register June 12, 1995 (U.S. Government 1995)].

Currently bull trout are found in many major river systems within the Basin, but spawning and juvenile rearing are believed to be restricted to cold and relatively pristine waters. Headwaters of most basins still support populations. The fish species assemblages in higher elevation streams of the Basin are typically simple. Because bull trout are the only native char and often the only important piscivore, the loss of a bull trout population can represent a major loss of species diversity and ecological function.

Historical Distribution—The historical range of bull trout was restricted to North America (Cavendar 1978; Haas and McPhail 1991). Bull trout have been recorded from the McCloud River in northern California, the Klamath River basin in Oregon and throughout much of interior Oregon, Washington, Idaho, western Montana, and British Columbia. They occur east of the Continental divide in headwaters of rivers entering Hudson Bay, and in headwaters of rivers entering the Arctic Ocean. Except in the Little Lost and Big Lost rivers in Idaho, bull trout are not known to occur in the Snake River subbasin above Shoshone Falls.

Bull trout are believed to be a glacial relict (McPhail and Lindsey 1986), and their broad distribution has probably contracted and expanded periodically with natural climate change (Williams and others, in press). Genetic variation suggests an extended and evolutionarily important isolation between populations in the Klamath and Malheur Basins and those in the Columbia River basin (Leary and others 1993). Populations within the Columbia River basin are more closely allied and are thought to have expanded from common glacial refugia or to have maintained higher levels of gene flow among populations in recent geologic time (Williams and others, in press).

Our evaluation of the probable historical range of bull trout within the Basin is summarized in appendix 4D. We estimate the historical range for bull trout as about 60 percent of the Basin (table 4.27). It is unlikely that bull trout occupied all of the accessible streams at any one time. Distribution of existing populations is often patchy even where numbers are still strong and habitat is in good condition (Rieman and McIntyre 1993; Rieman and McIntyre 1995). Habitat preferences or selection is likely important (Dambacher and others, in press; Goetz 1994; Rieman and McIntyre 1995;) but more stochastic extirpation and colonization processes may influence distributions even within suitable habitats (Rieman and McIntyre 1995).

Even though bull trout may move throughout whole river basins seasonally, spawning and juvenile rearing appear to be limited to the coldest streams or stream reaches. The lower limits of habitat used by bull trout are strongly associated with gradients in elevation, longitude, and latitude, that likely approximate a gradient in climate across the Basin (Goetz 1994). The patterns indicate that spatial and temporal variation in climate may strongly influence habitat available to bull trout (see Meisner 1990 for an example with brook trout). While temperatures are probably

suitable throughout much of the northern portion of the range, predicted spawning and rearing habitat are restricted to increasingly isolated high elevation or headwater "islands" toward the south (Goetz 1994; Rieman and McIntyre 1995)(map 4.9).

Current Status and Distribution—A total of 2,717 observations was available for the classification analysis. Overall classification success was 82 percent and ranged from 53 to 93 percent for each status class (see tables 4.22 and 4.24). Overall classification success was about 83 percent when limited to presence or absence (table 4.22). The classification success rates reflect the dominance of absence in the observations. Prediction success ranged from 61 to 70 percent. The models tended to over-predict absence and under-predict strong and depressed. Watershed characteristics most useful in the classifications included mean annual air temperature, vegetation cluster, road density, *hucorder*, mean annual precipitation, elevation, slope and several erosion and lithology variables (table 4.22, appendix 4E.). We used the classification models to estimate the probability of occurrence within 1,247 unclassified watersheds (28% of the range). We predicted spawning and rearing status in the unclassified watersheds and an additional 442 watersheds where bull trout were known present but status was unknown (total predictions represented about 38% of the range)(table 4.28).

Based on our known and predicted status and distribution, bull trout are widely distributed throughout the Basin. The largest contiguous areas supporting populations, however, are associated with the mountains of north central Idaho and northwestern Montana (map 4.9). The current distribution corresponds well with our predictions of potential spawning and rearing habitat (map 4.10 and 4.11).

Bull trout are now extinct in California and only remnant populations are found in much of Oregon (Ratliff and Howell 1992). A small population still exists in the headwaters of the Jarbidge River, Nevada which represents the present southern limit of the species range. Bull trout are known or predicted to occur in 45 percent of watersheds in the historical range and to be absent in 55 percent (map 4.10 and 4.11; tables 4.27 and 4.28). The historical range associated with the Owyhee Uplands, the Columbia Plateau, and the Upper Klamath are poorly represented with both the lowest number of subwatersheds and the lowest proportion of subwatersheds present or predicted within the potential historical range (table 4.27).

We found bull trout less widely distributed within the potential historical range than the other non-anadromous salmonids. Because much of the historical distribution is speculative, we cannot quantify distributional losses across the range. Current information indicates, however, that despite the relatively broad distribution, this species is in widespread decline (Howell and Buchanan 1992; Montana Bull Trout Scientific Committee, in preparation; Pratt and Huston 1993; Ratliff and Howell 1992; Thomas 1992; USDA 1996). Watersheds believed or predicted to be strong spawning and initial rearing areas represented only 6 percent of the historical range; if the sample is restricted to only those watersheds classified as strong or depressed in spawning and rearing habitat, about 25 percent were believed or predicted to be strong (table 4.28).

Migratory life histories have been lost or limited throughout the range (for example, Goetz 1994; Jakober 1995; Montana Bull Trout Scientific Committee, in preparation; Pratt and Huston 1993; Ratliff and Howell 1992; Rieman and McIntyre 1993, 1995). There is evidence of declining trends in some populations (Mauser and others 1988; Pratt and Huston 1993; Schill 1992; Weaver 1992) and extirpations of local populations are reportedly widespread. Goetz (1994) found that bull trout still exist in about 56 percent of the historically used habitat throughout the Deschutes River Basin, but only 0.5 percent of that in the upper basin. Brown (1992) reported

Table 4.27—Summary of the current status and distribution classifications (number of subwatersheds) for bull trout throughout the Ecological Reporting Units of the Basin. Potential spawning and rearing was predicted as in map 4.10.

				Status Where Present								
Ecological Reporting Unit	Total	Historical Range	Total Present	Strong*	Depressed*	Status Unknown	Corridor	Introduced	Absent	No Classification	Potential Spawning and Rearing
Northern Cascades	340	319	144	10	22	90	22	0	84	91	310
Southern Cascades	141	80	32	10	6	9	7	0	40	8	65
Upper Klamath	175	42	9	0	9	0	0	0	17	16	40
Northern Great Basin	506	0	0								
Columbia Plateau	1089	551	59	3	19	17	20	0	217	275	204
Blue Mountains	695	442	163	23	72	31	37	0	177	102	358
Northern Glaciated Mountains	955	955	316	26	125	77	88	0	335	304	924
Lower Clark Fork	415	415	166	4	75	46	41	0	160	89	408
Upper Clark Fork	306	306	145	21	109	5	10	0	84	77	306
Owyhee Uplands	956	174	7	0	2	1	4	0	102	65	43
Upper Snake	301	0	0								
Snake Headwaters	387	0	0								
Central Idaho Mountains	1232	1130	567	72	186	167	142	0	343	220	1065
Entire Assessment Area	7498	4414	1608	169	625	443	371	0	1559	1247	3723

* = Refers to spawning and rearing areas only

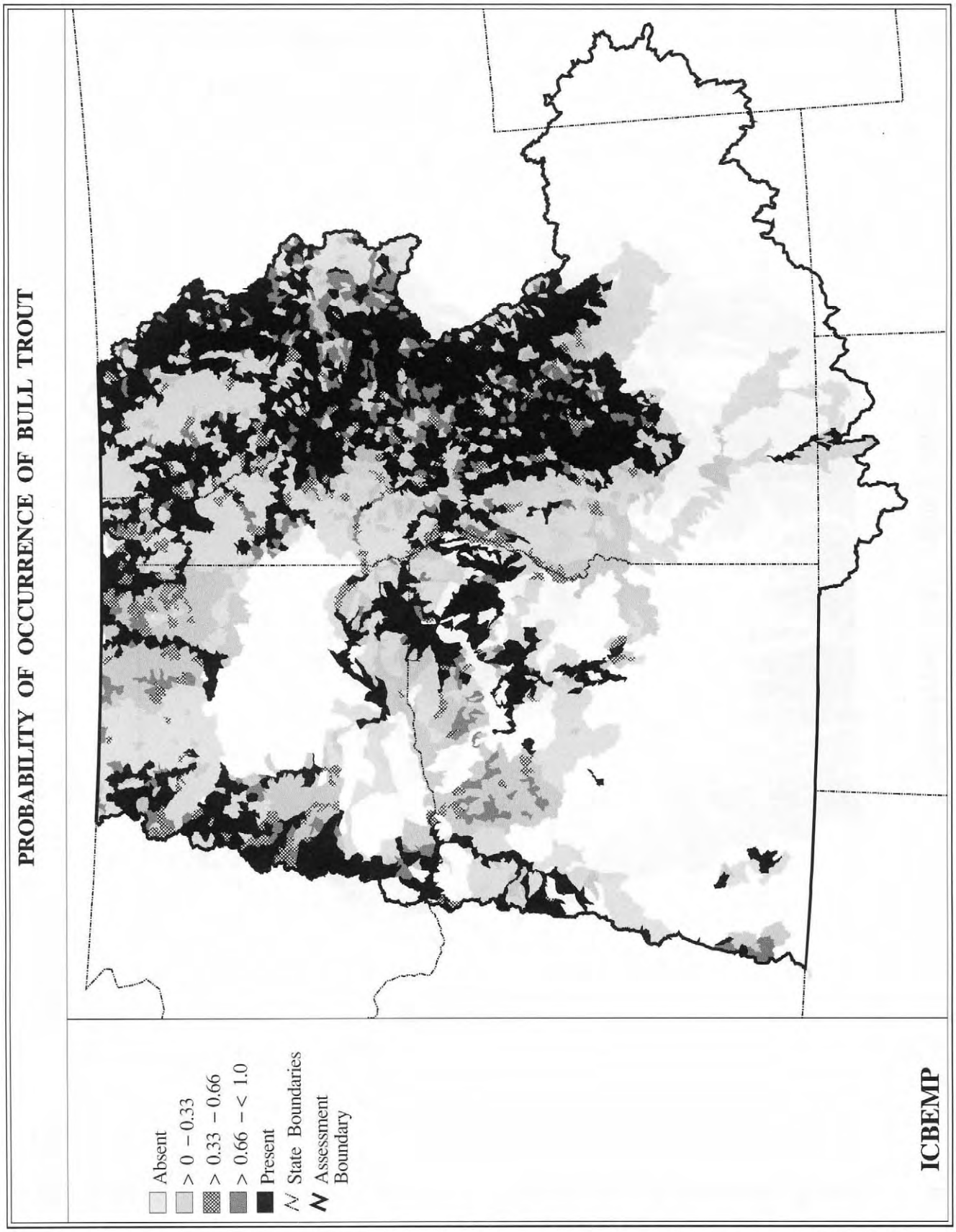
Table 4.28—Summary of total known and predicted classifications (number of subwatersheds) for status of bull trout. The classifications are from the current-status database. The numbers predicted are based on the classification trees for bull trout and are shown in parentheses. Thirteen subwatersheds classified as unknown did not have a prediction

Ecological Reporting Unit	Total	Historical Range	Present	Strong	Depressed	Absent
Northern Cascades	340	319	172 (28)	10 (0)	34 (12)	144 (60)
Southern Cascades	141	80	33 (1)	14 (4)	6 (0)	47 (7)
Upper Klamath	175	42	16 (7)		14 (5)	26 (9)
Northern Great Basin	506	0				
Columbia Plateau	1089	551	124 (65)	3 (0)	22 (2)	426 (209)
Blue Mountains	695	442	200 (37)	28 (5)	83 (11)	242 (65)
Northern Glaciated Mountains	955	955	365 (49)	38 (12)	156 (31)	582 (247)
Lower Clark Fork	415	415	197 (31)	8 (4)	107 (32)	218 (58)
Upper Clark Fork	306	306	197 (52)	26 (5)	128 (19)	109 (25)
Owyhee Uplands	956	174	7 (0)		2 (0)	167 (65)
Upper Snake	301	0				
Snake Headwaters	387	0				
Central Idaho Mountains	1232	1130	654 (87)	143 (71)	261 (75)	475 (132)
Entire Assessment Area	7498	4414	1965 (357)	270 (101)	813 (187)	2436 (877)

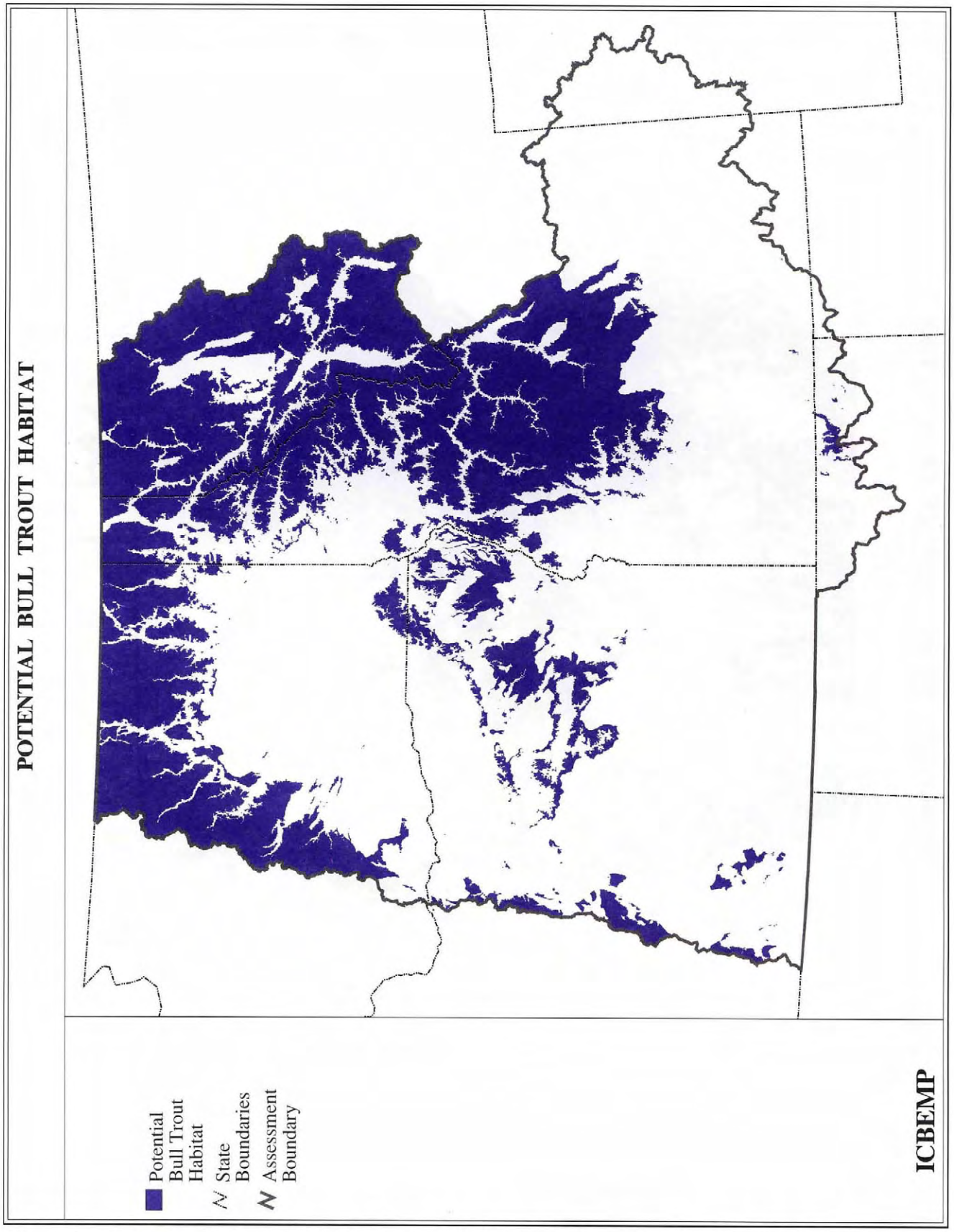
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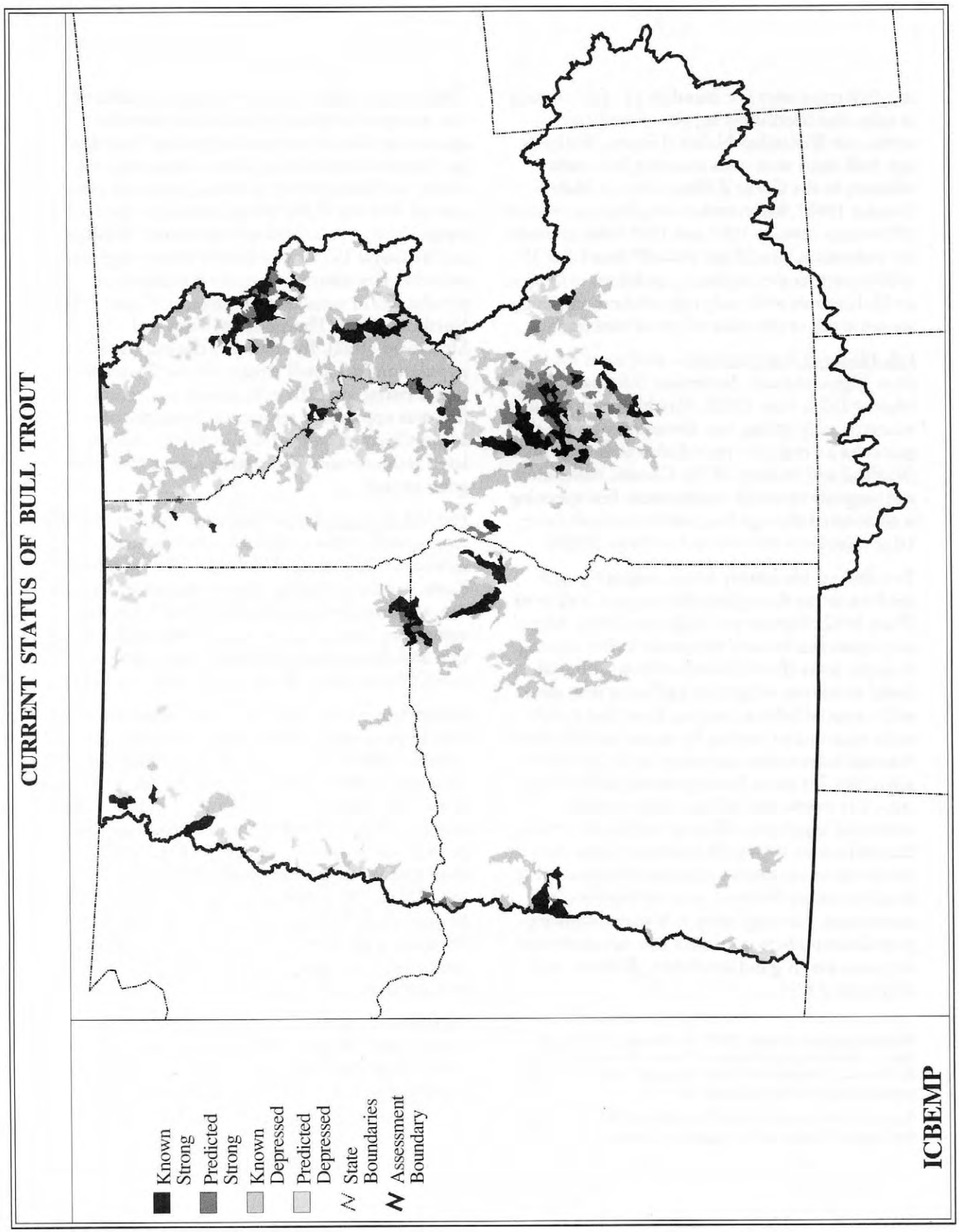
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Mis-scans identified by the software have been corrected;
however, some errors may remain.



Map 4.9—Current presence, absence, and estimated probability of occurrence within the historical range for bull trout by subwatershed. Current distributions are based on the current-status database. Probabilities of occurrence are based on the classification tree for presence or absence.



Map 4.10—Distribution of areas predicted to be suitable for bull trout spawning and initial rearing. Models were based on empirical relationships of occurrence with elevation, latitude, and longitude after Rieman and others (in preparation).



Map 4.11—Current distribution of spawning and rearing areas classified or predicted as strong or depressed for bull trout by subwatershed. Current distributions are based on the current-status database. Predictions are based on the full classification tree for spawning and rearing areas.

that bull trout were not found in 17 of 67 streams or lakes that historically supported bull trout within the Wenatchee National Forest, Washington. Bull trout were once common in streams tributary to the Coeur d'Alene River in Idaho (Maclay 1940), but extensive sampling in more than 100 streams between 1993 and 1995 failed to locate any individuals.[3] Ratliff and Howell[4] found that 15 of 69 known local or regional populations in Oregon are likely extinct while only eight of those remaining are not at risk or otherwise of special concern.

Life-History Characteristics—Bull trout spawn from August through November (McPhail and Murray 1979; Pratt 1992). Hatching may occur in winter or early spring, but alevins may stay in the gravel for an extended period after yolk absorption (McPhail and Murray 1979). Growth, maturation, and longevity vary with environment, first spawning is often noted after age four, with individuals living 10 or more years (Rieman and McIntyre 1993).

Two distinct life-history forms, migratory and resident, occur throughout the range of bull trout (Pratt 1992; Rieman and McIntyre 1993). Migratory forms rear in natal tributaries before moving to larger rivers (fluvial form) or lakes (adfluvial form) to mature. Migratory bull trout may use a wide range of habitats ranging from 2nd to 6th order streams and varying by season and life stage. Seasonal movements may range up to 300 km as migratory fish move from spawning and rearing areas into overwinter habitat in downstream reaches of large basins (Bjornn and Mallet 1964; Elle and others 1994). The resident form may be restricted to headwater streams throughout life. Both forms are believed to exist together in some areas, but migratory fish may dominate populations where corridors and subadult rearing areas are in good condition (Rieman and McIntyre 1993).

The divergent life histories are viewed as alternative strategies weighing reproductive potential against the risks of extensive migration. Variation in migratory form, timing of out-migration, and timing and frequency of spawning represent substantial diversity in life history across the species range and within individual populations (Rieman and McIntyre 1993). Life-history theory suggests such diversity contributes to the persistence of populations in variable environments (Gross 1991; Northcote 1992; Thorpe 1994; Titus and Mosegaard 1992). By example, the bull trout population in a small stream on the Boise National Forest virtually eliminated in a recent fire, was apparently refounded by migratory adults (Rieman and others, in press). An isolated resident-only population might well have gone extinct.

Habitat Relationships—Bull trout appear to have more specific habitat requirements than other salmonids (Rieman and McIntyre 1993). Habitat characteristics including water temperature, stream size, substrate composition, cover and hydraulic complexity have been associated with the distribution and abundance (Dambacher and others, in press; Jakober 1995; Rieman and McIntyre 1993).

Stream temperature and substrate composition may be particularly important characteristics of suitable habitats. Bull trout have repeatedly been associated with the coldest stream reaches within basins. The lower limits of bull trout distributions in map 4.9 correspond to a mean annual air temperature of about 4° C, (range 3° - 6° C) and should equate to ground water temperatures of about 5° to 7° C (Meisner 1990). Temperature may be strongly influenced by land management (Henjum and others 1994) and climate change; both effects may play an important role in the persistence of bull trout.

Bull trout are more strongly tied to the stream bottom and substrate than other salmonids (Pratt 1992). Substrate composition has repeatedly been correlated with the occurrence and abundance of

[3]Personal communication. 1995. B. Rieman, U.S. Forest Service, Intermountain Research Station, Boise, Idaho, and D. Bennett, University of Idaho, Moscow, Idaho. Personal communication of unpublished data.

[4]Unpublished update of Ratliff and Howell 1992; provided to the Oregon Chapter of the American Fisheries Society (AFS).

juvenile bull trout (Dambacher and others, in press; Rieman and McIntyre 1993) and spawning site selection by adults (Graham and others 1981; McPhail and Murray 1979). Fine sediments can influence incubation survival and emergence success (Weaver and White 1985), but might also limit access to substrate interstices that are important cover during rearing and overwintering (Goetz 1994; Jakober 1995).

Interpretation of causality in the classification trees is speculative, but the patterns in the current bull trout distributions are consistent with existing knowledge and speculation on bull trout habitat relationships. Mean annual air temperature was important in discrimination of status; watersheds less than 5.1° C were roughly four times more likely to have bull trout present and 7 times more likely to support strong populations than warmer areas. Given the loss of resolution in averaging information across whole watersheds, the splitting temperature is remarkably similar to the mean of about 4° C (range of about 3° to 6° C) associated with the lower limit of bull trout distributions throughout the basin. Other variables in the model suggest that bull trout are more likely to be found in areas with lower road densities, forested rather than unforested areas, mid-size streams, on steeper, wetter, higher elevation and more erosive lands. These results are consistent with the view that bull trout are associated with cold, relatively pristine environments, but they do not exclude bull trout from landscapes influenced by human disturbance.

Key Factors—Angling is a factor influencing the current status of bull trout. Bull trout may be vulnerable to over-harvest (Ratliff and Howell 1992; Rieman and Lukens 1979). Legal harvest of bull trout has been eliminated or substantially restricted by all state management agencies except Nevada. Protection of the remaining bull trout in Nevada may be of particular concern. The remaining fish in the Jarbidge River subbasin appear to be very restricted in number and distribution, but also provide the only representation for this species on the extreme southern fringe of the range. Direct harvest has been limited in most other areas, but incidental catch in expanding lake trout fisheries could pose some problems for populations in the large lakes of northern Idaho and northwestern Montana. Poaching is viewed as an important cause of mortality, especially in accessible streams that support large migratory fish.[5,6]

Watershed disruption is a second factor that has played a role in the decline of bull trout. Changes in or disruptions of watershed processes likely to influence characteristics of stream channels are also likely to influence the dynamics and persistence of bull trout populations. Bull trout have been more strongly associated with pristine or only lightly disturbed basins (Brown 1992; Clancy 1993; Cross and Everest 1995; Dambacher and others, in press; Huntington 1995; Ratliff and Howell 1992).

Patterns of stream flow and the frequency of extreme flow events that influence substrates are anticipated to be important factors in population dynamics (Rieman and McIntyre 1993). With overwinter incubation and a close tie to the substrate, embryos and juveniles may be particularly vulnerable to flooding and channel scour associated with the rain-on-snow events common in some parts of the range within the belt geology of northern Idaho and northwestern Montana (Rieman and McIntyre 1993). Channel dewatering tied to low flows and bed agradation has also blocked access for spawning fish resulting in year class failures (Weaver 1992). These effects could explain the apparent extirpation of bull trout in much of the heavily disturbed upper Coeur d'Alene River Basin.[7]

Changes in sediment delivery, agradation and scour, wood loading, riparian canopy and shading or other factors influencing stream temperatures,

[5]Personal communication. 1995. N. Horner, Idaho Department of Fish and Game, Coeur d'Alene, Idaho.

[6]Personal communication. 1995. J. Vashro, Montana Department of Fish, Wildlife, and Parks, Kalispell, Montana.

[7]Personal communication. 1995. D. Cross, Panhandle National Forest, Coeur d'Alene, Idaho.

and the hydrologic regime (winter flooding and summer low flow) are all likely to affect some, if not most, populations. Although we cannot build precise models predicting population responses, we can conclude that significant long-term changes in any of these characteristics or processes represent important risks for many remaining bull trout populations. Populations are likely to be most sensitive to changes that occur in headwater areas encompassing critical spawning and rearing habitat and remnant resident populations.

Introduced species are a third factor influencing bull trout. More than 30 introduced species occur within the present distribution of bull trout. Some introductions like kokanee may benefit bull trout by providing forage (Bowles and others 1991). Others such as brown, brook, and lake trout are thought to have depressed or replaced bull trout populations (Dambacher and others, in press; Donald and Alger 1992; Howell and Buchanan 1992; Kanda and others, in press; Leary and others 1993; Ratliff and Howell 1992). Brook trout are seen as an especially important problem (Kanda and others, in press; Leary and others 1993) and may progressively displace bull trout through hybridization and higher reproductive potential (Leary and others 1993). Brook trout now occur in the majority of the watersheds representing the current range of bull trout (see map 4.7). Introduced species may pose greater risks to native species where habitat disturbance has occurred (Hobbs and Huenneke 1992).

Isolation and fragmentation are the fourth factor we identified as likely to influence the status of bull trout. Historically bull trout populations were well connected throughout the Basin. Habitat available to bull trout has been fragmented, and in many cases populations have been isolated entirely. Dams have isolated whole subbasins throughout the Basin (see for example, Brown 1992; Kanda and others, in press; Pratt and Huston 1993; Rieman and McIntyre 1995). Irrigation diversions, culverts, and degraded mainstem habitats have eliminated or seriously depressed migratory life histories effectively isolating resident populations in headwater tributaries (Brown 1992; Montana Bull Trout Scientific Committee, in preparation; Ratliff and Howell 1992; Rieman and McIntyre 1993). Introduced species like brook trout may displace bull trout in lower stream reaches further reducing the habitat available in many remaining headwater areas (Adams 1994; Leary and others 1993). Loss of suitable habitat through watershed disturbance may also increase the distance between good or refuge habitats and strong populations thus reducing the likelihood of effective dispersal (Frissell and others 1993).

Risk of Extinction or Extirpation—Life-history and metapopulation theory suggests dispersal capabilities may be particularly important for the local and regional persistence of many species (Rieman and McIntyre 1995; Thorpe 1994). Recent work suggests bull trout are no exception. Rieman and McIntyre (1993) used analytic models and redd count data to evaluate extinction risks. They predicted that few monitored populations were likely to persist above critical thresholds if they were isolated from other populations. Rieman and McIntyre (1995) also found that the occurrence of bull trout in naturally fragmented habitat patches was significantly associated with the size of the patch. The available information, then, supports the predictions of metapopulation theory with important implications for the conservation of bull trout. Further isolation of populations in shrinking habitat will probably lead to increasing rates of extirpation not proportional to the simple loss of habitat area. Even with no further habitat loss, extirpations may be likely for many remaining isolated populations. Global climate change can be expected to exacerbate the problem (Rieman and McIntyre 1993). Long-term conservation of bull trout throughout much of the Columbia River basin may well depend on maintenance or restoration of networks of high quality habitats, and of migratory corridors in larger river subbasins.

Summary—Bull trout are still distributed throughout the Basin, but local extirpations are reportedly widespread and declining populations

are believed to be common. Many remaining populations are isolated in headwater streams. Migratory life histories may be severely limited or absent in many systems. Even with no further loss of habitat the likelihood of extirpations seems high. The core of the remaining bull trout distribution is in the Central Idaho Mountains, with important strongholds still evident or likely within the Upper Clark Fork, Northern Glaciated Mountains, Lower Clark Fork, and Blue Mountains. This latter collection of known or likely watersheds appears to be more strongly fragmented or restricted in size than the central Idaho core. These remaining strongholds represent the best opportunities for the long term persistence of bull trout within the Basin. Bull trout also remain within the Northern Cascades, Southern Cascades, Upper Klamath, and Owyhee Uplands. In each of these ERUs the remaining populations appear to be very narrowly distributed and often isolated in small, discontinuous watersheds. Because these fringe areas tend to be quite distinct, both geographically and environmentally, from the core of the distribution, further loss of bull trout would probably represent a disproportionately important loss of genetic diversity and evolutionary legacy. Conservation management of bull trout may therefore be most critical in the fringe areas.

Yellowstone Cutthroat Trout (*Oncorhynchus clarki bouvieri*)—The Yellowstone cutthroat trout is more abundant and inhabits a larger geographical range in the western United States than any other non-anadromous subspecies of cutthroat trout (Varley and Gresswell 1988). Individual populations of the Yellowstone subspecies have evolved numerous life-history characteristics in response to the diverse environments in which they have been isolated since the last glacial retreat. Anthropogenic activities have resulted in a substantial reduction in the historical distribution of this subspecies, however, and many unique local populations have been extirpated. As a result, the Yellowstone cutthroat trout has been designated as a species of special concern - class A by the American Fisheries Society (Johnson 1987). This status has been officially recognized by the Montana Department of Fish, Wildlife and Parks [Yellowstone Cutthroat Trout Working Group (YCTWG) 1994], and the subspecies has been recognized as a species of special concern in Idaho. Both the Northern and Rocky Mountain regions of the Forest Service consider the Yellowstone cutthroat trout a sensitive species (YCTWG 1994). Although the Yellowstone cutthroat trout has not been given formal status in Wyoming, the uniqueness of the subspecies has influenced management (YCTWG 1994).[8]

Historical Distribution—Yellowstone cutthroat trout were historically found in the Yellowstone River drainage in Montana and Wyoming and in the Snake River Drainage in Wyoming, Idaho, Utah, Nevada, and probably Washington (Behnke 1992; Varley and Gresswell 1988). In the Basin, it is the only native trout in the Snake River above Shoshone Falls (map 4.12). The fine-spotted Snake River cutthroat trout, a putative cutthroat trout subspecies, originally existed within the range of the Yellowstone subspecies in the upper Snake River (Behnke 1992), and the two groups are genetically similar (Loudenslager and Gall 1980; Loudenslager and Kitchin 1979). Because the Snake River form has not received formal taxonomic recognition, we considered both groups as Yellowstone cutthroat trout.

The subspecies was the most narrowly distributed of the seven key salmonids in the Basin, occurring in about 9 percent of the watersheds (table 4.29). The original range included primarily the Upper Snake and Snake Headwater where 74 and 98 percent, respectively, of the watersheds supported Yellowstone cutthroat trout. Yellowstone cutthroat trout were also present in a small number of watersheds in the Columbia Plateau and Owyhee Uplands (Behnke 1992)(map 4.12).

Current Status and Distribution—A total of 393 observations was available for the classification analysis (see table 4.22). The overall classification success rate was 85 percent for the three classes

[8]Also, personal communication. 1995. R. Wiley, Wyoming Game and Fish, Laramie, Wyoming.

Table 4.29—Summary of the current status and distribution classifications (number of subwatersheds) for Yellowstone cutthroat trout throughout the Ecological Reporting Units of the Basin.

Ecological Reporting Unit	Total	Historical Range	Total Present	Status Where Present					Absent	No Classification
				Strong*	Depressed*	Status Unknown	Corridor	Introduced		
Northern Cascades	340	0	0							
Southern Cascades	141	0	0							
Upper Klamath	175	0	0							
Northern Great Basin	506	0	0							
Columbia Plateau	1089	16	0	0	0	0	0	0	5	11
Blue Mountains	695	0	0							
Northern Glaciated Mountains	955	0	31	0	0	0	0	31	0	0
Lower Clark Fork	415	0	7	0	0	0	0	7	0	0
Upper Clark Fork	306	0	15	0	0	0	0	15	0	0
Owyhee Uplands	956	5	2	0	1	1	0	0	0	3
Upper Snake	301	261	100	4	28	47	4	17	73	105
Snake Headwaters	387	380	303	171	89	41	1	1	26	52
Central Idaho Mountains	1232	0	69	0	0	0	0	69	0	0
Entire Assessment Area	7498	662	527	175	118	89	5	140	104	171

* = Refers to spawning and rearing areas only

Table 4.30—Summary of total known and predicted classifications (number of subwatersheds) for status of Yellowstone cutthroat trout. The classifications are from the current-status database. The numbers predicted are based on the classification trees for Yellowstone cutthroat trout and are shown in parentheses. Forty-four subwatersheds classified as unknown did not have a prediction.

Ecological Reporting Unit	Total	Historical Range	Present	Strong	Depressed	Absent
Northern Cascades	340	0				
Southern Cascades	141	0				
Upper Klamath	175	0				
Northern Great Basin	506	0				
Columbia Plateau	1089	16				16 (11)
Blue Mountains	695	0				
Northern Glaciated Mountains	955	0				
Lower Clark Fork	415	0				
Upper Clark Fork	306	0				
Owyhee Uplands	956	5	2 (0)		1 (0)	
Upper Snake	301	261	105 (22)	4 (0)	34 (6)	118 (45)
Snake Headwaters	387	380	329 (27)	205 (34)	138 (49)	48 (22)
Central Idaho Mountains	1232	0				
Entire Assessment Area	7498	662	436 (49)	209 (34)	173 (55)	182 (78)

Map 4.12—Current presence, absence, and estimated probability of occurrence within the historical range for Yellowstone cutthroat trout by subwatershed. Current distributions are based on the current-status database. Probabilities of occurrence are based on the classification tree for presence or absence. Presence outside the historical range is shown as introduced.

(absent, depressed, and strong) and 98 percent when limited to presence or absence (table 4.22). Classification success ranged from 83 to 96 percent for each status class (table 4.24). Prediction success ranged from 67 to 82 percent. Watershed characteristics most useful in the classifications included mean annual air temperature, *hucorder* (stream size), and solar radiation (table 4.22, appendix 4E). We used the classification models to estimate the probability of occurrence of Yellowstone cutthroat trout in 130 watersheds (21% of the historical range) that were previously unclassified and to predict status (strong or depressed) in those watersheds and an additional 88 watersheds (14%) where Yellowstone cutthroat trout were classed as present but of unknown status (table 4.29).

From the known and predicted distributions, Yellowstone cutthroat trout are the most narrowly distributed of the seven key salmonids within the Basin. The current known distribution includes about 61 percent of the historical range (table 4.29). The known and predicted distribution includes about 66 percent of the historical range (table 4.30). Anthropogenic activities such as introduction of non-native fishes resulting in hybridization and interspecific competition, habitat degradation resulting from water diversions, grazing, mineral extraction, timber harvest activities, and angler harvest have caused extirpation of populations of Yellowstone cutthroat trout (Gresswell 1995; Varley and Gresswell 1988). Losses have been important in the Upper Snake (map 4.13), and in that portion of the range outside the Basin. Large-river populations, in particular, have declined or disappeared. Concomitant with declines in natural distributions of Yellowstone cutthroat trout, stocking activities by agencies and private individuals have expanded the species range, particularly in mountain lakes throughout Idaho and Montana (see map 4.12). Introductions of Yellowstone cutthroat trout have established them in 140 watersheds outside the historical range (table 4.29). Yellowstone cutthroat trout are now found in the Northern Glaciated Mountains, Upper and Lower Clark Fork, and Central Idaho Mountains (map 4.13). Watersheds with introduced Yellowstone cutthroat trout account for 27 percent of the present distribution. The effects of these introductions on genetic or biological integrity of other species and aquatic communities have not been assessed.

Despite the changes that have occurred, we estimated that Yellowstone cutthroat trout support the largest proportion of strong populations of any key salmonid. Watersheds known or predicted to support strong spawning and rearing represented 32 percent of the historical range and 48 percent of the present distribution (table 4.30; map 4.13). When only those watersheds supporting spawning and rearing were considered, 55 percent of the watersheds were strong (table 4.30).

These estimates of strong populations may be overly optimistic, however, because of a high probability of genetic introgression in most populations. Varley and Gresswell (1988) estimated that genetically unaltered populations of Yellowstone cutthroat trout occur in about 10 percent of the historical stream habitat and about 85 percent of the historical lacustrine habitat. They suggested that 91 percent of the present range of genetically unaltered Yellowstone cutthroat trout lies within the boundary of Yellowstone National Park (Gresswell and Liss 1995). Hadley (1984) suggested that only 8 percent of the original range of fluvial Yellowstone cutthroat trout in Montana was inhabited by genetically unaltered populations of Yellowstone cutthroat trout. In Wyoming, nearly all areas supporting Yellowstone cutthroat trout were judged by biologists to be strong (map 4.13), but there may have been little information to judge genetic purity (YCTWG 1994). There was no information to judge presence or absence of Yellowstone cutthroat trout in 171 watersheds within the Upper Snake, Snake Headwaters, Owyhee Uplands, and Columbia Plateau (table 4.29). Within the present known range, nearly 17 percent of the watersheds supporting Yellowstone cutthroat trout were of unknown status.

Life-history Characteristics—Low genetic diversity among populations of Yellowstone cutthroat trout

Map 4.13—Current distribution of spawning and rearing areas classified or predicted as strong or depressed for Yellowstone cutthroat trout by subwatershed. Current distributions are based on the current-status database. Predictions are based on the full classification tree for spawning and rearing areas.

may reflect a substantial compression of the geographical range of the subspecies during the Pleistocene (Behnke 1992; Gresswell and others 1994; Loudenslager and Gall 1980). In contrast, life-history strategies across the range, and even within individual assemblages of Yellowstone cutthroat trout, are highly diversified (Gresswell and others 1994; Varley and Gresswell 1988). The variability in life-history strategies may represent a complex response to environmental fluctuations operating at different temporal and spatial scales (Gresswell and others 1994).

Yellowstone cutthroat trout spawn exclusively in fluvial environments. Varley and Gresswell (1988) described four migratory-spawning patterns. The first three are consistent with the resident, fluvial, and adfluvial patterns mentioned earlier. The fourth, termed allacustrine, is represented by fish which spawn in lake outlets rather than tributary streams. Homing by Yellowstone cutthroat trout spawners is believed to influence life-history diversity through reproductive isolation (Gresswell and others 1994) and straying during the spawning migration is low (Ball 1955; Cope 1957a; Jones and others 1985; Thurow 1982). Migrations begin when temperatures approach 5° C (Byorth 1990; Thurow and King 1994; Varley and Gresswell 1988). Adults spawn between March and August after peak flows (Ball and Cope 1961; Jones and others 1990; Thurow and King 1994). Migration timing is affected by latitude, altitude, water temperature, and hydrographic relationships (Clancy 1988; Kelly 1993; Thurow and others 1988; Varley and Gresswell 1988).

Sex ratios in spawning migrations appear to vary with migratory-spawning pattern. Mean age of spawners varies across the range of the Yellowstone subspecies, typically ranging from three to five years (Clancy 1988; Thurow and others 1988). Few migratory fish mature at less than 250 millimeters (Benson and Bulkley 1963; Byorth 1990; Clancy 1988; Thurow and others 1988). In small subalpine lakes and streams, non-migratory Yellowstone cutthroat trout may mature between 100 and 130 millimeters. Fecundity is related to length, weight, and age of fish (Bagenal 1978; Moore and Schill 1984; Thurow and others 1988). Iteroparity is common in Yellowstone cutthroat trout (Clancy 1988). Repeat spawning may occur in consecutive or alternate years (Thurow and others 1988; Varley and Gresswell 1988) and is probably related to growth, parasitic infection, and other physiological factors (Ball and Cope 1961).

Incubation and emergence are temperature dependent; eggs typically hatch in 25 to 49 days, and fry emerge about two weeks later (Ball and Cope 1961; Kelly 1993; Mills 1966;). Juveniles often seek shallow, slow-flowing areas, and migratory individuals soon begin to emigrate (Kelly 1993; Varley and Gresswell 1988). Some Yellowstone cutthroat trout fry migrate downstream shortly following emergence while others do not emigrate for one to three years (Benson 1960; Byorth 1990; Thurow and others 1988; Gresswell and others 1994). Distance from redd to stream mouth (Welsh 1952) and habitat availability (Thurow and others 1988) may influence the timing of fry migrations. Growth of Yellowstone cutthroat trout is variable and dependent on population and environmental conditions.

Habitat Relationships—Yellowstone cutthroat trout occupy diverse habitats. Lacustrine populations inhabit waters ranging in size from small beaver ponds to large lakes [for example, Yellowstone Lake, 35,400 hectares (Varley and Gresswell 1988)]. Fluvial populations were historically present in streams ranging in size from large rivers such as the Snake River above Shoshone Falls (Varley and Gresswell 1988) to first-order tributaries with mean widths of one meter and less.

The subspecies is well adapted to relatively cold, harsh environments (Carlander 1969; Dwyer and Kramer 1975; Jones and others 1979; Varley and Gresswell 1988). Although Yellowstone cutthroat trout are associated with cold-water habitats, Varley and Gresswell (1988) reported that water temperatures within portions of the historical range exceeded 26° C. Most large-river, warm-water populations have been extirpated; however, several populations have been documented in

geothermally heated streams in Yellowstone National Park with an ambient water temperature of 27° C (Varley and Gresswell 1988). Yellowstone cutthroat trout probably survive in warm water by locating thermal refugia.

Yellowstone cutthroat trout tolerate a broad range of chemical conditions. Varley and Gresswell (1988) reported that the subspecies has been collected from waters in Yellowstone National Park with total dissolved solids ranging from about 10 to 700 milligrams/liter. Reported alkalinities in waters supporting Yellowstone cutthroat trout in Montana and Idaho ranged from 46 to 378 milligrams $CaCO_3$/liter (Byorth 1990; Thurow and others 1988). Although Yellowstone cutthroat trout have been found in waters with pH values ranging from 5.6 to over 10.0, none have been observed where pH is below 5.0 (Varley and Gresswell 1988).

Spawning streams are most commonly perennial with groundwater and snow-fed water sources; gradient is usually below 3 percent (Varley and Gresswell 1988). Although use of intermittent streams for spawning is not well documented, where it occurs there may be some reproductive advantage over non-indigenous fall-spawning salmonids (Varley and Gresswell 1988). Thurow and King (1994) emphasized the importance of physical cues, such as depth and velocity, for locating redds in areas with a high probability of hatching success and fry survival. Cope (1957b) reported that forest cover had little effect on the distribution of redds and spawners did not always congregate in areas with the greatest concentration of spawning gravel.

In streams, Yellowstone cutthroat trout fry generally seek areas of low velocity (Varley and Gresswell 1988) and shallow depth (Byorth 1990). As fish become larger, juveniles rear in areas with a larger range of depths and velocities. Yellowstone cutthroat trout occupy different habitats in winter than in summer. In late winter (March - April) at water temperatures ranging from 4° to 7° C, Griffith and Smith (1993) found juvenile Yellowstone cutthroat trout concealed in water shallower than 0.5 meters within 1 meter of the wetted perimeter of the stream. Density of age-0 Yellowstone cutthroat trout increased as the substrate size of non-embedded cover increased.

Adfluvial fry usually begin a downstream migration soon after emergence, but some may overwinter in the natal stream. After emigration, fry congregate in shallow water along the shoreline prior to movement into deeper water (Gresswell and Varley 1988). As lacustrine fish grow, most move back into the littoral zone where a shift in food preference occurs (Benson 1961; Gresswell and Varley 1988).

In the classification analysis variables including ERU, mean annual air temperature, number of upstream 6th code hydrologic units, and solar radiation were useful in discriminating watersheds supporting this subspecies (see table 4.22; appendix 4E). Populations rarely occurred in subwatersheds with mean annual air temperatures higher than 6.1° C. Variables related to land management were not useful in the classification. The core of the remaining range, however, is clearly centered in the Upper Snake which is represented in a large part by National Park and roadless lands. A more refined analysis will be necessary to evaluate the potential influence of disturbance on the status and distribution of Yellowstone cutthroat trout at this scale.

Key Factors— Introgression with introduced salmonids is clearly a key factor in the status of Yellowstone cutthroat trout. Hybridization resulting from introductions of rainbow trout and nonnative cutthroat trout is believed to be a primary cause in the decline of this form (Allendorf and Leary 1988; Varley and Gresswell 1988). Hybrids are developmentally successful, and progeny may appear as morphological and meristic intermediates between parental types or virtually identical to a single parental type (Ferguson and others 1985). Consequently, verifying genetic integrity with morphological data alone is virtually impossible. Nuclear allozymes and mitochondrial DNA (mtDNA) haplotypes have proved to be useful for detecting hybridization (Forbes and Allendorf 1991; Leary and others 1987).

Non-salmonid species are commonly indicted as competitors of salmonid species; however, it does not appear that introductions of longnose suckers, redside shiners, and lake chub into Yellowstone Lake have had negative effects on that population (Gresswell and Varley 1988). Although competition may be important in different environments, it would probably be greatest with species exhibiting similar niche requirements (for example, between salmonids; Marrin and Erman 1982). Introduction of brown and rainbow trout to the Madison River in Yellowstone National Park was followed by the extirpation of indigenous westslope cutthroat trout and fluvial Arctic grayling (Jones and others 1981), but Yellowstone cutthroat trout are still abundant in sections of the Yellowstone River where they are sympatric with these two non-native salmonids (Clancy 1988). Introductions of rainbow trout in the Henry's Fork of the Snake River, Idaho resulted in extirpation of Yellowstone cutthroat trout (Thurow and others 1988). In other Idaho streams, Yellowstone cutthroat trout are sympatric with introduced brown and brook trout, and Yellowstone cutthroat trout persist if habitat has not been degraded and angler harvest is not extreme (Thurow and others 1988). Thurow and others (1988) reported that angler harvest may limit Yellowstone cutthroat trout in sympatry with brown trout because cutthroat trout are more vulnerable to angler harvest. Griffith (1988) reported that cutthroat trout are less likely to coexist with brook trout than other non-native salmonids, and Yellowstone cutthroat trout have been extirpated from most areas in Yellowstone National Park where brook trout have been introduced (Gresswell 1991). Large predators such as lake trout may also pose a substantial threat to Yellowstone cutthroat trout (Varley and Schullery 1995).

Habitat degradation is a second factor important in the decline of this trout. Activities such as dam construction, water diversions, grazing, mineral extraction, road construction, and timber harvest have substantially degraded lotic environments throughout the historical range of Yellowstone cutthroat trout (Binns 1977; Clancy 1988; Thurow and others 1988). Recreational use can also be a significant source of disturbance (Gresswell and Liss 1995; Roberts and White 1992). Anthropogenic activities such as road construction have resulted in barriers to migration (Belford and Gould 1989), reduced flows, sediment deposition, groundwater depletion, streambank instability, erosion, and pollution. Efforts to curtail human activities and restore degraded stream segments are increasing, but habitat degradation continues.

Effects of livestock grazing on riparian habitats are well documented (for example, Gresswell and others 1989; Platts 1991). In the range of the Yellowstone cutthroat trout, Thurow and others (1988) reported that intensive livestock grazing has caused degradation of riparian areas and subsequent stream bank sloughing, channel instability, erosion, and siltation. Alterations are broadly distributed on private and public lands throughout the upper Snake River basin in Idaho and Wyoming (Thurow and others 1988). Degraded water quality and unscreened irrigation ditches contribute to the problems associated with water diversions throughout the range of the Yellowstone cutthroat trout (Byorth 1990; Clancy 1988; Johnson 1964; Thurow and others 1988;). Mineral extraction has negatively effected Yellowstone cutthroat trout in the Blackfoot River drainage, Idaho (Thurow and others 1988) and Soda Butte Creek, Montana (Arnold and Sharpe 1967; Jones and others 1982). Future expansions of mining operations may pose renewed threats to the Yellowstone cutthroat trout.

Angling is a third factor that may play an important role in the status of remaining Yellowstone cutthroat trout populations. Yellowstone cutthroat trout are extremely vulnerable to angling, and angler harvest has contributed to substantial declines in population abundance throughout the historical range of the subspecies (Binns 1977; Gresswell and Varley 1988; Hadley 1984; Thurow and others 1988). Schill and others (1986) estimated that individual Yellowstone cutthroat trout were captured an average of 9.7 times during a

single angling season; many fish were captured two or three times in a single day. Although high catchability contributes to recreational value, it may lead to substantial declines in abundance (Gresswell 1990; Gresswell and Liss 1995). Angler harvest can reduce mean age and length of spawners (Gresswell 1995; Gresswell and others 1994; Gresswell and Varley 1988) and the proportion of repeat spawners (Varley and Gresswell 1988). Harvest of native Yellowstone cutthroat trout has been restricted in most waters by state management agencies. Harvest of introduced populations, especially in alpine lakes, is less restricted.

Summary—Yellowstone cutthroat trout are the most narrowly distributed of the seven key salmonids, occurring naturally in only 8 percent of the Basin and only within the Upper Snake and Snake Headwaters ERUs. They have been widely introduced and now occur in about 2 percent of the Basin outside the historical range. Yellowstone cutthroat trout appear to be one of the most widely distributed key species within their historical range. Status of populations is uncertain, however, because many populations have hybridized with non-native trout. The range of genetically unaltered populations of Yellowstone cutthroat trout has probably been reduced. The core of remaining strong populations is the Snake Headwaters. Populations remain widespread in the Upper Snake but most are depressed and many appear isolated to small areas.

Population declines and extirpations have been most common in larger low-elevation, less than third-order streams (Hanzel 1959), as illustrated by the current distribution and status of Yellowstone cutthroat trout in the Upper Snake. Low elevation areas have historically been the focus of most agricultural development and resource extraction and access has encouraged angler harvest and non-native species introductions. Remoteness of portions of the native range probably contributed to the preservation of remaining populations, and in much of this area, public ownership in the form of parks and reserves has provided habitat protection that is lacking in low-elevation portions of the range (Varley and Gresswell 1988). Approximately 98 percent of the current strong watersheds in the Basin are in the Snake Headwaters.

Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*)—Westslope cutthroat trout were once abundant throughout much of the north and central portions of the Basin. Although this subspecies is still widely distributed, remaining populations may be seriously compromised by habitat loss and genetic introgression through hybridization (McIntyre and Rieman 1995; Rieman and Apperson 1989). Westslope cutthroat trout were listed in the U.S. Fish and Wildlife Service "Red Book" of endangered and threatened species from 1966 to 1972. The subspecies was subsequently dropped from the list due to confusion over its classification (Roscoe 1974). Westslope cutthroat trout are presently considered a sensitive or vulnerable species by management agencies in Washington, Oregon, Idaho, and Montana.

Historical Distribution—Westslope cutthroat trout were probably the earliest salmonid to populate the headwaters of the Basin and now exist above barrier falls that have limited the distributions of other species throughout the range (Behnke 1992). Westslope cutthroat trout have a much larger historical range (about 35% of the Basin) than Yellowstone cutthroat trout. Populations in the John Day drainage of Oregon and along the eastern slope of the Cascades in Washington may have been established from the core distribution in what is now Idaho and Montana, through glacial Lake Missoula floods 15,000 to 12,000 years ago (Behnke 1992). Headwater transfers are believed to account for distributions in the upper Missouri and South Saskatchewan river basins east of the Continental Divide (Schultz 1941), and perhaps those in Central Idaho as well (Behnke 1992).

Westslope cutthroat trout were first recorded in 1805 by the Lewis and Clark expedition (Behnke 1992). Early explorers' journals suggest that westslope cutthroat trout were extremely abundant and widely distributed (Trotter and Bisson 1988).

Where habitat remains in relatively good condition westslope cutthroat trout are often found in most streams accessible to them (Rieman and Apperson 1989; Rieman and McIntyre 1993). They probably also occupied many natural lakes within the range as well. We estimate the historical range for westslope cutthroat trout represented about 35 percent of the Basin (table 4.31), and summarize our description in appendix 4D.

Current Status and Distribution—A total of 1,640 watersheds was available for the classification analysis. Overall classification success was 80 percent and increased to 93 percent when restricted to presence and absence (see table 4.22). Classification success rates ranged from 61 to 91 percent across the status classes. The models tended to under-predict absent and strong although the prediction success rates were still good for each class. For example, if a watershed was predicted to be absent or strong, that classification was correct 82 and 73 percent of the time, respectively (table 4.24),

We used the classification models for westslope cutthroat trout to estimate the probability of occurrence in 426 watersheds (16% of the historical range) that were unclassified (table 4.31). We also predicted status in both the unclassified watersheds and 574 watersheds (22% of the historical range) where westslope cutthroat trout were believed to be present but status was unknown.

Watershed characteristics most useful in classifications included general location (ERU), management cluster, road density, and several of the biophysical variables (see table 4.22; appendix 4E).

The known and predicted status information indicated that westslope cutthroat trout remain widely distributed within their historical range. Some extension of the natural distribution has also occurred through hatchery introductions. From the current status classification and extrapolations from the classification tree we estimate that westslope cutthroat trout are still present in at least 85 percent of the historical range (map 4.14).

Despite the broad distribution there appear to be few remaining healthy populations outside the Central Idaho Mountains and potentially the Northern Cascades. We estimated that 22 percent of the historical range was classified or predicted as strong (table 4.32; map 4.15). If the sample is limited to watersheds classified as spawning and rearing areas, 28 percent were believed to be strong. Other status reviews suggest a less healthy condition. Rieman and Apperson (1989) estimated that strong westslope cutthroat trout numbers persisted in 11 percent of the historical range in Idaho, and populations that were both numerically strong and genetically pure existed in 4 percent of the historical range. Liknes and Graham (1988) estimated that the subspecies still occupied 27 percent of the historical range in Montana, and were genetically pure in only 2.5 percent. The largest extirpations may have occurred outside the Basin. We estimate that westslope cutthroat trout still occupy nearly 80 percent of that portion of historical range within the Basin in Montana. The discrepancies may result from the resolution of the summary of data. Because our summary was based on subwatersheds rather than on stream reaches some discrepancies are inevitable. For example, we might show westslope cutthroat trout as present in 100 percent of the watersheds considered when they may have occurred in only a fraction of the streams. In any case, clearly, few strong populations are left in Montana, continuing a decline first documented over 25 years ago (Hanzel 1959). In Oregon, Kostow and others (1994) estimated westslope cutthroat trout are limited to 41 percent of the historically used stream miles in the John Day River subbasins. In contrast, we estimated 64 percent of the subwatersheds were still occupied.

Life-History Characteristics—Similar to Yellowstone cutthroat trout, three life-history forms are commonly identified as adfluvial, fluvial, or resident. All three may occur in a single basin. Resident forms may predominate in headwater areas while migratory forms are more common in mid- and lower basin habitats (Averett and MacPhee 1971; Rieman and Apperson 1989; McIntyre and Rieman 1995). Westslope cutthroat

Table 4.31—Summary of the current status and distribution classifications (number of subwatersheds) for westslope cutthroat trout throughout the Ecological Reporting Units of the Basin.

Ecological Reporting Unit	Total	Historical Range	Total Present	Status Where Present					Absent	No Classification
				Strong*	Depressed*	Status Unknown	Corridor	Introduced		
Northern Cascades	340	265	202	33	11	152	0	6	23	46
Southern Cascades	141	0	0							
Upper Klamath	175	0	0							
Northern Great Basin	506	0	0							
Columbia Plateau	1089	174	18	1	5	10	2	0	79	77
Blue Mountains	695	33	21	0	17	0	0	4	13	3
Northern Glaciated Mountains	955	664	524	65	362	81	0	16	53	103
Lower Clark Fork	415	415	383	53	266	63	1	0	5	27
Upper Clark Fork	306	306	244	52	170	17	5	0	18	44
Owyhee Uplands	956	0	0							
Upper Snake	301	0	0							
Snake Headwaters	387	0	0							
Central Idaho Mountains	1232	789	599	128	160	251	43	17	81	126
Entire Assessment Area	7498	2646	1991	332	991	574	51	43	272	426

* = Refers to spawning and rearing areas only

Table 4.32—Summary of total known and predicted classifications (number of subwatersheds) for status of westslope cutthroat trout. The classifications are from the current-status database. The numbers predicted are based on the classification trees for westslope cutthroat trout and are shown in parentheses. Two subwatersheds classified as unknown did not have a prediction.

Ecological Reporting Unit	Total	Historical Range	Present	Strong	Depressed	Absent
Northern Cascades	340	265	216 (20)	144 (111)	24 (13)	49 (26)
Southern Cascades	141	0				
Upper Klamath	175	0				
Northern Great Basin	506	0				
Columbia Plateau	1089	174	37 (19)	7 (6)	8 (3)	137 (58)
Blue Mountains	695	33	19 (2)		20 (3)	14 (1)
Northern Glaciated Mountains	955	664	608 (100)	78 (13)	526 (164)	54 (1)
Lower Clark Fork	415	415	410 (27)	70 (17)	339 (73)	5 (0)
Upper Clark Fork	306	306	283 (39)	53 (1)	215 (45)	23 (5)
Owyhee Uplands	956	0				
Upper Snake	301	0				
Snake Headwaters	387	0				
Central Idaho Mountains	1232	789	678 (96)	235 (107)	353 (193)	111 (30)
Entire Assessment Area	7498	2646	2251 (303)	587 (255)	1485 (494)	393 (121)

Map 4.14—Current presence, absence, and estimated probability of occurrence within the historical range for westslope cutthroat trout by subwatershed. Current distributions are based on the current-status database. Probabilities of occurrence are based on the classification tree for presence or absence. Presence outside the historical range is shown as introduced.

Map 4.15—Current distribution of spawning and rearing areas classified or predicted as strong or depressed for westslope cutthroat trout by subwatershed. Current distributions are based on the current-status database. Predictions are based on the full classification tree for spawning and rearing areas.

trout mature at age three, but first spawning occurs mostly at age four or five. Sexually maturing fluvial and adfluvial fish move near spawning tributaries in fall and winter where they remain until migrating upstream in the spring (Liknes 1984). The patterns of movement and distribution suggest that landscapes may play an important role in the expression of life history. The full expression of varied life histories will likely require the maintenance of habitats across relatively large areas such as entire river and lake basins.

Habitat Relationships—In the portions of the Basin supporting westslope cutthroat trout most waters are relatively cold and nutrient poor (Liknes and Graham 1988; Rieman and Apperson 1989). Growth varies widely and is probably influenced by stream and lake productivity. Growth is also consistently higher for migrant forms that spend some period in larger rivers or lakes (Rieman and Apperson 1989). Growth likely has an important influence on the relative productivity and resilience of populations to disturbance and increased mortality (Rieman and Apperson 1989).

Substrate composition strongly influences survival. Weaver and Fraley (1991) demonstrated a negative relationship between emergence success and the percentage of fine sediments. Sediment reduces embryo survival (Irving and Bjornn 1984) and food and space for rearing juveniles (Bjornn and others 1977). Highly embedded substrates have been negatively correlated with juvenile abundance (Thurow 1987) and may be particularly harmful to trout that enter the substrate in winter (Peters 1988; Wilson and others 1987). Predicting the effects of fine sediment on wild populations remains difficult however (Chapman 1988; Everest and others 1987), and some populations clearly persist in systems with very high sediment levels (Magee and others 1996). Increased fines in substrates must be viewed as an increased risk for any population, but precise quantification of expected losses is unrealistic.

The distribution and abundance of larger (>150 mm) westslope cutthroat trout has been strongly associated with the number and quality of pools (Ireland 1993; Peters 1988; Pratt 1984; Shepard 1983). High quality pools appear to be especially important as wintering habitats (Lewynsky 1986; Peters 1988). Habitats that provide some form of cover also seem to be strongly preferred (Griffith 1970; Lider 1985; Pratt 1984). Fraley and Graham (1981) found the best models for predicting the distribution of trout in the Flathead River Basin included cover as an independent variable.

The association of westslope cutthroat trout with habitat characteristics influenced by land management suggests they are vulnerable to habitat disruption. Although this subspecies is still widely distributed, we found that both presence and the occurrence of strong populations were more likely on Forest Service than other lands, and in watersheds less influenced by roads or land management. Our classification analysis does not demonstrate causal linkages between management and habitat, but the pattern of our results is consistent with that hypothesis and the results of other studies (Rieman and Apperson 1989).

Key Factors—Introduced species have played a key role in the current status of westslope cutthroat trout. Non-native salmonids have been introduced throughout the range of westslope cutthroat trout including Glacier National Park (Marnell 1988). Behnke (1992) speculated that non-native kokanee, lake trout, and lake whitefish are important causes of decline through predation and competition in lakes. Mysids (*Mysis relicta*) have also been introduced in several lakes in Idaho and Montana and might influence westslope cutthroat trout populations (Bowles and others 1991). Behnke (1992) concluded that brown, brook, and rainbow trout along with changes in flow and water quality, were responsible for the demise of some westslope cutthroat trout populations in the Spokane and Clark Fork river drainages. Fausch (1988, 1989) suggested that the persistence of cutthroat trout is jeopardized in streams also supporting brook or brown trout. Brook trout are thought to have replaced many westslope cutthroat trout populations in headwater streams (Behnke 1992), but the mechanism

of interaction is not clear (Fausch 1988; Griffith 1988). When the two species coexist, cutthroat trout seem to predominate in the higher gradient reaches (Griffith 1988), while brook trout may prevail in lower gradients (Fausch 1989).

Although closely related, cutthroat and rainbow trout have remained reproductively distinct (Behnke 1992) where they evolved in sympatry. Where non-native rainbow trout have been introduced, hybridization is widespread (Behnke and Zarn 1976; Rieman and Apperson 1989). Yellowstone cutthroat trout have also been widely introduced into the westslope cutthroat trout range and hybridization between these two forms is common (Liknes 1984; Rieman and Apperson 1989). Genetic introgression was believed to be the most important cause for decline of westslope cutthroat trout populations in Montana (Liknes and Graham 1988), and may compromise populations throughout the range.

Angling is a second factor important in the status of these fish. Westslope cutthroat trout are highly susceptible to angling (Behnke 1992; Lewynsky 1986; MacPhee 1966). Many populations have increased in response to harvest restrictions (Johnson and Bjornn 1978; Peters 1988; Rieman and Apperson 1989; Thurow and Bjornn 1978). Rieman and Apperson (1989) found evidence of a depensatory effect in fishing (mortality increased with decline in population size) and speculated that harvest could lead to the elimination of some small populations. Others believe that angler harvest led to the virtual elimination of fluvial fish in some river systems.[9] Special harvest restrictions may be necessary to maintain most westslope cutthroat trout populations (Rieman and Apperson 1989). Most state management agencies limit harvest of native westslope cutthroat trout with restrictive angling regulations.

Habitat disruption is a third factor consistently identified in the decline in the status of westslope cutthroat trout. Habitat loss and degradation are primary concerns for persistence of westslope cutthroat trout (Liknes 1984; Liknes and Graham 1988; Rieman and Apperson 1989). Accumulation of fine sediments has been a primary concern for biologists dealing with fish habitat relations (for example, Rieman and Apperson 1989; Stowell and others 1983). In watersheds within the belt geologies of northern Idaho and western Montana, excessive bedload transport and scour are problems associated with watershed disruption and increased peak flow events (Cross and Everest 1995). In low-gradient channels bed aggradation may result both in the loss of pools or pool volume, and in channel dewatering during low flow periods. The relatively simple, and unstable channels that result from intensive management of these basins were overlooked as problems in earlier concerns focused on fine sediments (Gamblin 1988; Rieman and Apperson 1989). Intensive management may lead to habitat disruption through a variety of mechanisms.

Summary—The current abundance of westslope cutthroat trout appears to be restricted from historical conditions (Behnke 1992; Bjornn and Liknes 1986; Liknes and Graham 1988; Rieman and Apperson 1989). Local extirpations are also evident in portions of the range. Construction of dams, irrigation diversions, or other migration barriers has isolated or eliminated westslope cutthroat trout habitats that were once available to migratory populations (Rieman and Apperson 1989). Resident forms may persist in isolated segments of streams but the loss of the migratory life-history and the connection with other populations potentially important to gene flow or metapopulation dynamics, may seriously compromise the potential for long term persistence (McIntyre and Rieman 1995). Climate change might be important in further restriction of westslope cutthroat trout populations (Mullan and others 1992; Rieman and McIntyre 1995). Although small and often isolated populations appear to persist throughout the range, the long term outlook for many of these is poor.

[9]Personal communication. 1995. T.C. Bjornn, University of Idaho, Moscow, Idaho.

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There is little chance that populations strongly influenced by introgressive hybridization can ever be recovered as genetically pure. Because most of the genetic variation in the subspecies occurs among rather than within populations (Allendorf and Leary 1988) maintenance of the few remaining strong populations could be critical to preservation of remaining genetic diversity.

Westslope cutthroat trout are still widely distributed throughout the Basin. Among the salmonids, they are second in number of occupied subwatersheds to sympatric redband trout. They still occur in the largest part of the historical range of any of the seven key salmonids. The broad distribution suggests that westslope cutthroat trout are secure. This may be misleading, however, because of questions about the genetic integrity of remaining populations. Most populations are depressed, and genetic introgression, fragmentation and the loss of migratory life-history forms may limit truly healthy populations to a smaller proportion of the historical range than is evident here. The causes for decline of westslope cutthroat trout are varied. Many strong populations in Idaho and Montana occurred largely in roadless and wilderness areas or national parks (Liknes 1984; Liknes and Graham 1988; Marnell 1988; Rieman and Apperson 1989) suggesting that human intervention has been important. In general, strong populations are thought to be primarily associated with areas of limited human influence and the potential effects of fishing, watershed disturbance and non-native introductions (Rieman and Apperson 1989). The association of current distributions with areas of lower road density and with wilderness or low management impact in the classification-tree analysis is consistent with this view.

The core of the distribution for strong populations is clearly associated with the Central Idaho Mountains, and many populations there appear secure. Other important regions of known or likely habitat are in Idaho and Montana within the Upper Clark Fork and Northern Glaciated Mountains. These latter areas, however, are more fragmented and restricted to a relatively smaller portion of the historical distribution than the core of subwatersheds associated with central Idaho. Further erosion of remaining strongholds could influence both the broad representation of and the potential for long-term persistence of westslope cutthroat trout. The Northern Cascades was predicted to support a larger collection of subwatersheds, geographically distinct from the main distribution. The distribution and status were poorly known in this region, however, requiring extrapolation from relatively few subwatersheds to a much broader area. The origin of cutthroat trout throughout the Northern Cascades is also still in some question. More work will be necessary to better understand the status and distribution of native westslope cutthroat trout populations in the Northern Cascades. Westslope cutthroat trout were probably never widely distributed within the Blue Mountain or Columbia Plateau and only remnant or strongly isolated populations are found there now. Conservation of the remaining populations within the latter three regions may be more difficult but particularly important to conservation of the historical distribution and evolutionary legacy of westslope cutthroat trout.

Redband Trout (*Oncorhynchus mykiss*)—The rainbow trout is a widely distributed western North America native salmonid. Rainbow trout have been segregated into three forms (Behnke 1992): 1) Coastal rainbow trout west of the Cascade/Sierra mountain divide; 2) Interior Columbia River redband trout upstream of Celilo Falls, including the Fraser and Athabasca rivers in Canada, the upper Klamath River Basin, and the isolated interior basins of Oregon; and 3) the Sacramento-San Joaquin redband trout (Behnke, 1992). Although the systematics are incomplete, physical characteristics and genetic studies support the view that these three rainbow trout forms warrant subspecific recognition (Allendorf 1975; Allendorf and Utter 1979; Allison and Bond 1983; Berg 1987; Stearley and Smith 1993; Utter and Allendorf 1977).

The interior redband trout was more widely distributed within the Basin than any other salmonid (Behnke 1992). Redband trout probably replaced native cutthroat trout in many subbasins within the last 30,000 years, perhaps favored by climatic and hydrologic events during and following glaciation (Behnke 1992; McKee 1972). Introgressed forms of redband trout, hybrids with introduced rainbow or cutthroat trout, may be replacing native redband trout today. The redband trout is considered a species of special concern by the American Fisheries Society and all states in the historical range, and is classified as a sensitive species by the Forest Service and Bureau of Land Management (Williams and others 1989). The U.S. Fish and Wildlife Service lists the McCloud River, California stock as a Category 1 Candidate species (Beattie 1994). In 1994, the Kootenai River redband trout in northern Idaho and Montana was petitioned for listing under the federal Endangered Species Act.

Redband trout in the Basin have two distinct life histories, anadromous (steelhead), which we considered in a separate section, and non-anadromous, which we focus on here. In this section we have further divided non-anadromous redband trout into those sympatric with or allopatric with steelhead. We considered allopatric redband trout those that evolved outside the historical range of steelhead. We assumed the allopatric form was potentially genetically and evolutionarily distinct from other redband trout because of this isolation. We considered sympatric redband trout to be the non-anadromous form historically derived from or associated with steelhead. Sympatric redband trout have also been termed "residuals" (Mullan and others 1992). A non-anadromous form is likely to exist in sympatry with steelhead, however, the level of genetic or behavioral segregation between forms is unknown. Morphologically, anadromous and non-anadromous redband trout juveniles are indistinguishable, and one might anticipate that the life history differences have evolved repeatedly from a single form throughout the Basin (Behnke 1995). We relied on knowledge of established barriers to anadromy to define the range for the allopatric form. The distribution of small populations of allopatric redband trout isolated from, but within the general range of the steelhead (for example, above natural barriers in 2nd and 3rd order streams) was poorly documented and not considered here.

Historical Distribution—The historical range of all forms of redband trout included freshwaters west of the Rocky Mountains, extending from northern California to northern British Columbia, Canada (Behnke 1992). What may be a primitive form has been found in the Athabasca and Peace River drainages on the east flank of the Rocky Mountains (Carl and others 1994). We did not consider the distribution of redband trout in Canada but they are thought to have been present throughout the upper Columbia River basin with the exception of the upper Kootenai River basin above Kootenai Falls.[10] Redband trout were widely distributed and occupied most accessible waters from the southern desert basins to the high mountain coniferous forests (Behnke 1992; Cope 1879; Cope 1889; Gilbert and Evermann 1895; Jordan 1892; Jordan and Evermann 1896; Jordan and others 1930; Snyder 1908). A barrier falls below Upper Klamath Lake separated interior redband trout from coastal rainbow trout (Behnke 1992). A wet cycle in the Pleistocene allowed redband trout to move from the Columbia River basin to the upper Klamath and all but one of the closed desert basins along the southern margin of Oregon (Behnke 1992; Hubbs and Miller 1948). The only major areas within the Basin that did not support redband trout were the Snake River upstream from Shoshone Falls, tributaries to the Spokane River above Spokane Falls, Eastern Rocky Mountain basins in Montana, and portions of the northern Great Basin in Oregon (maps 4.16 and 4.17).

Redband trout were the most widely distributed key salmonid in the Basin, with both forms historically occupying 77 percent of the ERUs and 73 percent of the subwatersheds within the Basin

[10]Personal communication. 1995. E. Parkinson, British Columbia Ministry of Environment, British Columbia, Canada.

Map 4.16—Current presence, absence, and estimated probability of occurrence within the historical range for sympatric redband trout (within the range of steelhead) by subwatershed. Current distributions are based on the current-status database. Probabilities of occurrence are based on the classification tree for presence or absence.

Map 4.17—Current presence, absence, and estimated probability of occurrence within the historical range for allopatric redband trout (outside the range of steelhead) by subwatershed. Current distributions are based on the current-status database. Probabilities of occurrence are based on the classification tree for presence or absence.

(table 4.33). Sympatric redband trout were the most widely distributed form, occupying 56 percent of all watersheds and all but four ERUs (table 4.34; map 4.16). Allopatric redband trout were much less widely distributed, occupying 18 percent of all subwatersheds (table 4.35; map 4.17). Historical abundance of allopatric redband trout is poorly documented. Densities in high quality habitats would be expected to be similar to those observed for other resident salmonids (Thurow 1990).[11]

Current Status and Distribution—A total of 1,793 observations was available for the classification-tree analysis (see table 4.22). We used the classification models to estimate the probability of occurrence of redband trout in 1,648 subwatersheds (30% of the historical range) that were previously unclassified and to predict status (strong or depressed) in those subwatersheds and an additional 2,034 subwatersheds (37%) where redband trout were classed as present but of unknown status (table 4.33). We used models to predict the status of redband trout based on biophysical characteristics of the watershed and patterns of distribution reported for both sympatric and allopatric forms.

The tree classification models were the least successful for redband trout of any of the key salmonids but were still useful for extrapolating into unclassified watersheds. The model had an overall classification success rate of 76 percent for the three classes of status (absent, depressed, and strong) and 91 percent when limited to presence or absence (see table 4.22).

Based on our known and predicted status and distribution, redband trout remain the most widely distributed key salmonid in the Basin, with sympatric and allopatric forms jointly known or predicted to occupy 47 percent of the entire Basin. We estimate that they occur in 64 percent of their combined historical range (table 4.36; map 4.16 and 4.17). Despite their broad distribution, we know less about the current distribution of redband trout than any of the other key salmonids. About 30 percent of the historical range was not classified (unknown occurrence) in the current-status database (table 4.33). Another 37 percent of the historical range was judged to support redband trout but too little information was available to evaluate status. One reason for the lack of information was our inability to differentiate juvenile steelhead and sympatric redband trout. As a result, we considered the status of sympatric redband trout "unknown" when steelhead were present in a watershed.

Sympatric redband trout are the most widely distributed of the two forms, the known and predicted distribution includes 69 percent of the historical range (table 4.37). The largest areas of unoccupied habitat in the potential historical range are in the Owyhee Uplands and Columbia Plateau (table 4.37). Allopatric redband trout are not as widely distributed and are currently found or anticipated in 49 percent of the potential historical range (table 4.38).

Despite their broad distribution, relatively few strong sympatric redband trout populations were identified (map 4.18). Known or predicted strong areas included 17 percent of the potential historical range and 24 percent of the present distribution (table 4.37). If only subwatersheds supporting spawning and rearing were considered, 30 percent of the subwatersheds were classified as strong (table 4.37). Allopatric redband trout had even fewer strong populations (map 4.19), including 9 percent of the potential historical range and 18 percent of the present distribution (table 4.38). Allopatric redband trout populations are least well distributed in the Northern Great Basin and Columbia Plateau where they are believed absent in 72 percent of the potential historical range and few strong populations were known or predicted within the present distribution.

The classification tree for redband trout tended to under-predict the occurrence of strong populations. One might anticipate that this species is more persistent and widely distributed than

[11]Personal communication. 1995. S. Yundt, Idaho Department of Fish and Game, Boise, Idaho. Personal communication of unpublished data.

Table 4.33—Summary of the current status and distribution classifications (number of subwatersheds) for redband trout (sympatric and allopatric) throughout the Ecological Reporting Units of the Basin.

				Status Where Present						
Ecological Reporting Unit	Total	Historical Range	Total Present	Strong*	Depressed*	Status Unknown	Corridor	Introduced	Absent	No Classification
Northern Cascades	340	340	253	5	4	244	0	0	9	78
Southern Cascades	141	125	107	25	38	44	0	0	14	4
Upper Klamath	175	175	44	0	10	34	0	0	0	131
Northern Great Basin	506	405	99	2	49	48	0	0	165	141
Columbia Plateau	1089	1050	465	24	156	282	3	0	210	375
Blue Mountains	695	695	574	48	95	428	3	0	33	88
Northern Glaciated Mountains	955	456	281	25	13	243	0	0	52	123
Lower Clark Fork	415	99	68	3	17	48	0	0	8	23
Upper Clark Fork	306	0	0							
Owyhee Uplands	956	956	311	40	167	104	0	0	287	358
Upper Snake	301	0	0	0	0	0	0	0	0	0
Snake Headwaters	387	0	0							
Central Idaho Mountains	1232	1157	786	79	148	559	0	0	44	327
Entire Assessment Area	7498	5458	2988	251	697	2034	6	0	822	1648

* = Refers to spawning and rearing areas only

Table 4.34—Summary of the current status and distribution classifications (number of subwatersheds) for sympatric redband trout throughout the Ecological Reporting Units of the Basin.

				Status Where Present						
Ecological Reporting Unit	Total	Historical Range	Total Present	Strong*	Depressed*	Status Unknown	Corridor	Introduced	Absent	No Classification
Northern Cascades	340	292	222	5	4	213	0	0	7	63
Southern Cascades	141	125	107	25	38	44	0	0	14	4
Upper Klamath	175	35	8	0	0	8	0	0	0	27
Northern Great Basin	506	0	0							
Columbia Plateau	1089	796	398	23	94	278	3	0	148	250
Blue Mountains	695	643	534	35	69	427	3	0	23	86
Northern Glaciated Mountains	955	258	180	21	3	156	0	0	31	47
Lower Clark Fork	415	98	67	3	17	47	0	0	8	23
Upper Clark Fork	306	0	0							
Owyhee Uplands	956	898	279	38	154	87	0	0	283	336
Upper Snake	301	0	0							
Snake Headwaters	387	0	0							
Central Idaho Mountains	1232	1051	693	66	146	481	0	0	43	315
Entire Assessment Area	7498	4196	2488	216	525	1741	6	0	557	1151

* = Refers to spawning and rearing areas only

Table 4.35—Summary of the current status and distribution classifications (number of subwatersheds) for allopatric redband trout throughout the Ecological Reporting Units of the Basin.

Ecological Reporting Unit	Total	Historical Range	Total Present	Status Where Present					Absent	No Classification
				Strong*	Depressed*	Status Unknown	Corridor	Introduced		
Northern Cascades	340	48	31	0	0	31	0	0	2	15
Southern Cascades	141	0	0							
Upper Klamath	175	140	36	0	10	26	0	0	0	104
Northern Great Basin	506	405	99	2	49	48	0	0	165	141
Columbia Plateau	1089	254	67	1	62	4	0	0	62	125
Blue Mountains	695	52	40	13	26	1	0	0	10	2
Northern Glaciated Mountains	955	198	101	4	10	87	0	0	21	76
Lower Clark Fork	415	1	1	0	0	1	0	0	0	0
Upper Clark Fork	306	0	0							
Owyhee Uplands	956	58	32	2	13	17	0	0	4	22
Upper Snake	301	0	0				0	0		
Snake Headwaters	387	0	0							
Central Idaho Mountains	1232	106	93	13	2	78	0	0	1	12
Entire Assessment Area	7498	1262	500	35	172	293	0	0	265	497

* = Refers to spawning and rearing areas only

Table 4.36—Summary of total known and predicted classifications (number of subwatersheds) for status of redband trout (sympatric and allopatric) pooled. The classifications are from the current-status database. The numbers predicted are based on the classification trees for all redband trout and are shown in parentheses. One hundred four subwatersheds classified as unknown did not have a prediction.

Ecological Reporting Unit	Total	Historical Range	Present	Strong	Depressed	Absent
Northern Cascades	340	340	289 (36)	94 (89)	47 (43)	50 (41)
Southern Cascades	141	125	111 (4)	46 (21)	56 (18)	14 (0)
Upper Klamath	175	175	134 (90)		143 (133)	23 (23)
Northern Great Basin	506	405	117 (18)	5 (3)	89 (40)	258 (93)
Columbia Plateau	1089	1050	529 (64)	74 (50)	425 (269)	521 (311)
Blue Mountains	695	695	621 (47)	264 (216)	268 (173)	74 (41)
Northern Glaciated Mountains	955	456	283 (2)	86 (61)	39 (26)	167 (115)
Lower Clark Fork	415	99	69 (1)	14 (11)	51 (34)	30 (22)
Upper Clark Fork	306	0				
Owyhee Uplands	956	956	375 (62)	56 (16)	236 (69)	532 (245)
Upper Snake	301	0				
Snake Headwaters	387	0				
Central Idaho Mountains	1232	1157	972 (186)	177 (98)	667 (519)	185 (141)
Entire Assessment Area	7498	5458	3500 (510)	816 (565)	2021 (1324)	1854 (1032)

Table 4.37—Summary of total known and predicted classifications (number of subwatersheds) for status of sympatric redband trout. The classifications are from the current-status database. The numbers predicted are based on the classification trees for all redband trout and are shown in parentheses. Fifty-five subwatersheds classified as unknown did not have a prediction.

Ecological Reporting Unit	Total	Historical Range	Present	Strong	Depressed	Absent
Northern Cascades	340	292	258 (36)	93 (88)	35 (31)	34 (27)
Southern Cascades	141	125	111 (4)	46 (21)	56 (18)	14 (0)
Upper Klamath	175	35	23 (15)	0 (0)	31 (31)	8 (8)
Northern Great Basin	506	0				
Columbia Plateau	1089	796	457 (59)	73 (50)	305 (211)	339 (191)
Blue Mountains	695	643	579 (45)	249 (214)	241 (172)	64 (41)
Northern Glaciated Mountains	955	258	181 (1)	42 (21)	12 (9)	75 (44)
Lower Clark Fork	415	98	68 (1)	14 (11)	50 (33)	30 (22)
Upper Clark Fork	306	0				
Owyhee Uplands	956	898	336 (57)	54 (16)	213 (59)	513 (230)
Upper Snake	301	0				
Snake Headwaters	387	0				
Central Idaho Mountains	1232	1051	870 (177)	131 (65)	613 (467)	181 (138)
Entire Assessment Area	7498	4196	2883 (395)	702 (486)	1556 (1031)	1258 (701)

Table 4.38—Summary of total known and predicted classifications (number of subwatersheds) for status of allopatric redband trout. The classifications are from the current-status database. The numbers predicted are based on the classification trees for all redband trout and are shown in parentheses. Forty-nine subwatersheds classified as unknown did not have predictions.

Ecological Reporting Unit	Total	Historical Range	Present	Strong	Depressed	Absent
Northern Cascades	340	48	31 (0)	1 (0)	12 (12)	16 (14)
Southern Cascades	141	0				
Upper Klamath	175	140	111 (75)	0 (0)	112 (102)	15 (15)
Northern Great Basin	506	405	117 (18)	5 (3)	89 (40)	258 (93)
Columbia Plateau	1089	254	72 (5)	1 (0)	120 (58)	182 (120)
Blue Mountains	695	52	42 (2)	15 (2)	27 (1)	10 (0)
Northern Glaciated Mountains	955	198	102 (1)	44 (40)	27 (17)	92 (71)
Lower Clark Fork	415	1	1 (0)	0 (0)	1 (1)	0 (0)
Upper Clark Fork	306	0				
Owyhee Uplands	956	58	39 (7)	2 (0)	23 (10)	19 (15)
Upper Snake	301	0				
Snake Headwaters	387	0				
Central Idaho Mountains	1232	106	102 (9)	46 (33)	54 (52)	4 (3)
Entire Assessment Area	7498	1262	617 (117)	114 (79)	465 (293)	596 (331)

Map 4.18—Current distribution of spawning and rearing areas classified or predicted as strong or depressed for sympatric redband trout by subwatershed. Current distributions are based on the current-status database. Predictions are based on the full classification tree for spawning and rearing areas.

Map 4.19—Current distribution of spawning and rearing areas classified or predicted as strong or depressed for allopatric redband trout by subwatershed. Current distributions are based on the current-status database. Predictions are based on the full classification tree for spawning and rearing areas.

anticipated from our analysis. We suspect, however, that the empirical assessment is optimistic. The long history of stocking rainbow trout within the Basin (see map 4.7), and the proclivity for redband and rainbow trout to hybridize, suggests the true distribution and status of the original genotypes could be more depressed than our estimates indicate (Allendorf and others 1980; Anonymous 1995; Behnke 1992; Berg 1987; Currens and others 1990; Leary and others 1992; Moskowitz and Rahr 1994; Williams and Shiozawa 1993; Wishard and others 1984). Preliminary status reviews in Idaho, Oregon and Montana generally support this concern (Anonymous 1995; Moskowitz and Rahr 1994; Perkinson 1995).[12] Introgressive hybridization is viewed as one of the most pervasive problems in the management of other non-anadromous native salmonids (Allendorf and Leary 1988; Liknes and Graham 1988) and may be a serious threat to many fishes in general (Campton 1987).

Life-history Characteristics—Life histories of redband trout are variable and several forms have been described including adfluvial and fluvial migratory forms, non-migratory resident or stream-dwelling forms. Because redband trout have persisted in nearly every biophysical setting in the Basin, a variety of other life history adaptations may exist (see Thorpe 1994). Adfluvial redband trout (such as Kamloops rainbow trout) migrate from lentic waters to tributaries and fluvial redband trout remain in flowing waters throughout their entire life cycle, using streams ranging from small tributaries to large rivers (Moyle and others 1989). The adfluvial form of the allopatric redband trout was historically present in Canadian lakes, Crescent Lake, Washington and several of the isolated lake basins within the Northern Great Basin in Oregon (Behnke 1992; Moyle and others 1989). Allopatric redband trout are also isolated in small patches of habitat above migration barriers (Thurow 1987) and thus persist with only minimal movements. Movement among populations may be an important mechanism for maintenance of genetic variability in populations (Leary and others 1992) and for their persistence in variable environments. The role that isolation plays in local adaptation and development of unique alleles, however, may be important to total genetic variability in the species (Lesica and Allendorf 1995).

The ecology of redband trout remains largely unknown although many early life-history characteristics may be similar to those for steelhead. Other rainbow trout may also be representative, but because of the potential effects of introgression with introduced forms, that representation is not clear. It appears that steelhead confined above barriers adopt a non-anadromous lifestyle appropriate to the habitats available (Moffit and Bjornn 1984) but retain the potential for anadromy (Mullan and others 1992). The possibility that sympatric redband trout may be able to refound anadromous runs has importance for the potential recovery of unique populations of steelhead lost because of human-caused barriers (Mullan and others 1992). The maintenance of such distinct life histories may be an adaptation to variable environments (for example, Gross 1991).

The exceptional range and apparently broad adaptations of redband trout preclude narrow generalizations of life history but some observations are possible. Redband trout are primarily spring spawners (March-June) although they may reproduce at any time of the year (Kunkel 1976).[13] Redband trout spawn exclusively in flowing waters and typically migrate to spawning areas. Thurow (1990) observed allopatric redband trout migrating upstream to suitable spawning locations in spring. Migration timing is likely effected by water temperature and stream flow. Following spawning allopatric redband trout may maintain restricted home ranges until migrating to overwintering areas in the fall (Thurow 1990). Migratory juveniles typically move downstream to their ancestral lake or river after one to three years in natal areas.

[13]Personal communication. 1995. T. Klahr, U.S. Fish and Wildlife Service, Boise, Idaho.

[13]Personal communication. 1995. D. Buchanan, Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Sexual maturity typically occurs at three to five years except in very cold (Mullan and others 1992) or hot climates. Growth is variable but likely dependent on genetic and environmental conditions.

Little is known about the interaction of redband trout with other species. Where redband and westslope cutthroat trout are naturally sympatric, the two species appear to have evolved segregative strategies (Rieman and Apperson 1989).[14] Populations that evolved in lakes have adopted piscivorous food habits. It is generally assumed that populations associated with streams and rivers rely heavily on aquatic and terrestrial invertebrates but foraging strategies are not well known. Redband trout are part of a native community that includes cottids, catostomids, cyprinids, and salmonids including westslope cutthroat trout, bull trout, mountain whitefish, steelhead, and chinook salmon (Hosford and Pribyl 1991; Kunkel 1976).[15]

Habitat Relationships—Redband trout occupy a wide array of habitats (Scott and Crossman 1973) illustrated by the broad distribution within the Basin (see map 4.16 and 4.17). Judged from the distribution among ERUs, redband trout occupy the widest range of biophysical settings of any of the key salmonids we considered. In the classification-tree analysis, variables including management cluster, ERU, slope, mean temperature, *hucorder*, vegetation cluster, solar radiation, and precipitation were useful in discriminating subwatersheds supporting redband trout (see table 4.22). Redband trout were more likely to be present or strong in watersheds less influenced by land management on Forest Service administered land, in mid-size or smaller streams, and in higher gradient streams, with more solar radiation, precipitation greater than about 30 centimeters, and mean air temperatures less than 8°-9° C. Although the classifications performed well, they were generally less successful than for the other salmonids in the analysis.

Other work suggests that redband trout are found in a wide range of conditions, often more extreme than those associated with other species. Populations found in the deserts along the southern margin of the Basin inhabit turbid and alkaline waters that range from near freezing to over 25° C (Johnson and others 1985; Kunkel 1976; Zoellick 1995).[16] Growth has been positively associated with temperature in forested streams (Mullan and others 1992) and redband trout are often found in warmer waters than other salmonids. There is some evidence that removal of canopy may benefit production in colder, high elevation streams (Rieman and others, in press). There are undoubtedly limits to their tolerance, however. In warmer and dryer environments the loss of riparian cover has been associated with reduced numbers and production of fish (Li and others 1994; Tait and others 1994).

There has been relatively little work defining habitat use for this fish, but patterns are generally similar to other salmonids. Thurow (1988) found redband trout most abundant in pool habitats and in association with cover components including undercut banks, large woody debris, and overhanging vegetation. Some have suggested that redband trout, like steelhead, may be associated with higher gradient channels, often in riffles or with substrates dominated by boulders, cobbles and pocket water (Kunkel 1976).[17] Slope was a relatively important variable in the classification models associating the occurrence of fish with steeper landscapes (table 4.22; appendix 4E).

Key Factors—Hybridization and competition are biotic factors influencing redband trout status. At least 35 non-native species have been introduced within the range of redband trout in the Basin. Introduced fishes create risks of genetic introgression, competition for food and space, predation, and increased exposure to disease (Fausch 1988; Reisenbichler 1977). Introduced rainbow trout are

[14]Personal communication. 1995. R. Leary, University of Montana, Missoula, Montana.

[15]Personal communication. 1995. D. Perkinson, Kootenai National Forest, Libby, Montana.

[16]Personal communication. 1995. D. Buchanan, Oregon Department of Fish and Wildlife, Corvallis, Oregon. Personal communication of unpublished data.

[17]Personal communication. 1995. D. Perkinson, Kootenai National Forest, Libby, Montana. Personal communication of unpublished data.

now the most widely distributed fish in the Basin (see map 4.7) and have contributed to losses of the native redband trout genotype through introgression (Behnke 1992; Campton and Johnston 1985). In attempts to reduce introgression some hatchery programs use native brood stocks, however, the practice of selecting for traits that improve fish performance in hatcheries followed by widespread out-planting of a few stocks may also lead to losses of local adaptions (Reisenbichler, in press). Brown trout are widely introduced and represent a potentially important predator and competitor, particularly in the southern range where redband trout are associated with warmer water temperatures (see map 4.7). In attempts to sustain remaining native redband trout, several state agencies have suspended all stocking of non-native species in isolated watersheds.

Fragmentation and isolation of habitats influencing redband trout status. If watershed disturbances result in loss of corridors or connecting habitats, remaining redband trout populations can be progressively isolated into smaller and smaller patches of productive habitats. Corridors that provide habitat for migration, rearing, and overwintering may be critical to the conservation of species where connections among population are important (Hanski and Gilpin 1991; Rieman and McIntyre 1993). Such effects can be exaggerated by climate change. In the Goose Lake basin, Oregon, adfluvial redband trout find refuge in tributaries when the lake dries and recolonize the lake when it fills.[18] Factors that isolate tributaries from Goose Lake would increase the risk of extirpation during dry cycles. The loss of genetic variability through genetic drift may be a particularly important problem in the more isolated watersheds on the southern portion of the range of redband trout (Berg 1987; Wallace 1981).

Habitat degradation is a third factor influencing redband trout status. Interior redband trout habitats have been altered by a host of land use practices (Anonymous 1995; Moskowitz and Rahr 1994; Perkinson 1995; Williams and others 1989). Diverting water for irrigation threatens many populations in the southern portion of the range. Thurow (1988) reported four principal effects from water diversions: dewatering of stream reaches, loss of fish in unscreened diversions, blockage of migration corridors, and alteration of stream channels by earthmoving equipment. The loss or conversion of riparian cover has been caused by grazing, timber harvest, mining, urbanization and agriculture (Meehan 1991). In desert climates, the loss of riparian canopy has been associated with excessive temperature and reduced redband trout abundance (Li and others 1994; Tait and others 1994). Channel alterations associated with attempts to control flooding, develop floodplains, and construct roads have been extensive. Channel alterations adversely effect stream hydraulics (Bottom and others 1985), nutrient pathways (Schlosser 1982), invertebrate production (Benke and others 1985) and fish production. In Idaho, unaltered stream reaches supported eight to ten times the densities of redband trout observed in altered channels (Irizarry 1969; Thurow 1988). Habitat alterations may reduce the resilience and stability of the entire aquatic assemblage (Pearsons and others 1992; Thurow 1990).

Summary—Although redband trout appear to be widely distributed within the Basin their status is clouded by the uncertainty over taxonomic classification within the species, and by more than a century of stocking non-native rainbow trout and steelhead (Behnke 1992). Habitat degradation, hybridization or competition with introduced species, and a restricted range for some populations are the principal threats to conservation of the remaining redband trout (Williams and others 1989). Redband trout appear to have evolved over a broader range of environmental conditions than the other key salmonids and appear to have less specific habitat requirements. Their apparent persistence even in some heavily disturbed basins suggests they are less strongly influenced by habitat disruption than other salmonids. The loss of a

[18]Personal communication. 1995. J. Williams, Bureau of Land Management, Boise, Idaho.

redband trout population may be an indication of significant disruption in the processes influencing aquatic ecosystems.

Within the historical range of steelhead, sympatric redband trout are known or predicted to be widely distributed in large patches of suitable habitat in the Northern Cascades, Blue Mountains, and Central Idaho Mountains. These watersheds represent the core of the sympatric distribution and appear to be relatively secure. Introgression with introduced rainbow trout is potentially a serious but unevaluated threat. Known or predicted populations in watersheds within the Southern Cascades, Upper Klamath, Owyhee Uplands, and Northern Glaciated Mountains were recently (since 1900) isolated from steelhead by dams. These latter populations appear to be more fragmented in the remaining distribution. Allopatric redband trout within the Northern Great Basin, and portions of the Northern Glaciated Mountains, the Columbia Plateau, Central Idaho Mountains, and the Owyhee Uplands have been isolated from steelhead over geologic time. Remaining populations appear to be severely fragmented and restricted to small patches of known or potential habitat. These areas likely represent a critical element of the evolutionary history for this species and a major challenge in conservation management.

Steelhead (*Oncorhynchus mykiss*)—Steelhead, the anadromous form of rainbow/redband trout, are distributed within the Basin as two genetically distinct subspecies, coastal (*O. m. irideus*) and inland (*O. m. mykiss*) (Utter and others 1980). Coastal steelhead are found only in tributaries to the lower Columbia River west of the Hood River, Oregon (Kostow and others 1994). Each subspecies has two major forms, winter and summer, although coastal steelhead are predominately winter-run and inland steelhead summer-run. Winter-run steelhead enter freshwater three to four months prior to spawning (Withler 1966) and summer-run steelhead enter freshwater nine to ten months prior to spawning. Summer-run steelhead are described as either "A" run or "B" run, based on the time of passage over Bonneville Dam [Idaho Department of Fish and Game (IDFG) and others 1990].

The distribution and abundance of steelhead have declined from historical levels as a result of passage mortality at dams and obstructions, habitat degradation, loss of access to historical habitat, overharvest, and interactions with hatchery-reared and non-native fishes. A majority of the current populations consist of hatchery-reared fish (CBFWA 1990). Numerous state, federal, and provincial management agencies list remaining wild steelhead populations as species of special concern (Johnson 1987). The American Fisheries Society considers all stocks of winter-run steelhead upstream from Bonneville Dam to be at high or moderate risk of extinction and most summer-run steelhead stocks are considered at moderate risk of extinction or of special concern (Nehlsen and others 1991). Concern for the persistence of steelhead stocks culminated in 1994 petitions to the National Marine Fisheries Service for review of the species status under the Endangered Species Act. Steelhead represent a key species because of their broad distribution, value as a sport and commercial fish, and importance as a tribal ceremonial and subsistence resource.

Historical Distribution—The historical range of steelhead was the eastern Pacific Ocean and freshwaters west of the Rocky Mountains, extending from northwest Mexico to the Alaska Peninsula (Scott and Crossman 1973). The broad historical range of steelhead in the Basin is well documented [Howell and others 1985b; Northwest Power Planning Council (NWPPC) 1986] (Appendix 4D). Steelhead were present in most streams, both perennial and intermittent, that were accessible to anadromous fish including all accessible tributaries to the Snake River downstream from Shoshone Falls (Evermann 1896; Parkhurst 1950), and accessible tributaries to the Columbia River (Bakke and Felstner 1990; Fulton 1970; Howell and others 1985b) (map 4.20). Steelhead formerly

ascended the Snake River and spawned in reaches of Salmon Falls Creek, Nevada, more than 1,450 kilometers from the ocean. Approximately 16,935 kilometers of stream were accessible to steelhead in the Columbia River basin including Canada (NWPPC 1986).

Steelhead occupied about 50 percent of the subwatersheds in the assessment area (table 4.39) including all ecological units except the Northern Great Basin, Upper Clark Fork, Upper Snake, and Snake Headwaters. It is unlikely that steelhead occupied all reaches of all accessible streams. Water temperature may have restricted their historical distribution. Mullan and others (1992) suggested that rainbow trout/steelhead avoid water temperatures exceeding 22° C (lower limit) and that the distribution of steelhead may be restricted to stream reaches that exceed 1,600 annual temperature units (upper limit). Platts (1974) similarly reported an upper elevational limit in the South Fork Salmon River, rainbow/steelhead populations were not found above 2,075 meters. The resolution of our historical range information was not sufficient to map upper and lower distributional boundaries in individual watersheds, so our maps overestimate the historical range.

Historical steelhead runs were large. Steelhead have been reported in the commercial Columbia River catch since 1889 and 2.23 mega-kilograms of canned steelhead were produced in 1892 (Fulton 1970). Initial estimates of run sizes were derived after the construction of the Bonneville Dam in 1938. In 1940, 423,000 summer-run steelhead passed the dam (NWPPC 1986). Annual sport harvests averaged 117,000 summer-run and 62,000 winter-run fish from 1962 to 1966 (Fulton 1970).

Current Status and Distribution—A total of 1,355 observations was available for the classification analysis (see table 4.22). We used the classification models to estimate the probability of occurrence of steelhead in 279 subwatersheds (7% of the historical range) that were previously unclassified and to predict status (strong, depressed, or corridor) in those subwatersheds and an additional 289 subwatersheds (7.7%) where steelhead were classed as present but of unknown status (table 4.39).

The model was very effective in predicting the distribution of steelhead spawning and rearing areas and migration corridors. Subwatersheds predicted to have high probabilities for spawning and rearing areas and subwatersheds predicted to have high probabilities of migration corridors were very similar to known distributions. The overall classification success rate was 89 percent for the four classes (absent, depressed, strong, and migration corridor) (see table 4.22).

Based on our known and predicted status and distribution, steelhead are the most widely distributed anadromous salmonid, however, steelhead are extinct in large portions of their historical range (map 4.20). The current known distribution of steelhead includes about 41 percent of the historical range (table 4.39). The known and predicted distribution includes 46 percent of the historical range (table 4.40). Steelhead are extinct in the Upper Klamath, Lower Clark Fork, and Owyhee Uplands and are known to be absent in from 21 to 83 percent of the other ERUs (table 4.39). About 12,452 kilometers of the historical range is no longer accessible in the Columbia River basin in the United States and Canada (NWPPC 1986).

Despite their relatively broad distribution, very few healthy steelhead populations exist. Subwatersheds known or predicted to support strong spawning and rearing represented 0.6 percent of the historical range and 1.3 percent of the current range (table 4.40; map 4.21). If only those subwatersheds where fish spawn and rear are considered, 98 percent of the subwatersheds were classified as depressed (table 4.40). Recent status evaluations also suggest that many steelhead stocks are depressed. A recent multi-agency review shows that total escapement of salmon and steelhead to the various Columbia River regions has been in decline since 1986 (Anderson and others 1996). Washington state biologists analyzed 15 summer-run steelhead stocks and three winter-run steelhead stocks in the Basin. Eighty-seven percent of

Table 4.39—Summary of the current status and distribution classifications (number of subwatersheds) for summer steelhead throughout the Ecological Reporting Units of the Basin.

Ecological Reporting Unit	Total	Historical Range	Total Present	Status Where Present					Absent	No Classification	Wild Indigenous
				Strong*	Depressed*	Status Unknown	Corridor	Introduced			
Northern Cascades	340	274	186	1	115	63	7	0	58	30	3
Southern Cascades	141	67	42	0	33	4	5	0	25	0	0
Upper Klamath	175	35	0	0	0	0	0	0	35	0	0
Northern Great Basin	506	0	0								
Columbia Plateau	1089	554	332	6	200	37	89	0	138	84	56
Blue Mountains	695	584	375	13	312	11	39	0	204	5	169
Northern Glaciated Mountains	955	193	21	0	6	0	15	0	159	13	0
Lower Clark Fork	415	98	0	0	0	0	0	0	98	0	0
Upper Clark Fork	306	0	0								
Owyhee Uplands	956	898	0	0	0	0	0	0	887	11	0
Upper Snake	301	0	0								
Snake Headwaters	387	0	0								
Central Idaho Mountains	1232	1051	566	3	303	174	86	0	349	136	150
Entire Assessment Area	7498	3754	1522	23	969	289	241	0	1953	279	378

* = Refers to spawning and rearing areas only

Table 4.40—Summary of total known and predicted classifications (number of subwatersheds) for status of summer steelhead. The classifications are from the current-status database. The numbers predicted are based on the classification trees for summer steelhead and are shown in parentheses. Twenty-two subwatersheds classified as unknown did not have predictions.

Ecological Reporting Unit	Total	Historical Range	Present	Strong	Depressed	Corridor	Absent
Northern Cascades	340	274	201 (78)	1 (0)	192 (77)	8 (1)	65 (7)
Southern Cascades	141	67	42 (0)		37 (4)	5 (0)	25 (0)
Upper Klamath	175	35					35 (0)
Northern Great Basin	506	0					
Columbia Plateau	1089	554	392 (97)	6 (0)	289 (89)	97 (8)	160 (22)
Blue Mountains	695	584	378 (14)	13 (0)	326 (14)	39 (0)	206 (2)
Northern Glaciated Mountains	955	193	24 (3)		9 (3)	15 (0)	169 (10)
Lower Clark Fork	415	98					98 (0)
Upper Clark Fork	306	0					
Owyhee Uplands	956	898					887 (0)
Upper Snake	301	0					
Snake Headwaters	387	0					
Central Idaho Mountains	1232	1051	674 (282)	3 (0)	578 (275)	93 (7)	376 (27)
Entire Assessment Area	7498	3754	1711 (478)	23 (0)	1431 (462)	257 (16)	2021 (68)

Map 4.20—Current presence, absence, and estimated probability of occurrence within the historical range for steelhead by subwatershed. Current distributions are based on the current-status database. Probabilities of occurrence are based on the classification tree for presence or absence.

Map 4.21—Current distribution of spawning and rearing areas classified or predicted as strong or depressed for steelhead by subwatershed. Current distributions are based on the current-status database.

the summer-run steelhead and 33 percent of the winter-run steelhead stocks were judged to be depressed [Washington Department of Fisheries (WDF) and others 1993]. There was not sufficient information to judge the status of the other stocks. Wild/natural steelhead (defined below) in all Oregon basins were less than escapement goals and the 1994 return of wild/natural A-run fish was the lowest on record (Kostow and others 1994). Huntington and others (1994) surveyed stocks of steelhead in the Pacific Northwest and California and reported healthy stocks of summer-run steelhead only in the John Day River basin, Oregon.

Existing steelhead populations consist of four main types: wild, natural (non-indigenous progeny spawning naturally), hatchery, and mixes of natural and hatchery fish. Production of wild anadromous fish in the Columbia River basin has declined about 95 percent from historical levels (Huntington and others 1994). Most existing steelhead production is supported by hatchery and natural fish as a result of large-scale hatchery mitigation production programs. By the late 1960's hatchery production surpassed natural production in the Columbia River basin (NWPPC 1986). Wild, indigenous fish, unaltered by hatchery stocks, are rare (map 4.22) and present in 10 percent of the historical range and 25 percent of the current distribution (table 4.39). Remaining wild stocks are concentrated in reaches of the Salmon Selway rivers in Central Idaho and the John Day River basin in Oregon (map 4.22). Although few wild stocks were classified as strong, the only subwatersheds classified as strong were those sustaining wild stocks (6%) (table 4.40).

Life-history Characteristics—Life histories of steelhead are highly variable, both among and within populations (Shapovalov and Taft 1954; Withler 1966). Divergence of characteristics may be related to genetic and environmental influences (Bulkley 1967; Withler 1966). Their wide genetic repertoire enables steelhead populations to adapt to a wide range of physical circumstances (Thorpe 1994).

Mature adult summer-run steelhead ascend the Columbia River from May through October and winter-run steelhead from November to April (CBFWA 1990; Fulton 1970). Summer-run and winter-run steelhead may differ genetically because of spatial and temporal isolation (Leider and others 1984; Withler 1966). Age at maturity is highly variable depending on both fresh and salt water residence time. Withler (1966) reported 14 different life-history categories and Mullan and others (1992) reported 11 different categories. Length at maturity is positively related to length of ocean residence (Mallet 1974). Most steelhead remain in salt water for one to four years prior to maturation (Shapovalov and Taft 1954; Withler 1966). Fecundity is positively related to fish length (Bulkley 1967; Shapovalov and Taft 1954; Thurow 1987; Withler 1966) and may be genetically and environmentally influenced (Bulkley 1967; Mullan and others 1992). Sex ratios typically approximate 1:1 although many interior stocks have a larger ratio of females to males (Narver 1969). Male residualism may influence sex ratios (Mullan and others 1992).

Summer-run and winter-run steelhead spawn from March to June (CBFWA 1990), typically on a rising hydrograph and prior to peak streamflows (Thurow 1987). Similar to coastal steelhead (Shapovalov and Taft 1954), a dominant male usually pairs with a female, however, several other males, including small (< 200 mm) precocials may fertilize eggs. Spawning of precocial males may be particularly important when adult escapements are low. Parkinson (1984) reported genetic variation among steelhead in adjacent drainages indicating little interchange and a large number of individual populations. Reisenbichler and Phelps (1989) similarly believed that the variation in steelhead allele frequencies and the high degree of homing suggested that the basic breeding unit for steelhead occurred at the drainage or intradrainage scale.

Map 4.22—Watersheds supporting wild, native populations of steelhead and chinook salmon that have had little or no influence from introduced non-indigenous stocks.

Following spawning, spent adults (kelts) migrate downstream. Repeat spawning is highly variable among stocks (Shapovalov and Taft 1954) and is influenced by geographic location (Withler 1966). Iteroparity is uncommon in fish migrating several hundred kilometers inland (Simpson and Wallace 1978).

Incubation and emergence are temperature dependent and variable [Leitritz 1972; Thurow 1987; U.S. Department of Interior (USDI) and Confederated Yakama Indian Tribes (CYIT) 1993]. Parr rear in freshwater for varying periods ranging from two to seven years depending on water temperatures and growth rates (Mullan and others 1992). At smoltification, parr imprint on their natal stream and begin migrating to the ocean. The parr-smolt transformation typically occurs from April to mid-June and is associated with developmental changes in osmotic and ionic regulatory mechanisms (Wagner 1974a). Smoltification is influenced by photoperiod (Wagner 1974b) and is a function of fish size (Hoar 1976). When confined above barriers or in cold systems where growth is slow, steelhead may residualize to a nonanadromous form (Mullan and others 1992).

Habitat Relationships—Steelhead inhabit a wide range of diverse habitats, rearing, overwintering, and migrating through streams ranging from low order tributaries up to mainstem rivers. Habitat requirements of steelhead vary by season and life stage (Bjornn and Reiser 1991). Steelhead distribution and abundance may be influenced by water temperature, stream size, flow, channel morphology, riparian vegetation, cover type and abundance, and substrate size and quality (Everest 1973; Li and others 1994; Reiser and Bjornn 1979; Russell 1975; Salo and Cundy 1987; Stowell and others 1983).

Life stages are closely linked to habitat characteristics. Steelhead spawn in sorted gravels in both mainstem rivers and tributaries (Burner 1951; Needham and Taft 1934), including intermittent streams (Everest 1973). There is a marked variation in time of entry into spawning streams among populations (Ball 1985; Thurow 1987). Incubation success is influenced by fine sediment, temperature, and flow (Chapman 1988). After emergence, fry typically move into shallow and slow-moving channel margins (Everest and Chapman 1972). As fish become larger, preferred habitats change and fry use areas with deeper water, a wider range of velocities, and a larger substrate (Sheppard and Johnson 1985). Focal point velocity, distance from substrate, and maximum velocity all correlated significantly with fish size (Everest and Chapman 1972). In desert streams, densities of rainbow/steelhead were negatively correlated with solar radiation and maximum temperature, and streams with greater riparian canopy had higher standing crops (Li and others 1994; Tait and others 1994). Steelhead parr tend to select specific rearing habitats that segregate them, both temporally and spatially, from other native salmonids (Everest and Chapman 1972; Hanson 1977; Moffit and Bjornn 1984; Nilsson 1963).

Juvenile steelhead typically occupy different habitats in winter than in summer (Bustard and Narver 1975; Everest 1969). Steelhead may adopt two overwintering strategies, migration and concealment. Juveniles typically select areas of low water velocity and enter concealment cover beneath cobble or rubble substrate (Bustard and Narver 1975; Edmundson and others 1968; Everest and Chapman 1972).

Variables including hucorder, ERU, slope, solar radiation, vegetation and management clusters, and variables related to lithology and sensitivity to erosion were useful in discriminating subwatersheds supporting steelhead (see table 4.22; appendix 4E). Our results suggest that spawning and rearing areas for steelhead were likely to be found within specific core ERUs, in small to mid-size streams, in erosive land types and in steeper, higher elevation watersheds. Spawning and rearing also occurred primarily on Forest Service administered lands. Migration corridors represented probable steelhead occurrence in larger mainstem streams at lower elevations. Disturbance-related

variables had a relatively minor influence in the model classifications. Management cluster and the number of dams steelhead must pass en route to the ocean were useful but not dominant.

There are several potential reasons for the lack of influence of disturbance variables on steelhead status. First, the current presence of steelhead is influenced by environmental factors within the watersheds in addition to factors outside the Basin. The disturbance variables we have access to may not adequately reflect "outside basin" disturbances including passage mortality, harvest, and ocean survival. Second, the model does not differentiate wild and hatchery origin steelhead. In some heavily disturbed areas, remnant numbers of steelhead may be present only because of annual hatchery supplementation so disturbance is not a good predictor of hatchery steelhead presence. Third, too few strong populations are present to relate their presence to disturbance. As a result, the model does not provide an adequate prediction of risk associated with different management scenarios.

Like the other anadromous fish, the status and distribution of steelhead are confounded by a large number of factors operating at multiple scales in both space and time. Ocean and passage conditions, harvest, and the use of hatchery fish have undoubtedly played a major role in the condition of the remaining populations. Sorting out the role of habitat change and land management effects in the decline of this species will likely result only through specific analysis capable of finer resolution and control of confounding effects.

Key Factors—Predation and competition are biotic factors that may influence the abundance of steelhead. More than 55 introduced species occur within the current range of steelhead and introduced species occupy a majority of the watersheds in the current steelhead range. Because introduced species did not evolve in sympatry with steelhead, there has been no opportunity for adaption to ameliorate competition (Fausch 1988) or predation. In many reaches of the Snake and Columbia rivers, introduced species outnumber indigenous fish (Li and others 1987). Hobbs and Huenneke (1992) suggest that non-natives may pose a greater risk to native species where habitat has been disturbed. Dams have created habitat that is suitable for a variety of non-native predators and potential competitors (Beamesderfer and Rieman 1991). Native predators may also be influenced by anthropogenic habitat alterations. Northern squawfish have become well adapted to habitat created by dams (Beamesderfer and Rieman 1991). Attempts to quantify the effects of predation in the Snake and lower Columbia rivers suggest an annual system-wide loss of 15 to 20 million juvenile salmonids to northern squawfish (Collis and others 1995).

Blocked access to historical habitat is a second factor influencing steelhead status. An estimated 12,452 kilometers of steelhead habitat are no longer accessible in the Columbia River basin in the United States and Canada (NWPPC 1986). Although undocumented, the historical range likely supported diverse and locally adapted populations. Extinctions have resulted in lower diversity and lower total abundance of steelhead. Cumulative habitat changes that eliminate or isolate segments of populations may increase both demographic and environmental stochasticity (thereby increasing the risk of extirpation or extinction of remaining populations) because of lower numbers and lower diversity in population structure or distribution (Rieman and others 1993).

Passage mortality is a third factor influencing steelhead status. Construction and operation of mainstem dams on the Columbia and Snake rivers are considered the major cause of decline of anadromous fish (CBFWA 1990). Hydroelectric development changed Columbia and Snake river migration routes from mostly free-flowing in 1938 to a series of dams and impoundments by 1975. Reservoirs reduce flows in most years by about 50 percent during smolt migration (Raymond 1979). Steelhead must navigate up to nine mainstem dams. At each dam, adult steelhead are delayed

during upstream migrations. Smolts may be killed by turbines; become disoriented or injured, making them more susceptible to predation; or become delayed in the large impoundments behind dams (IDFG and others 1990). Smolt-to-adult return rates declined from more than 4 percent in 1968 to less than 1.5 percent from 1970-1974. In 1973 and 1977, low flows resulted in 95 percent of migrating smolts never reaching the ocean (Raymond 1979). The influence of passage mortality on steelhead stocks is illustrated by Huntington and others (1994) who concluded that although much of the Pacific Northwest's best remaining spawning and rearing habitat is in Idaho, no healthy stocks of anadromous fish were found.

Habitat degradation is a fourth factor influencing steelhead status. More than 95 percent of the healthy native stocks of anadromous fish identified by Huntington and others (1994) were judged by biologists to be threatened by some degree of habitat degradation. Similarly, Nehlsen and others (1991) identified habitat loss or degradation as a major problem for 90 percent of the 195 at-risk salmon and steelhead stocks they identified. Fish habitat quality in most watersheds has declined. During the past 50 years, numbers of pools have decreased and fine sediment has increased in selected Northwest watersheds (McIntosh and others 1994a). In addition to hydroelectric development, most alterations of steelhead habitat can be attributed to mining (Nelson and others 1991), timber harvest (Chamberlain and others 1991), agriculture (NWPPC 1986; Platts 1991), industrial development, and urbanization (NWPPC 1986).

Hatcheries are a fifth factor influencing steelhead status. Hatcheries have been widely used in attempts to mitigate losses of steelhead caused by construction and operation of dams (NWPPC 1986). Hatcheries may effect wild steelhead populations through genetic introgression and loss of fitness, creation of mixed-stock fisheries (see harvest below), competition for food and space, and changes in the abundance of disease organisms (Reisenbichler 1977). Studies of the interaction between wild and hatchery fish illustrate that survival of progeny from hatchery or hybrid (wild x hatchery) parentage is less than for progeny of wild fish pairings (Chilcote and others 1986; Reisenbichler and McIntyre 1977). Introduced rainbow trout also have the potential to mature and hybridize with steelhead (Chapman and others 1994b); and the species has been introduced throughout the current steelhead range (see map 4.7). Byrne and others (1992) suggested that supplementation of native stocks with hatchery fish have typically resulted in replacement, not enhancement of native steelhead. Most (107/121) of the healthy anadromous salmonid stocks identified by Huntington and others (1994) have either had no fish culture activities in the home watershed or been exposed to little risk from stock transfers or interaction with hatchery fish. Adult steelhead collection and egg taking operations may also be detrimental to individual populations (Chapman and others 1994b). Introductions of large numbers of hatchery-reared parr may cause localized decreases in the density of juvenile steelhead (Pollard and Bjornn 1973) and induce early migration of wild fish (Hillman and Mullan 1989).

Harvest is a sixth factor influencing steelhead status. Steelhead stocks have historically provided harvest opportunities for tribal, commercial, and sport fisheries. Wild steelhead populations have declined as numbers of hatchery steelhead have increased, creating harvest management problems. Hatchery steelhead that are surplus to egg taking needs can be harvested, in contrast to declining runs of wild steelhead that cannot. In response, sport and commercial harvest of wild adult steelhead has been closed (Chapman and others 1994b; IDFG 1992; NWPPC 1986), harvest of juvenile steelhead has been restricted in some areas (IDFG 1992), and tribal fisheries are regulated (Chapman and others 1994b; NWPPC 1986). Although the harvest of wild stocks has been reduced, declining runs of wild steelhead are still harvested in tribal fisheries, and steelhead are killed during commercial salmon fisheries in the

Columbia River and coastal marine waters, and in high seas driftnet fisheries (Chapman and others 1994b; Cooper and Johnson 1992-cited in Chapman and others 1994b).

Summary—The combination of low abundance, decreasing time trends in abundance, widely dispersed spawning populations, fragmented habitats, degraded freshwater and estuarine habitats, high risks of genetic introgression in most stocks, low frequency of wild indigenous stocks, high rates of non-native fish introductions, continued harvest in mixed-stock fisheries, and high-risks of smolt and adult passage mortality result in a high risk for individual steelhead stocks. Long-term persistence of steelhead will likely depend on maintaining and restoring migration corridors, mosaics of high quality habitats, and wild gene pools.

Steelhead are still relatively widely distributed in the Basin, however, they are extinct in nearly 60 percent of the historical range. Although steelhead are widespread throughout the remaining accessible range, most populations are severely depressed and heavily influenced by hatchery supplementation. Wild stocks are rare; core areas for remaining wild populations include the Salmon, Selway and John Day river basins. The only remaining strong populations are found among wild stocks, primarily in the Columbia Plateau and Blue Mountains. Within the Central Idaho Mountains recent steelhead runs have been critically low.

Restoration of habitats and habitat connectivity in both mainstem rivers and subbasins will be necessary for steelhead stocks to persist. The decline of steelhead stocks in the Basin in recent years can be attributed primarily to mainstem dams. However, until passage problems are resolved the resilience and persistence of remaining steelhead stocks will be largely dependent on the quality and diversity of remaining stream habitats. All remaining populations and habitats for steelhead within the Central Idaho Mountains, Blue Mountains, Northern Cascades, Columbia Plateau, Northern Glaciated Mountains, and Southern Cascades are critical to the persistence of this species within the Basin.

Chinook Salmon (*Oncorhynchus tshawytscha*)—Chinook salmon are widely distributed in the Basin. Traditionally they have been described as spring, summer, and fall races, separated primarily by their time of passage over Bonneville Dam (Matthews and Waples 1991). Spring chinook salmon cross Bonneville Dam from March to May, summers from June to July, and falls from August to September (Burner 1951). This nomenclature has led to some confusion across the Basin because stocks of similar run timing may differ considerably between the Snake and Columbia rivers in their spawning areas, life histories, behavior, and genetic characteristics. Gilbert (1912 as cited by Matthews and Waples 1991) first categorized juvenile chinook salmon that migrate seaward as yearlings as stream-type and those that migrate as subyearlings as ocean-type. We adopted these definitions to characterize chinook salmon stocks in the Basin. Within the Snake River basin and tributaries to the Columbia River downstream from the Snake River, stream-type chinook salmon include spring- and summer-run fish and ocean-type chinook salmon include fall-run fish (Fulton 1968; Gebhards 1959; IDFG 1992; Parkhurst 1950). Within the Columbia River upstream from its confluence with the Snake River "stream-type" chinook salmon include spring-run fish and "ocean-type" chinook salmon include summer- and fall-run fish (Matthews and Waples 1991, Mullan and others 1992).

Snake River chinook salmon (stream- and ocean-types) were listed as threatened under the federal Endangered Species Act in 1992. Their status was changed by emergency rule to endangered in 1994 because of continuing declines in abundance. The emergency rule terminated in 1995, and although their status has not improved, the species is again listed as threatened. Snake River chinook salmon populations in Oregon were also listed as threatened under the State endangered species statute in 1993. A petition was filed in 1993 to list mid-Columbia River (Chief Joseph to Priest Rapids dams) summer chinook salmon. The status review by the National Marine Fisheries Service (NMFS) determined that listing was not warranted. In

1994 NMFS began a status review of the remaining chinook salmon stocks in the United States outside Alaska.

Historical Distribution—The historical range of chinook salmon in North America was the eastern Pacific and Arctic oceans and accessible freshwaters (Scott and Crossman 1973). The broad historical range of chinook salmon in the Basin is well documented (Evermann 1896; Fulton 1970; Howell and others 1985a; NWPPC 1986; Parkhurst 1950) (appendix 4D). Chinook salmon were found in all accessible areas of the Snake River downstream from Shoshone Falls (Evermann 1896) and in all accessible areas of the Columbia River downstream from Windermere Lake, British Columbia (Fulton 1970) (maps 4.23 and 4.24). Like steelhead, chinook salmon were found in most accessible watersheds and formerly ascended the Snake River and spawned in reaches of Salmon Falls Creek, Nevada, more than 1,450 kilometers from the ocean. An estimated 16,935 kilometers of stream were accessible to chinook salmon in the Columbia River basin in the United States and Canada (NWPPC 1986).

Stream-type chinook salmon were the most widely distributed, occupying about 46 percent of the subwatersheds in the Basin and occurring in all ERUs except the Northern Great Basin, Upper Clark Fork, Snake Headwaters, and Upper Snake above Shoshone Falls (table 4.41). Ocean-type chinook salmon were much less widely distributed, occupying about 7 percent of the available subwatersheds and occurring in six of 13 ERUs (table 4.42). Ocean-type chinook salmon were historically present in the fewest subwatersheds of any key salmonid. The Snake River was considered the most important production area for ocean-type fall chinook salmon in the Columbia River Basin (Fulton 1968).

Cold water temperatures at high elevations (Mullan and others 1992) and the need for relatively large areas of suitable spawning gravel (Burner 1951) may have restricted the upper limit of chinook salmon but this is not well defined. Chinook salmon parr are also associated with low gradient, meandering, unconstrained stream channels (Scully and others 1990) which may further restrict their distribution.

Historical runs of chinook salmon were immense; estimates of annual run sizes prior to 1850 range from 3.4 to 6.4 million fish (NWPPC 1986). Most native people in the Basin shared a significant dependence on salmon as a subsistence and ceremonial resource (NWPPC 1986). Commercial harvest of chinook salmon in the mainstem Columbia River peaked in 1883 at 2.3 million fish and yield was about 1.3 million fish from 1890-1920 (Mullan and others 1992).

Current Status and Distribution—A total of 1,262 observations was available for stream-type and 224 observations for ocean-type chinook salmon classification-tree analysis, respectively (see table 4.22). We used the classification models to estimate the probability of occurrence of stream-type chinook salmon in 281 subwatersheds (8% of the historical range) that were previously unclassified (table 4.41). We predicted status (strong, depressed, or corridor) in those subwatersheds and an additional 141 subwatersheds (4%) where salmon were classed as present but of unknown status (table 4.41). We also used the classification models to estimate the probability of occurrence of ocean-type chinook salmon in 50 subwatersheds (9% of the historical range) that were previously unclassified (table 4.42). We predicted status (strong, depressed, or corridor) in those subwatersheds and an additional 20 subwatersheds (4%) where salmon were classed as present but of unknown status (table 4.42).

The model was very effective in predicting the distribution of chinook salmon spawning and rearing areas and migration corridors. Subwatersheds predicted to have high probabilities for depressed or strong spawning and rearing areas and subwatersheds predicted to have high probabilities of migration corridors were very similar to known distributions. For stream-type chinook salmon, the overall classification success rate was

Continue

Table 4.41—Summary of the current status and distribution classifications (number of subwatersheds) for stream-type chinook salmon throughout the Ecological Reporting Units of the Basin.

Ecological Reporting Unit	Total	Historical Range	Total Present	Status Where Present					Absent	No Classification	Wild Indigenous
				Strong*	Depressed*	Status Unknown	Corridor	Introduced			
Northern Cascades	340	219	105	0	71	16	18	0	74	40	0
Southern Cascades	141	51	26	0	13	8	5	0	25	0	0
Upper Klamath	175	35	0	0	0	0	0	0	35	0	
Northern Great Basin	506	0	0								
Columbia Plateau	1089	465	133	0	34	19	80	0	285	47	0
Blue Mountains	695	504	199	8	138	7	46	0	273	32	68
Northern Glaciated Mountains	955	172	7	0	1	0	6	0	160	5	0
Lower Clark Fork	415	98	0	0	0	0	0	0	98	0	
Upper Clark Fork	306	0	0								
Owyhee Uplands	956	866	0	0	0	0	0	0	866	0	0
Upper Snake	301	0	0								
Snake Headwaters	387	0	0								
Central Idaho Mountains	1232	1051	405	0	213	91	101	0	489	157	60
Entire Assessment Area	7498	3461	875	8	470	141	256	0	2305	281	128

*Refers to spawning and rearing areas only.

Table 4.42—Summary of the current status and distribution classifications (number of subwatersheds) for ocean-type chinook salmon throughout the Ecological Reporting Units of the Basin.

Ecological Reporting Unit	Total	Historical Range	Total Present	Status Where Present					Absent	No Classification	Wild Indigenous
				Strong*	Depressed*	Status Unknown	Corridor	Introduced			
Northern Cascades	340	79	37	12	12	12	1	0	28	14	0
Southern Cascades	141	31	9	0	0	0	9	0	19	3	0
Upper Klamath	175	0	0								
Northern Great Basin	506	0	0								
Columbia Plateau	1089	147	58	9	11	7	31	0	65	24	11
Blue Mountains	695	99	39	0	25	1	13	0	51	9	16
Northern Glaciated Mountains	955	149	15	0	9	0	6	0	134	0	0
Lower Clark Fork	415	0	0								
Upper Clark Fork	306	0	0								
Owyhee Uplands	956	48	0	0	0	0	0	0	48	0	0
Upper Snake	301	0	0								
Snake Headwaters	387	0	0								
Central Idaho Mountains	1232	0	0								
Entire Assessment Area	7498	553	158	21	57	20	60	0	345	50	27

* = Refers to spawning and rearing areas only

Previous

This file was created by scanning the printed publication. Miss-scans identified by the software have been corrected; however, some errors may remain.

Map 4.23—Current presence, absence, and estimated probability of occurrence within the historical range for stream-type chinook by subwatershed. Current distributions are based on the current-status database. Probabilities of occurrence are based on the classification tree for presence or absence.

Map 4.24—Current presence, absence, and estimated probability of occurrence within the historic range for ocean-type chinook by subwatershed. Current distributions are based on the current-status database. Probabilities of occurrence are based on the classification tree for presence or absence.

83 percent for the four classes. For ocean-type chinook salmon, the overall classification success rate was 92 percent for the four classes.

Based on our observed and predicted status and distribution, chinook salmon are the most endangered of the key salmonids; populations have been extirpated in large portions of their historical range (maps 4.23 and 4.24). Current known and predicted distributions of stream-type and ocean-type chinook salmon include 28 and 29 percent, respectively, of the historical range (tables 4.41, 4.42, 4.43, 4.44). Stream-type chinook are extinct in all of the Upper Klamath, Lower Clark Fork, and Owyhee Uplands; and in large portions of other ERUs that support populations. Ocean-type chinook are extinct in large portions of the ERUs that support populations and in all of the Owyheee Uplands. About 12,452 kilometers of the historical range in the Basin in the United States and Canada is no longer accessible to chinook salmon (NWPPC 1986). Major drainages where stream-type chinook salmon are extinct include the upper Klamath, Hood, Klickitat, Umatilla, and Walla Walla river basins and the Metolius River above the Pelton and Round Butte dams. Ocean-type chinook salmon are extirpated from the upper Big White Salmon, East and West forks of the Hood River, and the John Day, Umatilla, and Walla Walla river basins (Bakke and Felstner 1990; Kostow 1995; Nehlsen and others 1991). Construction of the Grand Coulee Dam in 1941 and the Hells Canyon dam complex in 1967 exterpated chinook salmon above those locations in the Columbia and Snake rivers, respectively (IDFG 1992). Chinook salmon are extinct in the Entiat River (Nehlsen and others 1991) and much of the Yakima River subbasin (Bakke and Felstner 1990).

Most chinook salmon stocks in the remaining accessible range are severely depressed and at risk. Subwatersheds known or predicted to support strong spawning and rearing represented 0.2 percent of the historical range and 0.8 percent of the current range of stream-type chinook salmon (table 4.43; map 4.25). If only those subwatersheds where stream-type salmon spawn and rear are considered, 99 percent of the watersheds were classified as depressed (table 4.43). Subwatersheds known or predicted to support strong spawning and rearing represented 5 percent of the historical range and 15 percent of the current range of ocean-type chinook salmon (table 4.44; map 4.26). If only those subwatersheds where ocean-type salmon spawn and rear are considered, 74 percent of the subwatersheds were classified as depressed (table 4.44). The North Fork of the John Day River contains the only strong population of stream-type chinook salmon and the Northern Cascades and Columbia Plateau support a small number of strong ocean-type chinook salmon populations.

The depressed state of most salmon stocks is well documented. In the Snake River, an estimated 1,882 naturally produced stream-type chinook salmon reached Lower Granite Dam in 1994 (NMFS 1995) compared with an estimated production of 1.5 million fish in the late 1880s (Bevan and others 1994). From 1985-93 an average of 387 naturally produced ocean-type chinook salmon reached Lower Granite Dam (NMFS 1995). Nehlsen and others (1991) categorized summer chinook salmon in the Okanogan as a population of "special concern" and the Methow populations at "moderate risk of extinction" and WDF and others (1993) classified both populations as depressed. Huntington and others (1994) identified the ocean-type chinook salmon population in the Hanford Reach of the Columbia River as the only healthy native fall chinook salmon population in the Basin. NMFS (1994) concluded that mid-Columbia River summer and fall chinook salmon, as a whole, were healthy relative to other chinook salmon stocks in the Basin.

Like steelhead, many remaining chinook salmon populations have been influenced by hatchery-reared fish. Production of wild anadromous fish in the Columbia River basin has declined by about 95 percent from historical levels (Huntington and others 1994).

Table 4.43—Summary of total known and predicted classifications (number of subwatersheds) for status of stream-type chinook salmon. The classifications are from the current-status database. The numbers predicted are based on the classification trees for stream-type chinook salmon and are shown in parentheses. Eight subwatersheds classified as unknown did not have predictions.

Ecological Reporting Unit	Total	Historical Range	Present	Strong	Depressed	Corridor	Absent
Northern Cascades	340	219	123 (34)		104 (33)	19 (1)	94 (20)
Southern Cascades	141	51	26 (0)		21 (8)	5 (0)	25 (0)
Upper Klamath	175	35					35 (0)
Northern Great Basin	506	0					
Columbia Plateau	1089	465	129 (15)		39 (5)	90 (10)	331 (46)
Blue Mountains	695	504	208 (16)	8 (0)	152 (14)	48 (2)	295 (22)
Northern Glaciated Mountains	955	172	7 (0)		1 (0)	6 (0)	165 (5)
Lower Clark Fork	415	98					98 (0)
Upper Clark Fork	306	0					
Owyhee Uplands	956	866					866 (0)
Upper Snake	301	0					
Snake Headwaters	387	0					
Central Idaho Mountains	1232	1051	465 (151)		351 (138)	114 (13)	586 (97)
Entire Assessment Area	7498	3461	958 (216)	8 (0)	668 (198)	282 (26)	2495 (190)

Table 4.44—Summary of total known and predicted classifications (number of subwatersheds) for status of ocean-type chinook salmon. The classifications are from the current-status database. The numbers predicted are based on the classification trees for ocean-type chinook salmon and are shown in parentheses. Five subwatersheds classified as unknown did not have predictions.

Ecological Reporting Unit	Total	Historical Range	Present	Strong	Depressed	Corridor	Absent
Northern Cascades	340	79	39 (14)	13 (1)	21 (9)	5 (4)	39 (11)
Southern Cascades	141	31	9 (0)			9 (0)	22 (3)
Upper Klamath	175	0					
Northern Great Basin	506	0					
Columbia Plateau	1089	147	57 (6)	12 (3)	14 (3)	31 (0)	86 (21)
Blue Mountains	695	99	41 (3)		27 (2)	14 (1)	58 (7)
Northern Glaciated Mountains	955	149	15 (0)		9 (0)	6 (0)	134 (0)
Lower Clark Fork	415	0					
Upper Clark Fork	306	0					
Owyhee Uplands	956	48					48 (0)
Upper Snake	301	0					
Snake Headwaters	387	0					
Central Idaho Mountains	1232	0					
Entire Assessment Area	7498	553	161 (23)	25 (4)	71 (14)	65 (5)	387 (42)

Map 4.25—Current distribution of spawning and rearing areas classified or predicted as strong or depressed for stream-type chinook by subwatershed. Current distributions are based on the current-status database. Predictions are based on the full classification tree for spawning and rearing areas.

Map 4.26—Current distribution of spawning and rearing areas classified or predicted as strong or depressed for ocean-type chinook by subwatershed. Current distributions are based on the current-status database. Predictions are based on the full classification tree for spawning and rearing areas.

Wild populations unaltered by hatchery stocks are rare and present in 5 percent of the historical range and 15 percent of the current range of stream-type chinook salmon (see table 4.41; map 4.22) and 5 percent of the historical range and 17 percent of the current range of ocean-type chinook salmon (table 4.42; map 4.22). Except for strong populations in the Hanford reach of the Columbia River in the Northern Cascades, the only subwatersheds classified as strong were those sustaining wild stocks.

Life-history Characteristics—Life histories of chinook salmon are highly variable, both among and within populations. Their wide genetic repertoire enables salmon to adapt to a wide range of physical circumstances (Thorpe 1994). Complex habitats with a high degree of connectivity permit the development and expression of diverse life histories (Lichatowich and Mobrand 1995). Two juvenile behavioral forms (yearling and subyearling migrants) account for much of the diversity in life history of chinook salmon in the Basin (Mullan and others 1992). Under healthy habitat conditions, however, a population of juvenile chinook salmon may exhibit a full range of stream- and ocean-type life histories (Lichatowich and Mobrand 1995).

Stream-type chinook salmon are primarily age-1 migrants. Adults destined for Columbia River tributaries between Bonneville Dam and the Snake River in Oregon enter tributaries in mid-April, spawn from late August to September, and fry emerge from mid-March to mid-June (Howell and others 1985a). Most parr smolt in their second year, enter the Columbia River during April and May, and enter the Columbia River estuary in May and June (Lindsay and others 1986). Adult spring chinook salmon destined for the Snake River enter the Columbia River in early spring, pass Bonneville Dam and reach the Snake River by late April, arrive at staging areas from late May to early July (Chapman and others 1991; Howell and others 1985a), and spawn from August to mid-September (IDFG 1992). Adult ages range from 3 to 6, with age-4 and age-5 dominant in the Grande Ronde and Salmon rivers, respectively (Howell and others 1985a; Matthews and Waples 1991). Fry emerge from February to April; some fry rear in natal streams until the following spring, but most migrate downstream into mainstem or larger tributaries to overwinter (Gaumer 1968). Smolts pass Lower Granite Dam from late April through June on their seaward migration (Chapman and others 1991).

Ocean-type chinook salmon are primarily age-0 migrants. Fall chinook salmon destined for Columbia River tributaries between Bonneville Dam and the Snake River pass Sherars Falls on the Deschutes River from mid-June through November and spawn in the mainstem from October through November (Aho and others 1979). Most subyearling migrants return at age-4, and most yearling migrants return at age-5 (Howell and others 1985a). Fry emerge from February to mid-May and rear in the main stem before emigrating during June to August as subyearlings or the following spring as yearlings (Aho and others 1979). Fall chinook salmon destined for the Snake River enter the Columbia River from August to early October; the run past Ice Harbor Dam peaks in September (Howell and others 1985a). Spawning occurs from late October to mid-November. Most fry migrate to the ocean as subyearlings (Waples and others 1991b) and move through the Snake River from March through June. Summer and fall chinook salmon in the Wenatchee and Methow rivers spawn from late September to early November; spawning in the Okanogan River is later (Chapman and others 1994b). Adults mature primarily at age-5. Fry emerge between mid-February and April in the Wenatchee River and from January through April in the Wells spawning channel (Chapman and others 1994b). Fry leave natal areas within weeks after emergence, and continue to rear in the Columbia River. Parr primarily smolt as subyearlings (NMFS 1994), although numbers of yearling migrants vary annually (Chapman and others 1994b).

Habitat Relationships—Habitat requirements of chinook salmon vary by season and life stage, and the fish occupy a diverse range of habitats. Distri-

bution and abundance of chinook salmon may be influenced by cover type and abundance, water temperature, substrate size and quality, channel morphology, and stream size.

Cover is essential for adult chinook salmon prior to spawning, especially early migrants that may remain in tributaries for several months (Reiser and Bjornn 1979). In the John Day River, for example, adult spring chinook salmon stage primarily in deep pools (> 1.5 m.) with cover (Lindsay and others 1986). Fish also use deep water near cover or undercut banks.

Temperature may influence suitability of spawning habitat. The primary evolutionary factor determining time of spawning may be the number of temperature units required for successful incubation of embryos (Heggberget 1988). In the Snake River, suitable spawning areas for fall chinook salmon may have been restricted to mainstem reaches that accumulated at least 960 temperature units from November 15 (spawning) to late April to early May.[19] Fry that emerge later than mid-May may not be large enough to begin their downstream migration as age-0 fish. Spawning in the Hanford Reach may now occur about a month later than it did in the early 1800s, possibly as a result of changes in water temperatures (Chapman and others 1994b). Extremely cold temperature can also influence egg and fry mortality when anchor ice reduces water interchange in gravel (Reiser and Bjornn 1979). Survival and emergence success of chinook salmon embryos is also influenced by fine sediment and flow (Chapman 1988). Other factors that reduce egg-to-fry survival include: redd disturbance and excavation, bottom scour, and microbial infestation (Beauchamp and others 1983; Healey 1991).

After emergence, fry concentrate in shallow, slow water near stream margins with cover (Hillman and others 1989a; 1989b). As fry grow they occupy deeper pools with submerged cover during the day (Reiser and Bjornn 1979) and shallower inshore habitat at night. Areas of shade near stream margins are the preferred habitat of juvenile salmonids including chinook salmon (Chapman 1966; Everest and Chapman 1972). Suspended sediment may effect juvenile fish by damaging gills, reduced feeding, avoidance of sedimented areas, reduced reactive distance, suppressed production, and increased mortality (Castillo and others 1994; Hicks and others 1991; Reiser and Bjornn 1979). Sediment deposition can also reduce habitat capacity (Reiser and Bjornn 1979).

Key habitat factors for juvenile rearing include streamflow, pool morphology, cover and water temperature (Steward and Bjornn 1990). Chinook salmon parr tend to select specific rearing habitats that segregate them, both temporally and spatially, from other native salmonids (Everest and Chapman 1972; Nilsson 1963). They also tend to be most abundant in low gradient, meandering stream channels (Scully and others 1990).[20] Parr are sensitive to alteration of water temperatures, particularly increases during the summer. Bell (1973) reported a preferred temperature range for juvenile chinook salmon of 7.3° to 14.6° C and Brett (1952) an upper lethal temperature of 25.1° C. Water temperatures in reaches of the John Day, upper Grande Ronde, and other basins in eastern Oregon commonly exceed the preferred ranges and often exceed lethal temperatures (McIntosh and others 1994a; ODFW and others 1990).

Juvenile chinook salmon often occupy different habitats in winter than in summer with two overwintering strategies, migration or concealment. Juveniles select areas of low water velocity and enter concealment cover beneath cobble or rubble substrate or beneath undercut banks (Edmundson and others 1968; Hillman and others 1987).

[19]Personal communication. 1995. B. Connor, U.S. Fish and Wildlife Service, Orofino, ID.

[20]Personal communication. 1995. K. Overton and R. Thurow, U.S. Forest Service, Intermountain Research Station, Boise, Idaho. Personal communication of unpublished data.

In our classification analysis, variables including number of dams, *hucorder*, precipitation, management clusters, and mean temperature were useful in discriminating watersheds supporting stream-type chinook salmon (see table 4.22, appendix 4E). Spawning and rearing areas were more likely to be found in mid-size streams, above fewer mainstem dams, in wetter, cooler landscapes, and on Forest Service-administered lands. Larger mainstem streams at lower elevations were more likely to represent migratory corridors. A notable exception was the distribution of ocean-type chinook where remaining spawning sites were associated with mainstem segments of the Columbia and Snake rivers.

Key Factors—A number of factors including habitat degradation, disease, predation, harvest, artificial propagation (Bevan and others 1994; Chapman and others 1991), and fluctuations in ecosystem productivity (Lichatowich and Mobrand 1995) have influenced the status of chinook salmon in the Basin.

Habitat degradation has influenced the status of chinook salmon. The overall pattern of decline of chinook salmon suggests the species is sensitive to habitat degradation throughout their entire range (for example, Nehlsen and others 1991). Livestock grazing, timber harvest, and irrigation diversions effect habitat (Beschta and others 1991; Henjum and others 1994). Reduced stream habitat complexity has been one of the most pervasive cumulative effects of forest management practices and may have substantially altered fish communities (Bisson and others 1992). Forest management practices, including timber harvest activities, have reduced salmon habitat quantity, reduced habitat complexity, increased sedimentation and eliminated sources of woody debris needed for healthy salmon habitat (Henjum and others 1994; Lichatowich and Mobrand 1995).

The integrity of salmon ecosystems is linked to the condition of riparian and upland areas and their influence on water temperature (Marcot and others 1994; Theurer and others 1985), sediment (Castillo and others 1994), the aquatic food base (Li and others 1994, Tait and others 1994), and pools (McIntosh and others 1994b). Land-use histories in eastern Oregon and Washington illustrate habitat degradation in the Columbia River basin (McIntosh and others 1994b; Wissmar and others 1994b). A comparison of managed (roaded) and unmanaged (wilderness or roadless) basins in eastern Oregon and Washington illustrated that managed basins had a significantly lower frequency of coarse woody debris and a significant decrease in large pools (> 20 m^2 surface area and > 0.9 m deep) compared with unmanaged basins (McIntosh and others 1994b). In the Snake River basin, more than 80 percent of the salmon production occurs on Forest Service and BLM lands, and most salmon spawning occurs in grazed areas (Bevan and others 1994). In Idaho, more than 80 percent of the riparian areas managed by the BLM are in degraded condition (Chapman and others 1991). In portions of the Snake River basin still accessible to salmon, management practices on Forest Service lands have been largely responsible for reducing the suitability of about 3,100 kilometers of stream (Haugen 1991 as cited in Bevan and others 1994). Chinook salmon habitat in upper Columbia River tributaries, especially the upper Methow and Wenatchee rivers, remains minimally altered by development compared with the main stem of the Columbia River and its other tributaries (Chapman and others 1994b; Mullan and others 1992). Restoring connectivity in reaches of lower subbasins should be a management priority (Lichatowich and Mobrand 1995).

Hydropower development is a second factor influencing chinook salmon status. Construction and operation of mainstem dams on the Columbia and Snake rivers are considered the major cause of decline of anadromous fish (CBFWA 1990). Similar to steelhead, adult chinook salmon are delayed during upstream migrations and smolts may be killed by turbines; become disoriented or

injured, making them more susceptible to predation; or become delayed in the large impoundments behind dams (Bevan and others 1994; Chapman and others 1994b; IDFG and others 1990). Development and operation of hydropower facilities in the Basin have reduced salmon and steelhead production by about eight million fish: four million from blocked access to habitat above Chief Joseph and Hells Canyon dams, and four million from ongoing passage losses at other facilities (NWPPC 1986). Passage losses are cumulative depending on the number of dams; chinook salmon in the Basin must pass one to nine dams. Losses of mid- and upper-Columbia River ocean-type chinook salmon were estimated to be about 5 percent per dam for adults and 18 to 23 percent per dam for juveniles (Chapman and others 1994b).

Hatcheries are a third factor influencing chinook salmon status. Hatcheries have been used extensively in attempts to compensate for losses, primarily from hydroelectric projects, of natural production (Howell and others 1985a; Matthews and Waples 1991). Salmon of hatchery origin comprise about 80 percent of the Columbia river salmon run (Lichatowich and Mobrand 1995). Problems associated with hatchery production include genetic introgression from non-native stocks and loss of fitness, reduced wild spawning escapement from the collection of broodstock, ecological interactions between hatchery and wild fish, mixed hatchery and wild stock fisheries, and transmission of diseases (Bevan and others 1994). Most (107/121) of the healthy anadromous salmonid stocks identified by Huntington and others (1994) have either had no fish culture activities in the home watershed or have been exposed to little risk from stock transfers or interaction with hatchery fish. Adult chinook salmon collection and egg-taking operations may also be detrimental to individual populations (Chapman and others 1994b). Introductions of large numbers of hatchery-reared parr may induce early migration of wild fish (Hillman and Mullan 1989).

Harvest is a fourth factor influencing chinook salmon status. Harvest has contributed to the decline of spring and summer chinook salmon in the Basin since the late 1800s (Fulton 1970) and to the decline of fall chinook salmon after 1920 (Lichatowich and Mobrand 1995). Historical ocean and river harvest rates exceeded 80 percent (Ricker 1959 as cited in Bevan and others 1994). Thompson (1951) reported that as a result of excessive harvest, by 1919 the characteristics of the Columbia River chinook salmon run had changed. Formerly large portions of the run were reduced, thus making smaller portions of the run more important to the fishery. The once nearly continuous run of salmon became segregated into more discrete groups. Lichatowich and Mobrand (1995) divided the fishery into four phases: initial development (1866 to 1888), sustained production (1889 to 1922), resource decline (1923 to 1958), and maintenance at a depressed level (post 1958). Declining runs of wild chinook salmon are still harvested in mixed-stock commercial and tribal fisheries. Sport harvest of wild chinook salmon has been curtailed in most states. In Idaho, for example, sport harvest of chinook salmon has been closed since 1975, except for periodic terminal fisheries on hatchery stocks.

Predation and competition are biotic factors influencing chinook salmon status. Predation is one of the major causes of mortality to fry and fingerling chinook salmon (Healey 1991). Introduced species may prey upon and compete with native fishes. Many middle and lower reaches of the Columbia River are dominated by introduced species (Li and others 1987). Northern squawfish, a native predator, have become well adapted to the habitat created by dams (Beamesderfer and Rieman 1991). It has been estimated that 15 to 20 million juvenile salmonids in the Snake and lower Columbia rivers annually succumb to northern squawfish predation (Collis and others 1995).

Summary—Prior to overfishing and habitat alterations, migrating chinook salmon in the Columbia River formed a continuum from March to October with the largest part of the run likely consist-

ing of summer chinook salmon (Thompson 1951). At present, the combination of low abundance, decreasing time trends in abundance, widely dispersed spawning populations, fragmented habitats, degraded freshwater and estuarine habitats, high risks of genetic introgression in most stocks, low frequency of wild indigenous stocks, high rates of non-native fish introductions, continued harvest in mixed-stock fisheries, and high-risks of smolt and adult passage mortality result in a high risk of extinction for individual chinook salmon stocks.

Chinook salmon represent the most imperiled of the key salmonids we considered. Both forms of chinook salmon are extinct in more than 70 percent of the historical range. The distribution of stream-type chinook appears to be widespread throughout the remaining accessible range, but most populations are severely depressed and heavily influenced by hatchery supplementation. The only remaining strong populations are restricted to relatively small areas of the John Day River basin within the Blue Mountains. Within the central Idaho Mountains recent runs of stream-type chinook salmon have been critically low and most populations are believed to be on the brink of extinction. Ocean-type chinook salmon are found in a more restricted range linked principally to mainstem rivers and larger tributary systems. Populations associated with the Snake River Basin in Idaho are also considered on the verge of extinction. The remaining distribution of spawning and rearing includes very few subwatersheds in each occupied ERU and many areas of contiguous occupied habitat are small and disjunct.

Restoration of habitats and habitat connectivity in both mainstem and subbasins will be necessary for salmon stocks to persist. The declines of chinook salmon stocks in the Basin in recent years can be attributed primarily to mainstem dams, however, until passage problems are resolved, the resiliency and persistence of remaining chinook salmon stocks will be largely dependent on the quality and diversity of remaining stream habitats. All remaining populations and habitats for both forms of chinook salmon within the Central Idaho Mountains, Blue Mountains, Northern Cascades, Columbia Plateau, Northern Glaciated Mountains, and Southern Cascades are critical to the persistence of this species within the Basin.

Introduced Salmonids

Eight species of non-native salmonids have been introduced and maintain self-sustaining populations in the Basin. They include lake whitefish; Atlantic salmon; Arctic grayling; and brook, brown, golden, and lake trout; and Sunapee char (see table 4.16). Several species native to the Basin have been introduced outside their natural range. These include Lahontan, Yellowstone, and westslope cutthroat trout; redband trout and several other forms of rainbow trout; chinook and coho salmon; kokanee; and steelhead. All were introduced to create or expand fishing opportunities and are managed and protected as game fishes by state agencies. Established populations of these fishes now support many important fisheries throughout the region.

Current Distribution and Status

Arctic grayling, golden trout and Sunapee char, have relatively narrow distributions in the Basin. Grayling were reported in 1.3 percent of the subwatersheds, golden trout in 0.3 percent, and Sunapee char in only one subwatershed (see table 4.16). These species were primarily introduced in high elevation and formerly fishless alpine lakes to provide unique sport fishing opportunities.

In contrast to the many examples of introduced species contributing to declines in native fishes and other aquatic organisms, introduced Sunapee char may represent one of the last remaining genetic refuges for the species. The Sunapee char, a landlocked Arctic char endemic to Sunapee Lake, New Hampshire, became extinct in New Hampshire in the mid-1900s as a result of competition with introduced species (Kircheis and others 1995). In 1925, prior to extinction in Sunapee Lake, Sunapee char were introduced into two high eleva-

tion and fishless lakes in Idaho's Sawtooth Mountain Range (Kircheis and others 1995) and established a reproducing population. The American Fisheries Society listed the Sunapee char and blueback trout (a phenotypically distinct form endemic to Maine) as a Threatened species (Williams and others 1989). Because the species is non-native, Idaho does not list it as a species of special concern. However, protection of the Sunapee char and its habitat is suggested as a priority (IDFG 1991). Sunapee char differed from other North American lacustrine char in their unique coloration, large size, and use of a mid-lake spawning shoal (Kircheis and others 1995). The fish stocked in Idaho were not "rediscovered" until 1978 (IDFG 1991). Kircheis and others (1995) recently examined the genetic identity of 17 Sunapee char collected from one Idaho lake. The samples displayed four haplotypes, three of them uniquely divergent from other landlocked arctic char and the other similar to a blueback char haplotype. The authors reported that the divergent portion of the Idaho char population represented a distinct, native population formerly in Sunapee Lake. Despite the unique haplotype, Kircheis and others (1995) recommended against using Idaho Arctic char to restock New Hampshire waters because brook trout were stocked in the Idaho lakes in the 1940s. The authors, however, presented no data assessing the degree of introgression with brook trout.

Lake whitefish, kokanee, Gerrard and Kamloops rainbow trout, Atlantic salmon, and lake trout were introduced primarily in lakes and reservoirs that also held native salmonids. Lake whitefish supported an early commercial fishery around 1900 on Pend Oreille Lake (Simpson and Wallace 1978), but are a less important sport fish today. Introduced lacustrine rainbow and lake trout currently support trophy fisheries in larger lakes and have been particularly important where kokanee provide a forage base (Wydoski and Bennett 1981). Kokanee have supported some of the most heavily used fisheries in the region (Rieman and Maiolie 1995) and have been introduced into virtually every lake and reservoir deep enough to sustain a population.

Brook, introduced rainbow, and brown trout, are among the most widely distributed species in the region. All are found in both lowland and alpine lakes but have become much more widely established in streams. Introduced rainbow trout were found in 78 percent of the watersheds in our database, while brook trout were recorded in about 50 percent (see map 4.7). They are the most widely distributed species in the Basin. Brown trout were found in 23 percent of the watersheds (see map 4.7). All three provide fishing opportunities, but rainbow and brown trout have become particularly popular, supporting nationally and internationally recognized sport fisheries. They are well adapted to habitats ranging from small streams and to large rivers, often preying on native and introduced fishes. They are prized by anglers because of their ability to achieve relatively large size in these more productive environments.

Expansion of ranges through introduction of the non-native and native salmonids has been common in alpine lakes, most of which were historically fishless (Bahls 1992). Many of these systems do not support self-sustaining populations, but the introductions have resulted in the establishment of new populations downstream. Cutthroat, rainbow and brook trout appear to have been particularly successful through this means of expansion.

Like the native salmonids, the life histories of introduced forms are highly variable and include adfluvial and fluvial migratory forms and non-migratory resident forms. In some cases (such as kokanee in Pend Oreille Lake, Idaho) the apparent variation in life history is the result of stocking several evolutionarily distinct forms that have both adapted to the new system (Rieman and Bowler 1980). We have little knowledge of whether the expression of varied life histories among the introduced species represents adaptation to new environments through recent selection or reflects the expression of a plastic or broad set of environmental tolerances.

The broad distribution of many of the introduced species suggests that they are more tolerant of habitat disturbance than many of the native forms. Brown trout for example, occupy a wide range of habitats ranging from alpine lakes to small, low-elevation reservoirs and large low-elevation rivers, to small springs. Brown trout tolerate some degradation of habitat that would be lethal to native salmonids. For short periods, brown trout tolerate water temperatures exceeding 27° C, oxygen levels near 5 milligrams/liter, and high levels of suspended sediment (Brynildson and others 1963). To sustain wild, self-sustaining populations, however, brown trout still require abundant and high-quality habitats similar in many aspects to those required by native salmonids. Brown trout spawn in sorted gravels, often in areas used by native salmonids (Scott and Crossman 1973). Newly emerged fry seek shallow, low-velocitiy areas along stream margins. Cover is one of the most important habitat features controlling the number of rearing brown trout (Lorz 1974).

Key Factors

Habitat degradation has influenced the status of introduced salmonids. Although the introduced salmonids may be more tolerant, like native salmonids they have declined as a result of habitat degradation. Activities such as dam construction, water diversion, grazing, mineral extraction, road construction, and residential development have degraded habitats that affect these species. In the Deschutes River, for example, brown trout were effected by loss of migrating fish in irrigation canals, reductions of riparian areas by grazing and housing developments, and siltation of stream substrate (Lorz 1974).

Angler harvest is a second factor that has an important influence on the status of most of the introduced salmonids. Special angling restrictions designed to limit mortality are common throughout the region. Numerous studies have demonstrated the influence of angling on population size structures and abundance and clearly show a negative response of populations to increasing or unrestricted harvest.

Summary

The introduced salmonids are an important and permanent part of many aquatic ecosystems, often desired by anglers. The introduction and expansion of non-native salmonids have played a definite role in the decline of native species. Displacement likely occurs through competition, predation, and hybridization (Fausch 1988; Leary and others 1993; Rieman and McIntyre 1993). The expansion of non-native fishes represents a loss of biological diversity and integrity for many systems, but ironically, a desirable social and economic component in some cases. In most cases, elimination of the non-native forms is infeasible and may be socially unacceptable. Conservation management of these species will be an important consideration of aquatic ecosystem management. The widespread establishment of some introduced salmonids suggests that they may be less sensitive to habitat disruption. Any attempts to conserve or strengthen habitats for the native species will likely either benefit or have no influence on most introduced salmonids.

Community Integrity and Conservation Emphasis Areas

The species assemblage and key salmonid information collectively highlight areas that retain their historical species diversity and ecological structure and point to other areas that are severely altered. In this section, we attempt to further delineate areas of high community integrity and diversity. Such areas could be useful in defining conservation emphasis areas necessary for rebuilding and maintaining healthy and productive aquatic systems. We also consider areas that support important fisheries sustained by wild salmonids of introduced origin. Although the latter areas may be of less ecological significance than native salmonid assemblages, they represent high social and economic values.

Four criteria were used in our analysis, as follows: 1) population strongholds for key salmonids, 2) native species richness, 3) diversity and evenness, and 4) uniqueness. The first three were combined to create a numerical measure of integrity that is applicable at the watershed level. We also listed important wild trout waters as a final criterion available for further analysis. However, we did not map the wild trout waters or use them to rank integrity.

Population Strongholds

Subwatersheds that support strong populations of any of the key salmonids likely represent a fortuitous balance of habitat quality, climatic and geologic constraint, and geographic location which effectively minimize cumulative threats to these species. The classification of strong included only subwatersheds that supported spawning and rearing. Because full life-history expression was part of the criteria for defining strong populations, however, the occurrence of strong populations may also indicate the relative integrity of the larger system of watersheds. The most productive, abundant, and diverse populations are likely to be most resistant and resilient to environmental disturbance and most likely to survive catastrophic disturbance. Thus, they are more likely to serve as sources for supporting weak or at risk populations, refounding locally extinct populations, or refounding habitats made available through restoration. Strong populations are potentially critical for short-term persistence and long-term recovery. To identify important strongholds, we summarized the number of strong species known or predicted to occur within subwatersheds throughout the Basin.

We estimate that less than 0.01 percent of the subwatersheds support three strong salmonids, 3 percent support two, and about 20 percent support one. The largest patches of contiguous or clustered habitats supporting strong populations are associated with the major river subbasins found in the Central Idaho Mountains, Blue Mountains, Northern Cascades, and the Snake Headwaters (map 4.27). Smaller patches are found in the Upper Clark Fork and extreme eastern fringe of the Northern Glaciated Mountains. Strong populations of chinook salmon and steelhead were rare or absent, even in relatively undisturbed habitats in the Central Idaho Mountains. This suggests that factors outside the Basin strongly influence the status of anadromous species. Most of the subwatersheds supporting strong populations were found on Forest Service administered lands (75%) and a substantial number (29%) are located within designated Wilderness areas or National Parks. Strong populations occurred more frequently in areas with lower road densities (fig. 4.20).

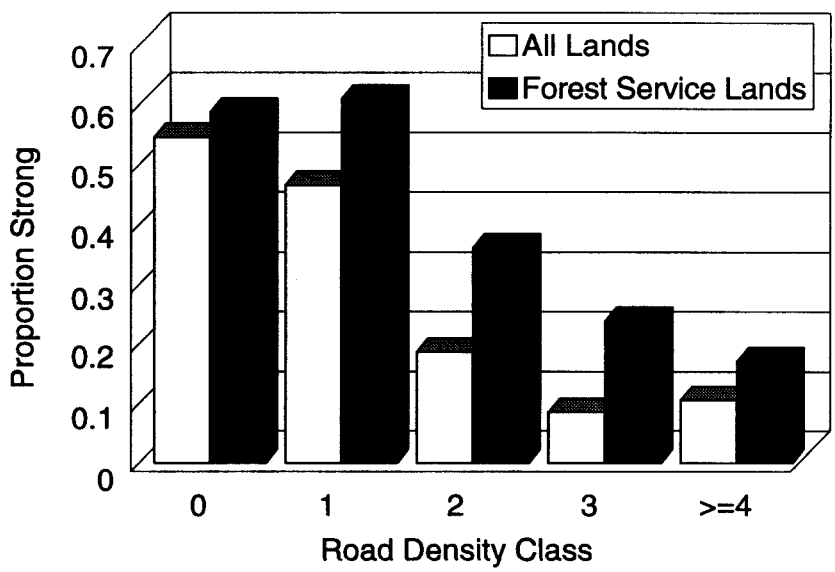


Figure 4.20. Proportion of subwatersheds supporting strong populations of key salmonids by road density class and land ownership.

Map 4.27—Number of key salmonids classified or predicted as strong by subwatershed.

Native Species Richness

The number of native species present in a watershed is an important element of diversity, and reflects heterogeneity in the physical environment. A high degree of species overlap might reflect strong habitat diversity. Even within a fairly narrow group like salmonids, each species relies on different habitats and environments, with variable and wide-ranging life-history patterns. The co-occurrence of several salmonids suggests suitable habitats exist over relatively large landscapes, not just those directly tied to the local subwatershed. High richness may also indicate critical common areas that serve as corridors, wintering areas, or seasonal refuges for the varied life histories in the assemblage. The loss of such areas could portend a loss of richness on both local and regional scales.

To characterize species richness, we used two measures, the number of key salmonids known or predicted to occur within each subwatershed, and the total number of native species known to occur in each watershed. We recorded from 0 to 28 native species within watersheds throughout the basin. The largest number of native species was found in the large river corridors, particularly the lower and middle Columbia and the lower Snake rivers. Moderate native-species numbers were observed in lower-order watersheds associated with the Blue Mountains, along the transition between the North Cascades and Columbia Plateau, and throughout much of the Basin within Montana (map 4.28).

Historically there may have been broad overlap in the distribution of the key salmonids at the subwatershed level. The Central Idaho Mountains, Northern Cascades, and Northern Glaciated Mountains, along with the river corridors connecting all of the watersheds accessible to anadromous fish, probably supported multiple species. We estimate that 97 percent of the subwatersheds could have supported at least one key salmonid historically and 74 percent could have supported two or more, about 2 percent could have supported six (map 4.29). We estimate that about 74 percent of the subwatersheds currently support at least one, and less than 38 percent support two or more, about 0.5 percent support 6 (map 4.30). The largest remaining regions of high species overlap are associated with the Central Idaho Mountains, the Blue Mountains, the Northern Cascades and, notably, their connecting river corridors. Two or more species are still found in subwatersheds scattered throughout Montana and a patchwork of watersheds and river corridors throughout the Basin.

Diversity and Evenness

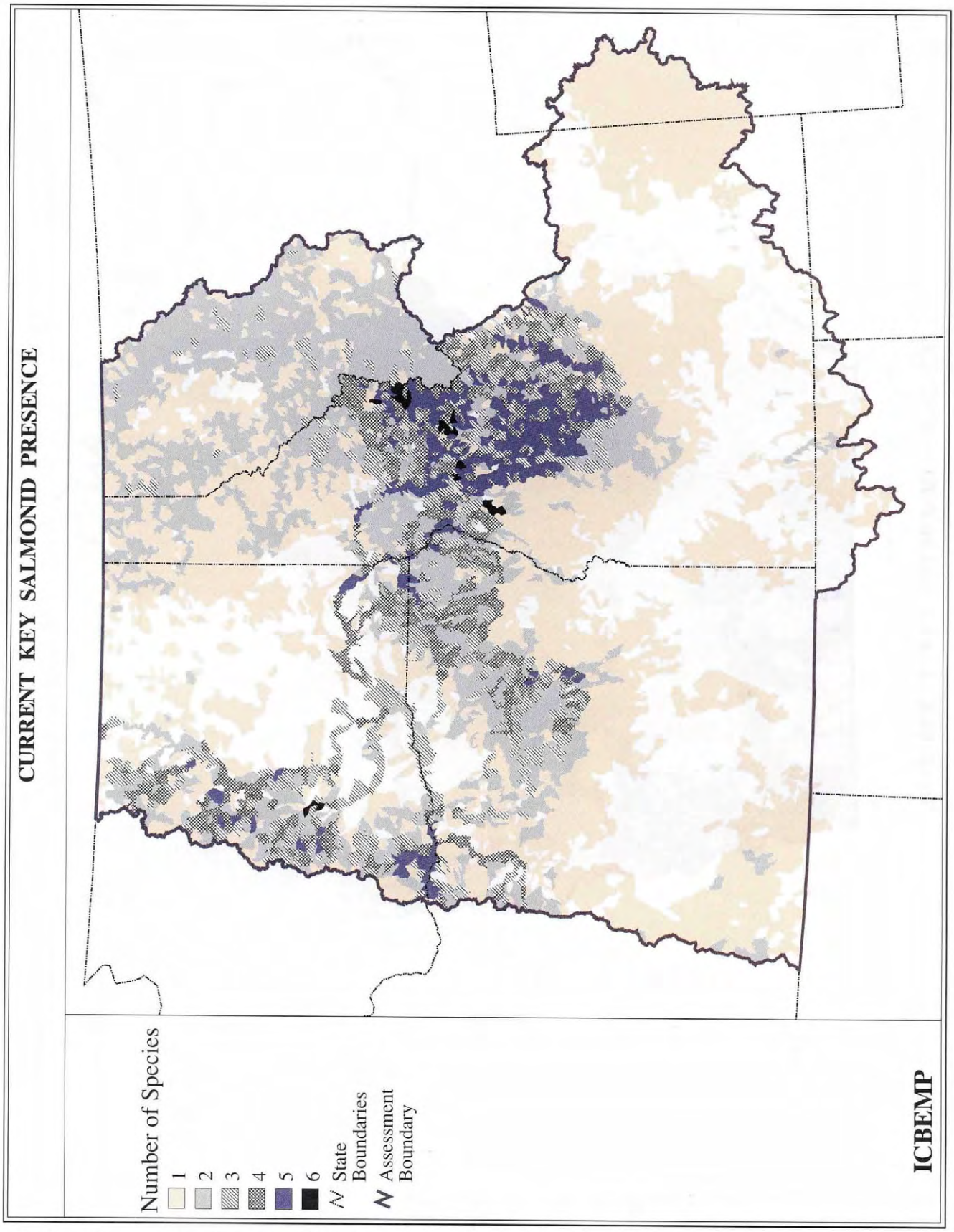
In the ecological literature, diversity refers to both the number of species present and their relative abundance. Thus, an area with many abundant species is more "diverse" than an area with an equal number of species, few of which are abundant and most of which are rare. As its name suggests, evenness simply refers to the degree to which species are evenly distributed. Our indices of native diversity and evenness were described earlier. Since the diversity measures apply to an assemblage class as a whole rather than individual watersheds, the diversity and evenness maps would be equivalent to the assemblage map presented in map 4.8. Note that because the diversity measures do not rely exclusively on the presence or absence of species from a single watershed, they more accurately reflect *potential* diversity rather than realized diversity within a given watershed. Both diversity and evenness are instructive, in that they reflect the capacity of an area to accommodate multiple species.

Uniqueness

We defined uniqueness by four measures: 1) watersheds representing fringes of a species range; 2) watersheds supporting unusual genetic integrity; 3) watersheds supporting narrowly distributed endemic species; and 4) watersheds with species formally listed under the federal Endangered Species Act.

Map 4.28—Number of native species reported by watershed.

Map 4.29—Historical number of key salmonids potentially present by subwatershed.



Map 4.30—Current number of key salmonids (classified or predicted as present) by subwatershed.

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Fringe Distributions—Because extreme or fringe environments may support a disproportionately large part of the genetic diversity within a species, populations persisting in these areas may represent distinct adaptations and an important source of genetic variability for that species (Lesica and Allendorf 1995; Scudder 1989). Populations that maintain native gene complexes and the widest possible diversity likely offer the best resources for refounding extinct populations in similar environments. Populations that historically were distributed over broad geographic areas have likely evolved under relatively distinct environments with little gene flow across the species range (Lesica and Allendorf 1995). Conservation of the genetic diversity in these species then implies sustaining populations over the broad geographic area (Allendorf and Leary 1988; Leary and others 1993).

Because the ERUs represent distinct biophysical environments, the potential for adaptive divergence for any species distributed across these units may be strong. As a first step to identify fringe areas, we summarized key salmonid presence in spawning and rearing areas by ERU (fig. 4.21) and noted regions where a particular species was weakly distributed, but still within its historical range. Each species was generally widely distributed, that is, found in more than 100 spawning and rearing subwatersheds within an ERU (often with several strong populations) near the core of their respective ranges. We assumed that a species with known or predicted presence in fewer than 30 subwatersheds within an ERU indicated a weak or fringe distribution. We then considered whether the limited distributions identified within an ERU were isolated from other parts of the range.

Bull trout are found in a limited number of subwatersheds within the Southern Cascades, the Upper Klamath, the Owyhee Uplands, and the Walla Walla and Umatilla subbasins within the Columbia Plateau. Although the distribution of bull trout in several ERUs is weak, we recognized only those subwatersheds within the Owyhee Uplands and Upper Klamath as distinctly isolated fringe distributions. Bull trout within the Southern Cascades probably have not been strongly isolated from similar environments in the lower Columbia River tributaries of the Northern Cascades. Bull trout in the Columbia Plateau are limited to streams of the Blue Mountains and were therefore considered an extension of the populations found in the Blue Mountains.

We placed the fringe of the range for westslope cutthroat trout within the Blue Mountains (map 4.31). The Columbia Plateau also met our criteria for fringe distribution (that is, less than 30 subwatersheds). The subwatersheds included in that ERU, however, are in the lower Clearwater River and are really part of a much larger distribution of westslope cutthroat trout in the Lower Clark Fork. For that reason, we did not include the Columbia Plateau as part of the fringe for westslope cutthroat trout.

We modified our criteria to consider the fringe distribution for redband trout. Although the taxonomic status of redband trout is uncertain, studies suggest long-term isolation of the allopatric form has occurred in a number of isolated subbasins (Behnke 1992; Berg 1987) that fall within individual ERUs. As a result, our criteria based on distribution within an ERU may not represent the degree of isolation and genetic differentiation that has occurred with this species (Williams and others 1989). Important isolated groups are associated with the Wood, Yaak, and Kootenai rivers, several subbasins in the Klamath River basin and a complex of isolated subbasins in south central Oregon (Goose Lake, Warner, Catlow Valley, and Harney). Because of the clear isolation, we considered any of these subbasins supporting fewer than 30 subwatersheds to be part of the fringe distribution for allopatric redband trout. Our formally defined fringe distribution included the Big and Little Wood, Warner Lake, Guano, and Goose Lake subbasins. However, because of potentially unique characteristics in the other isolated subbasins and because the distribution and status are so poorly known in these waters (map 4.19), managers should consider all these

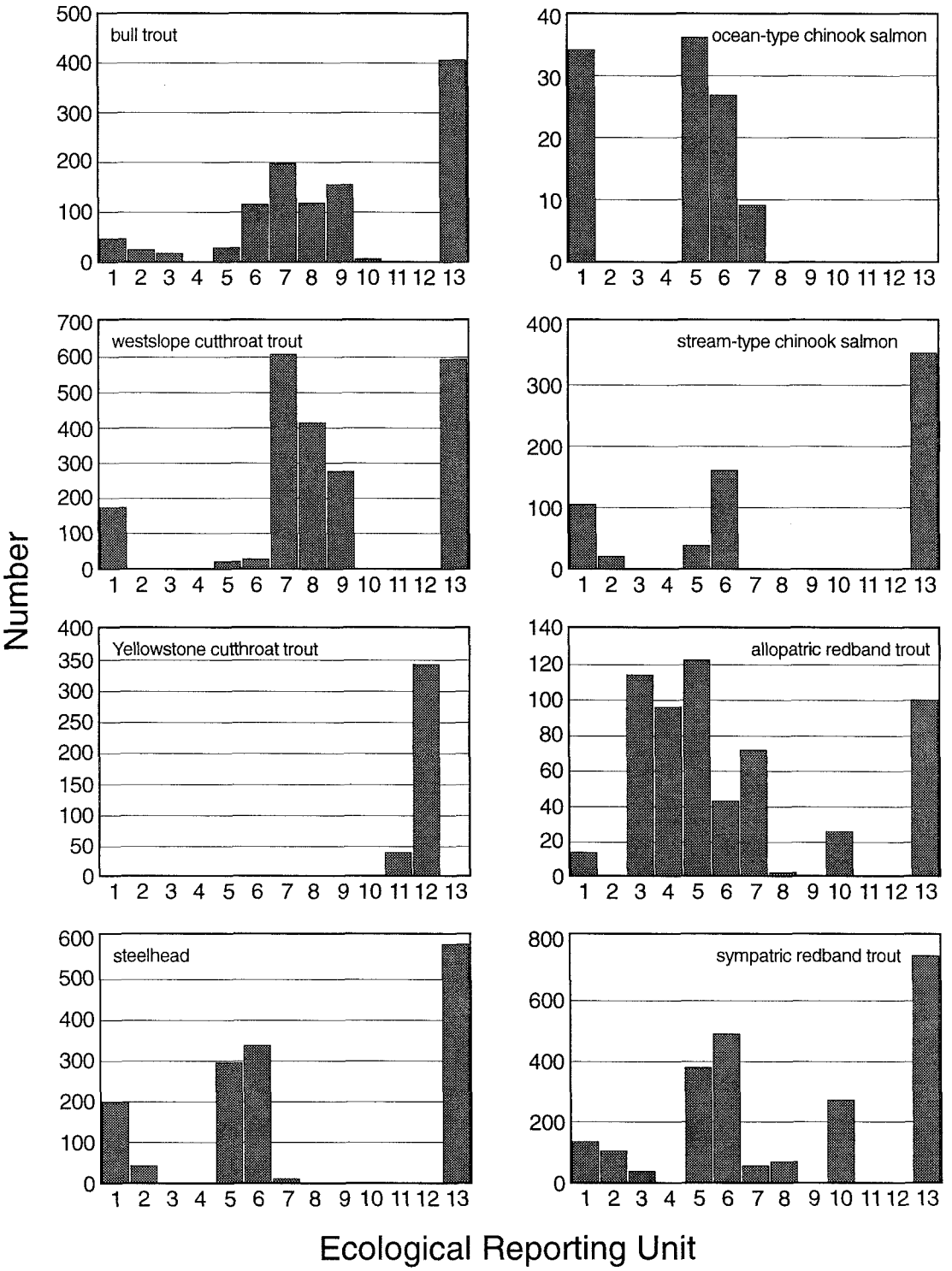


Figure 4.21—Number of subwatersheds classified as known or predicted spawning and rearing areas for each of the seven key salmonids, including both allopatric and sympatric redband trout, within each of the Ecological Reporting Units. ERUs: (1) Northern Cascades, (2) Southern Cascades, (3) Upper Klamath, (4) Northern Great Basin, (5) Columbia Plateau, (6) Blue Mountains, (7) Northern Glaciated Mountains, (18) Lower Clark Fork, (9) Upper Clark Fork, (10) Owyhee Uplands, (11) Upper Snake, (12) Snake Headwaters, (13) Central Idaho Mountains.

Map 4.31—Subwatersheds classified as fringe areas in the distribution of key salmonids.

populations as potentially unique. Further work is needed to clarify the current status of this form. No subwatersheds were considered fringe distributions for sympatric redband trout, although populations in the Klamath are candidates. Again, confusion over the extent of isolation between the two forms clouds the status of redband trout within this ERU.

We identified no fringe distributions for Yellowstone cutthroat trout, steelhead, or stream-type chinook salmon. Although only one subwatershed was reported for Yellowstone cutthroat trout within the Owyhee Uplands, it is found above Shoshone Falls and is part of the historical distribution of that species within the Snake River. Steelhead and stream-type chinook salmon have limited distributions within the Southern Cascades and Northern Glaciated Mountains, but these populations appear to be extensions of much broader distributions in adjacent subbasins and ERUs.

Ocean-type chinook salmon have a limited distribution in all of the ERUs across the range. They occurred in fewer than 30 watersheds in the Blue Mountains and Northern Glaciated Mountains. Because the latter group of subwatersheds is closely associated with the Northern Cascades, we considered only the Blue Mountain group, represented primarily by the lower Snake River in Hells Canyon, as a fringe distribution.

Genetic Integrity—Hatchery programs may erode genetic diversity and alter co-adapted gene complexes characteristic of locally adapted stocks of salmonids (Reisenbichler, in press; Waples and Do 1994). The effects may include a loss of fitness or performance (such as growth, survival, and reproduction) and a loss of genetic variability important to long-term stability and adaptation in varying environments. To map areas of potential importance as wild, indigenous gene pools, we asked biologists familiar with specific subwatersheds to identify chinook salmon and steelhead spawning and rearing areas that are unaltered by hatchery stocking, regardless of whether the populations are strong or depressed. Because data describing genetic purity of populations was not available across the Basin, we chose not to rely solely on genetic analysis. Instead, we defined wild, indigenous areas as subwatersheds with a low probability of strays from non-indigenous sources spawning with indigenous fish and as: 1) subwatersheds that had no history of hatchery-reared or non-indigenous introductions; or 2) subwatersheds that had been stocked rarely with hatchery-reared or non-indigenous fish, but where evidence suggested poor survival of stocked fish and a low probability of introgression; or 3) subwatersheds that had been stocked regularly in the past, but genetic analyses found existing wild fish identical to the original wild gene pool. Several biologists believed our criteria were too conservative because some potentially intact gene pools were not included. Biologists cited examples of stocks that had been heavily supplemented with hatchery-reared fish but where genetic analysis revealed substantial differences between wild and hatchery fish, suggesting that hatchery fish survived poorly. None of these cases, however, met the third criterion. The areas important to the genetic integrity of the anadromous salmonids are found principally within the Blue Mountains and Central Idaho Mountains (see map 4.22).

We could not identify similar pure populations for non-anadromous salmonids because (excepting Montana) there has been little genetic inventory (Rieman and Apperson 1989; Young 1995) or documentation of stocking that could be used in this scale of analysis. We also did not use the presence of introduced trout as an indicator of genetic integrity because those data were available only at the watershed level, potentially overestimating the influence of stocking in subwatersheds considered here. As a result, our analysis of genetic integrity is incomplete and would require a finer level of analysis for a consistent application to non-anadromous salmonids.

Narrowly Distributed Endemic and Federally Listed Species—We recognized species that are very narrowly distributed and endemic either to the Basin or to a relatively small region including

the Basin as potentially sensitive and evolutionarily distinct. Fishes listed under the federal Endangered Species Act (see table 4.16) have a similar though more formal recognition. We summarized the occurrence of both groups across watersheds. Narrowly distributed endemics were found principally in Oregon and southern Idaho. The Upper Klamath was a particularly important area for endemism, with up to six species reported in a single watershed (map 4.32). Most of the endemic species are associated with closed basins and many are isolated in relatively small portions of watersheds. The Central Idaho Mountains and the major river corridors emerged as important areas of convergence for federally listed species (map 4.33).

Integrity of the Fish Assemblage

Biotic integrity provides a conceptual metric for identifying aquatic systems that more closely approximate historical levels of natural diversity. Karr and Dudley (1981) define biotic integrity as "the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region". Unlike species diversity, integrity specifically refers to *native* biota that reflect natural evolutionary and biogeographic processes (Angermeir and Karr 1994). Several measures of biotic integrity have been proposed, which often reflect different attributes for communities of invertebrates and amphibians, and fish (Fisher 1989; Lyons and others 1995).

We developed a simple measure of integrity that reflects the status, diversity and structure of the native fish assemblage. Our measure includes three metrics described above: key salmonid strongholds, native species richness, and our composite index (Z) of native diversity and evenness. We built our index at the watershed level, using information from subbasins, watersheds, and subwatersheds. We totaled strong populations in subwatersheds within each watershed, used species richness at the subbasin level to assign a value to every watershed contained therein, and used our Z values from each watershed. The first two metrics were normalized such that they could assume a maximum value of 1, the same as Z. Our index of integrity was defined simply as the arithmetic average of the three normalized indices.

Values for our index of integrity range from 0.23 to 0.87, units with missing data were assigned a value of 0. The spatial pattern of the integrity index reflects the overlap of population strongholds, high species richness, and a predominance of native species (map 4.34). The highest concentrations of high-integrity values are found in the Northern and Southern Cascades, the Blue Mountains, the Central Idaho Mountains, and the southern edge of the Columbia Plateau. Smaller areas of high integrity are found in the Lower Clark Fork. These ERUs had the highest median values, and with the exception of the Lower Clark Fork, also exhibited the widest variability in integrity (fig. 4.22). There are varied reasons for each score. Many of the high-value areas are forested areas within the range of anadromous fish. Rangeland and agricultural areas tend to have lower integrity values.

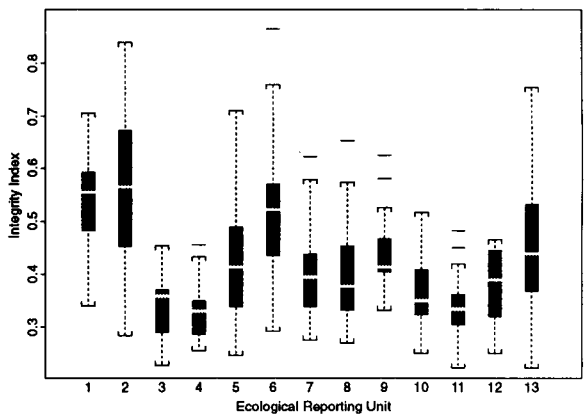
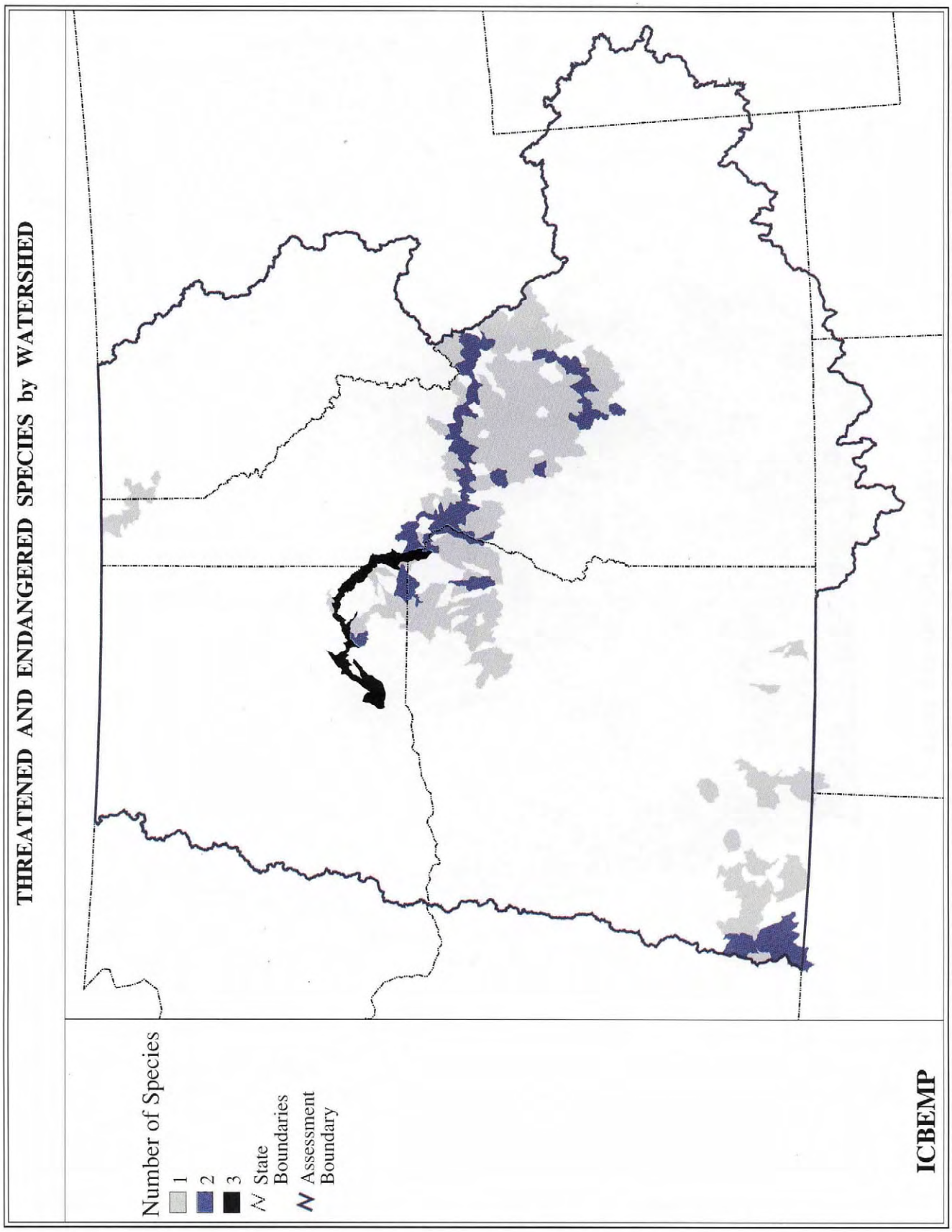


Figure 4.22. Box and whisker plots illustrating the range of fish assemblage integrity values by Ecological Reporting Unit. The horizontal line in the interior of the box represents the median, the box height equals the interquartile distance, and the dotted lines extend to the extreme values of the data. Data points outside the dotted lines may be outliers and are indicated by horizontal lines.

Map 4.32—Number of narrowly distributed endemic species reported by watershed.



Map 4.33—Number of species formally listed under the Endangered Species Act reported by watershed.

Map 4.34—Distribution of fish assemblage integrity scores by watershed.

Wild Trout Waters

While our analysis focused primarily on native fish, we recognize that many subwatersheds support high-value, wild-trout fisheries, but are supported by introduced salmonids including brook, brown, rainbow, and lake trout. Habitat in these subwatersheds remains suitable for natural reproduction of salmonids, although native salmonids may be depressed or extinct. In the Henry's Fork Snake River, Idaho, for example, native Yellowstone cutthroat trout are virtually extinct in large portions of their historical range but wild, self-sustaining populations of introduced rainbow trout thrive and support an internationally recognized trout fishery. In the Blackfoot River, Montana, native westslope cutthroat trout similarly have been replaced by introduced brown and rainbow trout that support a renowned wild-trout fishery.

We contacted state and tribal biologists in Idaho, Montana, Nevada, Oregon, Washington, and Wyoming and compiled a list of high-value recreational fisheries supported by wild, self-sustaining salmonid populations, regardless of original origin (appendix 4F). We encountered many definitions of wild, high-value salmonid fisheries, including waters described as Trophy, Quality, Blue Ribbon, and Wild Trout. All these waters shared three characteristics, as follows: 1) they were at least partially supported by wild, naturally spawning salmonids; 2) fisheries were regulated by special regulations consisting of reduced bag limits, size limits, gear restrictions, season closures, or mandatory catch-and-release; and 3) the waters typically received increased emphasis on habitat protection. The list includes a wide variety of salmonid assemblages and regulations. In some cases, special regulations (such as size limits) were applied to large numbers of streams to sustain wild native trout (such as cutthroat trout) while differential general regulations were applied to other species (such as rainbow trout) in the same streams. In other cases, special regulations, such as catch-and-release, were applied to both native and introduced salmonids.

Supplemental Analysis of Road Impacts

Much of our previous discussion and results points to negative consequences that often accompany roads. The effects associated with roads reach beyond their direct contribution to disruption of hydrologic function and increased sediment delivery to streams. Roads provide access, and the activities which accompany access magnify the negative effects on aquatic systems beyond those due solely to roads themselves. Activities associated with roads include, but are not limited to, fishing, recreation, timber harvest, livestock grazing, and agriculture. Roads also provide avenues for stocking non-native fishes. Unfortunately, we do not have adequate broad-scale information on many of these attendant effects to identify their component contributions accurately. Thus, we are forced to use roads as a catch-all indicator of human disturbance.

In preceding sections, we presented results based on analyses which used the variable, *roaddn*, to indicate road density. Each of these analyses supports the general conclusion that increasing road density is correlated with declining aquatic habitat conditions and aquatic integrity. Yet to some reviewers, our arguments are not convincing given the weak statistical relationships found within the data. Here, we reinforce and expand our conclusions based on a supplemental analysis of road density and the distributional data of four key salmonids. This analysis is based in part on information that was compiled after the earlier analyses were completed, and seeks to rectify some of the shortcomings of the earlier analyses. Time constraints did not allow us to redo the earlier analyses.

Focus on Non-anadromous Salmonids

Land-use disturbances within a given watershed affect anadromous and non-anadromous fishes in similar ways. The complex life history of anadromous fishes, however, confounds the effect of any single activity. The effects of habitat degradation within a spawning area on population status, for example, may be masked by migrational and ocean-related losses. Analytical resolution is

further compounded by the fact that anadromous species often inhabit larger rivers than their non-anadromous relatives. These larger rivers both integrate and diffuse the effects of land-use activities over large areas, often well beyond the local subwatershed. It is not surprising to find little apparent relationship between subwatershed features and the population status of anadromous species found there. We simply have a poor experimental design for single-variable analyses of fine-scale factors on anadromous fishes. In contrast, non-anadromous fishes more readily display the effects of local disturbance because they spend a much larger portion of their life within the confines of a single watershed.

In our analyses reported earlier, the seven key salmonids followed this pattern. Status of anadromous fishes was principally tied to stream size, the number of dams between the subwatershed and the ocean, and broad geographical descriptors such as ERU and elevation. The non-anadromous fishes showed increased sensitivity to more local factors such as management and ownership, vegetation indices, and road density class. Therefore, we focused on analysis of the non-anadromous species in our supplemental analysis of road density. Similar exploratory analyses of anadromous species proved inconclusive in terms of identifying consistent relationships between population status and road density, as expected.

Methods

Part of the reason for the weak statistical relationships found in earlier analyses is due to the lack of resolution provided by our measure of road density. The predicted road density class, *roaddn*, is a categorical variable that is limited to six levels. As such, it is useful for making broad characterizations but lacks the resolution of continuous variables such as the arithmetic mean from which *roaddn* is derived. *Roaddn* was created by calculating the area-weighted, arithmetic mean road density (*rdmean*) for each subwatershed using the 1 square kilometer road-density map (see Landscape Dynamics chapter of this report), and assigning one of six levels to each subwatershed based on the value of *rdmean* (fig. 4.23). Most subbasins are grouped within the moderate and high categories, which cover a disproportionate share of the observed range. The resulting frequency histogram for *roaddn* masks much of the variability inherent in *rdmean*.

To recover information lost in the derivation of *roaddn*, we choose to use *rdmean* instead of *roaddn* in our supplemental analyses. We also calculated the area-weighted, geometric mean road density (*rdgeo*), which is defined as the n-th root of the product of n values, where each value is the midpoint of the road density class assigned to each of n 1 square kilometer pixels within each subwatershed. The geometric mean minimizes the effect of outliers with large positive values, thus increasing the weight given to less-roaded areas of a subwatershed. Geometric means are consistently less than the arithmetic means and show a more skewed frequency histogram (fig. 4.23). Since streams may be affected by upstream processes beyond the local subwatershed, we also calculated the arithmetic mean road density for the entire area that drains into each subwatershed (*ups_rdms*).

We used classification trees to identify areas within the range of each species where roads appear influential and then tested the strength of these relationships using logistic regression. Classification trees were constructed using a reduced set of the available landscape variables and the newer measures of road density (table 4.45). The classification trees were used to help identify portions of each species's range that might be sensitive to road density. For example, the classification tree for redband trout suggested roads were important in forested areas outside the range of anadromous fish. For each of the four species, we then performed a two-step logistic regression on selected subgroups of the data. The bull trout and Yellowstone cutthroat trout subgroups included all subwatersheds that were predominantly managed by the Forest Service or BLM. Westslope cutthroat trout were split into two subgroups; one included

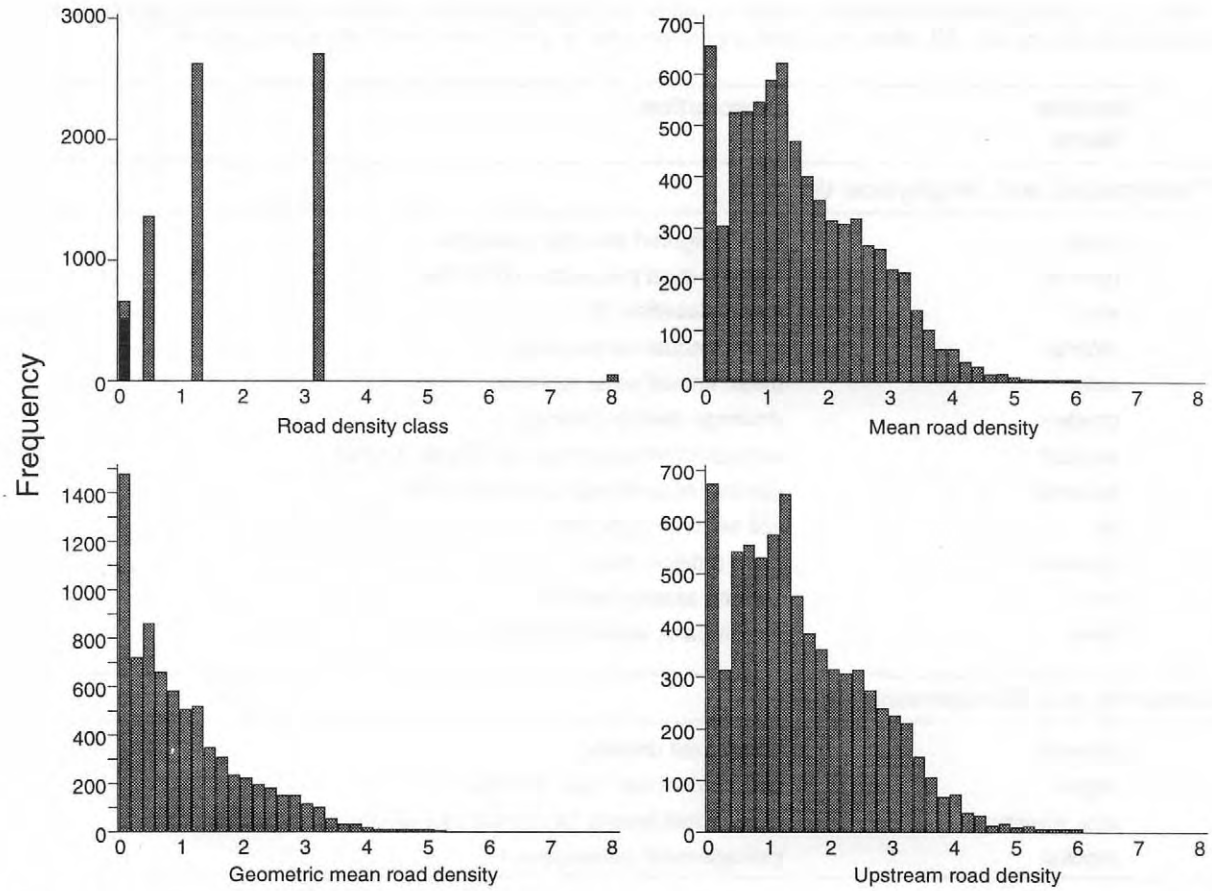


Figure 4.23—Histograms showing the frequency of road density class, mean road density, geometric mean road density, and upstream road density. Plotted values are midpoints of road density classes: none (solid black bar under 0) = 0 - 0.02; very low (hatched bar under 0) = 0.02 - 0.1; low = 0.1 - 0.7; moderate = 0.7 - 1.7; high = 1.7 - 4.7; extreme = > 4.7.

FS/BLM subwatersheds outside the range of anadromous fish, and the second included all subbasins within the range of anadromous fish where the mean annual air temperature is less than 5.8° C. The redband trout subgroup was limited to subwatersheds with a large forest component outside the range of anadromous fish.

In the first step of the logistic regression, the response variable indicated whether or not the species used the subwatershed for spawning and rearing. A positive response (1) was recorded if the species's status was known strong or depressed. Negative responses (0) were recorded for known absence or migration corridors. Possible explanatory variables included *rdgeo* and *ups_rdms* to reflect road density, and the additional landscape variables described in table 4.46. We used an iterative-selection modeling process in which variables were iteratively added and removed from the model according to minimum significance criteria (SAS Institute Inc. 1989). In the second step, we used the same set of potential explanatory variables to distinguish between strong and depressed responses.

Table 4.45—Descriptions of landscape variables used in the logistic regression analysis of subsampled groups of non-anadromous salmonids. All values expressed as percents refer to the percent area of the subwatershed.

Variable Name	Description
Physiographic and Geophysical Variables	
slope	area weighted average midslope
pprecip	mean annual precipiation (PRISM)
elev	mean elevation (ft)
mtemp	mean annual temperature
solar	mean annual solar radiation
drnden	drainage density (mi/mi^2)
anadac	access for anadromous fish (0=no, 1=yes)
hucorder	number of upstream subwatersheds
hk	soil texture coefficient
baseero	base erosion index
ero	surface erosion hazard
bank	streambank erosion hazard
Ownership and Management Variables	
rdmean	mean road density
rdgeo	geometric mean road density
ups_rdmsss	mean road density for current and all upstream subwatersheds
mgclus	management classification

Results

All subgroups except one showed significant road effects—either when distinguishing occupied spawning and rearing areas from unoccupied areas (step 1), or when distinguishing strong from depressed status (step 2). The geometric mean road density had a significant effect in step 1 for bull trout in FS/BLM lands (p=0.0001), in step 2 for westslope cutthroat trout in FS/BLM lands outside the range of anadromous fish (p=0.0007), and in step 2 for redband trout in forested areas outside the range of anadromous fish (p=0.0001). The arithmetic mean road density for all upstream areas had a significant effect in step 2 for bull trout in FS/BLM lands (p=0.0001), and in step 1 for westslope cutthroat trout within the cooler portions of the range of anadromous fish (p=0.002). In all cases, the sign of the coefficient associated with the road density measurements was negative (table 4.46), which suggests a decreasing likelihood of occupancy, or a decreasing likelihood of strong status if occupied, with increasing road density. Other variables also were found to be significant in different combinations for each species. As indicated by the sign of the coefficients associated with each variable (table 4.46), no other variables except *slope* showed the consistent patterns across all species shown by the road density measures.

The influence of roads on population status indicated in the logistic regression analysis is reinforced by graphical displays of the cumulative

Table 4.46—Results of logistics regression analysis for subsampled groups of non-anadromous salmonids. The variables listed refer to only those variables found to be significant. Direction indicates the sign of the estimated coefficient associated with each variable.

	Bull trout		Westslope cutthroat subgroup 1		Westslope cutthroat subgroup 2		Yellowstone cutthroat		Redband trout	
Response[1]	variables	direction	variables	direction	variables	direction	variables	direction	variables	direction
*spawning/rearing	rdgeo	-	slope	+	ups_rdms	-	elev	+	solar	+
vs.	hucorder	-			hucorder	-	mtemp	-	hk	-
absent/migration	mtemp	-			drnden	+	pprecip	-		
	pprecip	+								
*strong	ups_rdms	-	rdgeo	-	mtemp	-	drnden	-	rdgeo	-
vs.	solar	+	hucorder	+	solar	-	hk	+		
depressed	slope	+	elev	+	slope	+				
	drnden	+	mtemp	+						
	hk	+	bank	-						
			hk	+						

[1] Modeled responses are indicated by asterisks.

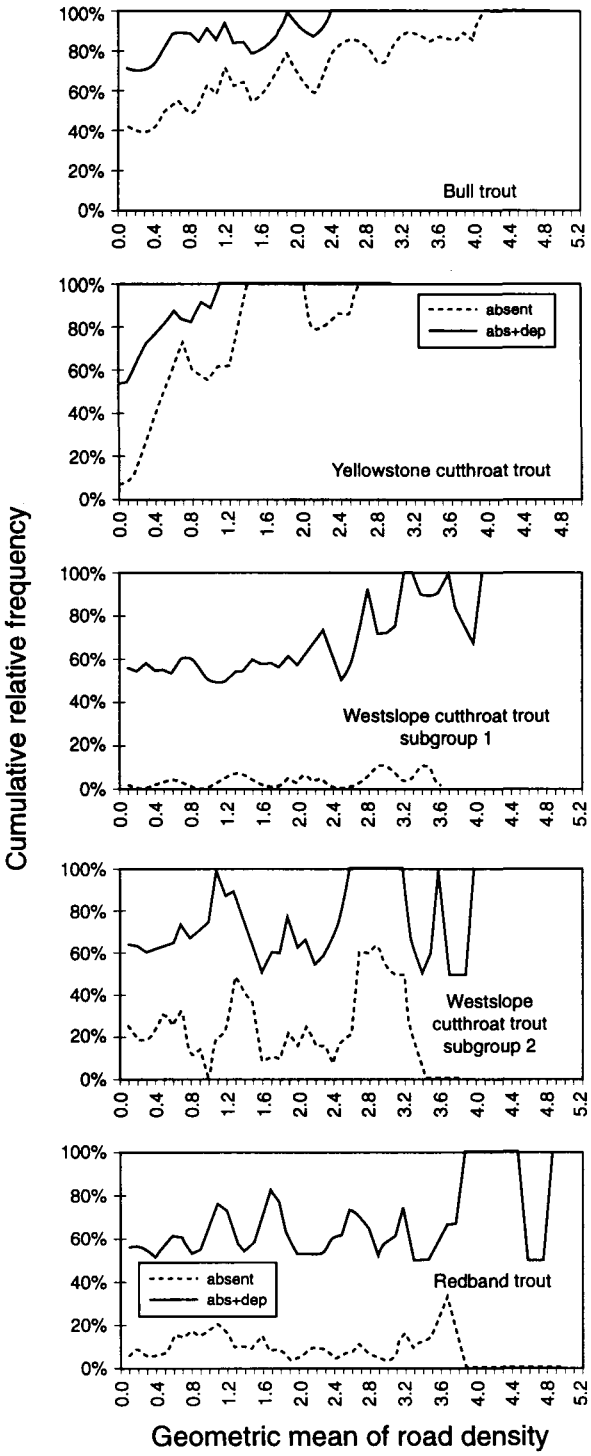


Figure 4.24—Cumulative relative frequencies for absent, and absent or depressed versus geometric mean density (*rdgeo*, table 4.46), using a moving window on *rdgeo*.

relative frequencies for absent, and absent or depressed versus *rdgeo*, using a moving window on *rdgeo* (fig. 4.24). These graphs clearly show increasing absence and decreasing proportion of strong populations with increasing road density for several subgroups. Additional evidence is suggested by the mean values for *rdgeo* and *ups_rdms* by status level for each subgroup (table 4.47). In all cases, the lowest mean road density values are associated with strong population status.

The graphical trend and the progression in mean road density values are quite apparent for Yellowstone cutthroat trout, even though it was the only subgroup that did not show a significant road effect in the logistic regression exercise. The lack of statistical significance in the face of apparent trends points to complex interactions among the explanatory variables that are not adequately addressed in the relatively simple logistic model that looks only at additive main effects irrespective of interactions. The fact that we detected consistent, significant effects for other species using a limited model is further testament to the strength and pervasiveness of the effects.

Discussion

Our results clearly show that increasing road densities and their attendant effects are associated with declines in the status of four non-anadromous salmonid species. They are less likely to use highly roaded areas for spawning and rearing, and if found are less likely to be at strong population levels. This is a consistent and unmistakable pattern based on empirical analysis of 3,327 combinations of known species' status and subwatershed conditions, limited primarily to forested lands administered by the Forest Service and BLM. We would not expect the relationship to be as strong on the non-forested, lower-gradient lands administered by the BLM. Of the four species examined, these lands tend to support only redband trout. Our results suggested that redband trout status could be clearly associated with road density only within forested, higher-elevation areas.

Table 4.47—Average road densities by population status for subsampled groups of non-anadromous salmonids.

Species	Status	Frequency	rdgeo[1]	ups_rdms[2]
Bull trout				
	Absent	932	1.13	1.71
	Depressed	477	0.67	1.36
	Strong	155	0.18	0.45
Westslope cutthroat trout				
subgroup 1	Absent	23	1.67	1.87
	Depressed	443	1.45	2.14
	Strong	165	0.59	1.16
subgroup 2	Absent	113	0.6	1.04
	Depressed	174	0.66	1.07
	Strong	144	0.31	0.55
Yellowstone cutthroat trout				
	Absent	42	1.16	1.81
	Depressed	54	0.27	1.01
	Strong	126	0.1	0.41
Redband trout				
	Absent	46	1.46	2.32
	Depressed	274	1.5	2.19
	Strong	159	1.03	1.73

[1]rdgeo = geometric mean of road density (mi/mi^2)

[2]ups_rdms = arithmetic mean of road density of all upstream subwatersheds (mi/mi^2)

The non-anadromous salmonid species are important elements in aquatic communities and deserve increased stature in policy deliberations. In some ways, their importance has been overshadowed in recent years due to the plight of the anadromous species in the Columbia River Basin. This is unfortunate given their distribution and contribution to aquatic integrity. The historical range of the four non-anadromous salmonids examined above includes 96 percent of the subwatersheds under substantive FS and BLM management. In contrast, only 27 percent of the subwatersheds so classified currently are accessible to anadromous fishes and fall within the range of the three anadromous key salmonids. Thus, the non-anadromous salmonids provide a much broader picture of watershed conditions. One of the elements that we used to identify areas of high aquatic integrity was whether or not a watershed supported strong populations of key salmonids. There were 52 known strong populations of anadromous fish at the subwatershed scale, and 927 known strong populations of non-anadromous fish were recorded.

The declines in population status of the non-anadromous key salmonids should be viewed as an indication of the types of responses that may be experienced by other native species in similar

habitats. Those most like the non-anadromous key salmonids in distribution or habitat requirements would be expected to show the most similar responses. This would include the anadromous species such as steelhead, stream-type chinook salmon, and Pacific lamprey that broadly overlap in range with the non-anadromous salmonids and use many of the same habitats for significant portions of their life. There are no logical reasons to expect anadromous fishes to be immune to the effects of habitat change evident in the non-anadromous species. Other species, including sculpins, dace, and some suckers also have considerable overlap in range and may follow similar trends in population abundance and distribution.

Summary and Conclusions

We have assessed the current status of select fishes, identified areas with high biotic integrity and diversity, and identified linkages between fish, the biophysical environment, and humans. In this final section, we synthesize our results and consider the implications for management. We organize our conclusions along four major themes.

1. The composition, distribution, and status of fishes within the Basin are very different than they were historically. The overall changes are dramatic and extensive, and in many cases irreversible. Some forms, such as the Alvord cutthroat trout (*Oncorhynchus clarki* spp.) and the Miller Lake lamprey (*Lampetra minima*), are extinct (table 4.16). Many others, especially anadromous fish, are extirpated from large portions of their historical range. While we may be able to reestablish some depressed taxa in portions of the range, reopening large tracts of the former range to anadromous salmonids is unlikely in the short term.

Our clearest understanding of fish status comes from the analysis of the seven key salmonids.

Our analysis of available data suggests the historical condition of native fishes has changed dramatically. Several of the key or sensitive species are distributed throughout most of their historical range (notably cutthroat and redband trout), however, declines in abundance, the loss of important life histories, genetic introgression, local extirpations, and fragmentation and isolation of high-quality habitats into smaller patches are apparent for all of the key salmonids and many other species. Yellowstone and westslope cutthroat trout appear to be the most successful of the key salmonids. They were found or predicted in 71 and 85 percent of the historical range, respectively. With the exception of Yellowstone cutthroat trout, however, none of the key salmonids have known or predicted strong populations in more than 22 percent of their historical ranges (table 4.48). The non-anadromous trouts may be in even worse condition than suggested because of introgressive hybridization with introduced salmonids. Chinook salmon are the most restricted of the key salmonids. Both forms of chinook salmon are extinct in more than 70 percent of their historical ranges, steelhead in more than 50 percent, and all are approaching extinction in important portions of their remaining ranges. With few exceptions, most subwatersheds supporting chinook salmon and steelhead are also likely to be influenced by hatchery stocks.

If current distributions of the key salmonids are good indicators of aquatic ecosystem health, many systems remain only as remnants of what were larger, more complex, diverse and connected systems. Even with no further habitat loss the fragmentation and isolation may place remaining populations at risk. With the exception of the Central Idaho Mountains, Snake Headwaters, and perhaps the Northern Cascades, most of the important areas for the key salmonids exist as patches of scattered subwatersheds. Many are not well connected or are restricted to much smaller areas than historically. Many of the important subwatersheds are associated with high-elevation, steep, and more erosive landscapes. These may be more extreme or variable environments contributing to higher variability in the associated populations, and higher sensitivity to watershed disturbances. Risks could be aggravated with further development.

Table 4.48—Summary comparison of the known and predicted present and strong distributions for each of the seven key salmonids. The proportion of subwatershed areas in each class is shown within the Basin and within the historical range. The unknown subwatersheds included both unclassified and present but status unknown that required predictions for a complete distribution.

	Assessment Area		Historical Range		
Species	Historical	Present	Present	Strong	Unknown
Bull trout	0.59	0.26	0.45	0.06	0.38
Yellowstone cutthroat	0.09	0.07	0.66	0.32	0.39
Westslope cutthroat	0.35	0.27	0.85	0.22	0.38
Redband trout					
Sympatric	0.56	0.38	0.69	0.17	0.67
Allopatric	0.17	0.08	0.49	0.09	0.62
Steelhead	0.50	0.23	0.46	0.01	0.15
Stream-type chinook	0.46	0.13	0.28	<0.01	0.12
Ocean-type chiniook	0.07	0.02	0.30	0.05	0.13

The patchwork of important watersheds also suggests that remaining populations of salmonids are not well distributed within the subbasins. Watersheds that were once likely to support a complex of life-history patterns and subpopulations within larger regional or metapopulations are now often fragmented. The loss of spatial diversity in population structure and of the full expression of life-history pattern may lead to a loss of productivity and stability important to long-term persistence. If connectivity among populations is limited by a matrix of poor quality habitats interspersed among remaining high quality areas, gene flow and the potential for refounding or demographic support among populations will also be limited. Local extirpations may occur through random events even in high-quality environments with no further habitat change, but in many cases the spatial and life-history diversity necessary to mitigate the losses is no longer present.

All populations are likely variable in time and many have patchy distributions even in high-quality environments. Local extirpation may be a natural and perhaps common element in the dynamics of many species (Rieman and McIntyre 1995). Natural climate change and associated events such as glaciation and the Bonneville and Missoula glacial floods, have undoubtedly influenced the current distribution of these fishes (Behnke 1992). Climatic variation associated with fluctuating ocean conditions, drought and flood patterns, and local storm frequency and intensity may influence abundance and distributions in shorter time scales. The recent declines in Columbia River salmon, for example, have been influenced by recent ocean conditions (for example, Lichatowich and Mobrand 1995) and a period of extended drought. Although environmental variability is a factor and may be the proximate cause of decline or extinction in some cases, the effects of human-caused disturbance appear to be far more important. Population declines for many of the fishes, including Columbia River salmon, can be associated with a variety of factors that include habitat disruption linked to land management; watershed development for hydropower and irrigation; competition, hybridization and predation linked to the introduction of non-native species, races or stocks of fish; harvest; and even the intentional eradication of some populations. The native-fish assemblages have generally persisted best in the areas least influenced by humans.

Population fragmentation and lost resilience may place many remaining populations at increased risk to natural and human-caused disturbance. Recognition and conservation of important or sensitive populations and habitats will likely be critical to broad-scale persistence of many of these fishes.

Our analysis of species assemblages led to similar conclusions. Although we were unable to map the distribution of all species accurately, the trends are clear. We found large numbers of introduced species throughout all major river systems. The changes are most severe in lowland rivers, but higher-elevation tributaries are also affected. The current distributions of the native fishes likely reflect specific habitat requirements, the availability of suitable habitats constrained by the biophysical environment and dispersal mechanisms, and the persistence of local stocks influenced by population dynamics and habitat quality. The distributions of native fishes probably reflect natural disturbance patterns, but human influences have profoundly altered those distributions and the condition of populations throughout the Basin.

2. Though much of the native ecosystem has been altered, core areas remain for rebuilding and maintaining functional native aquatic systems. Even though they are reduced in numbers and distributions, native trouts remain one of the most widely distributed taxa within the basin. These indicators of environmental quality suggest that we have serious problems, particularly in the larger rivers and in the low-elevation agricultural and range lands. Many of these areas likely were fringe areas for several species. The situation is somewhat better in the forested lands, especially in those that have experienced less disturbance. We see a higher proportion of strong populations in higher-elevation forested lands than others, and the proportion declines with road density. Most of the areas exhibiting high integrity fall within forested areas, with the exception of areas inherently high in native species richness near the southern edge of the Basin.

The largest areas of contiguous or clustered watersheds supporting strong populations of key salmonids are associated with the major river subbasins found in the Central Idaho Mountains, the Snake Headwaters and the Northern Cascades. Important areas are also found in the Blue Mountains, Upper Clark Fork and the Northern Glaciated Mountains, but are scattered or generally restricted to only portions of interior river subbasins. Each of the key salmonids supported some strong populations, ranging from less than 1 percent of the historical range for stream-type chinook salmon to 32 percent for Yellowstone cutthroat trout (map 4.27). There was, however, little overlap in the strong distributions at our scale of analysis. Differences in habitat requirements and life-history patterns likely lead to the lack of overlap. With the exception of the Central Idaho Mountains and Northern Cascades there are few clusters of subwatersheds likely to provide highly productive habitat for multiple species, but collections of subwatersheds still exist within larger subbasins.

Native species still dominate most of the Basin. When we examined species assemblages, we could not detect trends indicating that introduced species were replacing native species. We know that introduced species can and do replace natives. For example, introduced rainbow trout have replaced Yellowstone cutthroat trout in large portions of the Henrys Fork Snake River (IDFG 1991). Our inability to detect such replacement may be an artifact of the scale at which our data were collected, and be influenced by our lack of information on introgression. Introduced and native trouts are sometimes spatially segregated within streams (Rieman and Apperson 1989), but appear to overlap within a watershed because of the resolution of our data distributions. The general pattern, however, based on over 2,000 sample points, indicates native species richness persisting even as non-native richness increases.

Our contention is that although native fish species have declined and fish communities have been altered, important elements remain. A core of habitats and populations for maintaining and

perhaps restoring much of the biological diversity associated with historical aquatic communities still exists. Where introgressive hybridization has seriously compromised native gene pools, hybrid and introduced trouts probably cannot be eliminated. Hybrids may adapt well to existing conditions, however, and provide at least some of the function and value of the historical forms and species complexes.

3. Protection and maintenance of system integrity and functioning will require innovative approaches. Simple solutions such as setting aside small, scattered subwatersheds probably will not be adequate for the persistence of even current distributions and diversity. The problems are too complex and too pervasive. However, there are several actions which could be taken to maintain or restore the integrity of aquatic ecosystems.

First, conservation of watersheds and habitats that support remaining areas of high intrinsic value or condition for aquatic species is critical. These include areas supporting strongholds for one or multiple species, areas of high genetic integrity, fringe distributions, and areas that support narrowly distributed endemic or listed species. Though it may be unpopular to suggest land-use restrictions to protect fishes that are poorly known or support little recreational and economic opportunity, maintenance of biological diversity and integrity implies recognition of values other than those defined solely by charismatic game species. As Norton (1991) points out, it is not so important why one chooses to protect biodiversity—there are any number of reasons—but that you actively do it.

Narrowly distributed endemics are generally associated with closed basins; obvious exceptions are margined sculpin and Shoshone sculpin. All would benefit from special emphasis. Most endemic species have been isolated in basins over geologic time, contributing to their speciation and narrow distribution. Many of these species are associated with the interior Oregon Lakes and Klamath basins, and their presence emphasizes the special significance of these areas. Management and analysis of these aquatic systems probably can proceed independently of the Columbia River Basin. Conservative approaches to land management are more important here because virtually all these species and most of the waters that support them exist as small, isolated systems. Problems associated with habitat disruption and non-native species magnify themselves in such restricted spring and stream systems. Climate change alone may place many of these fishes at extreme risk.

Second, reconnection and expansion of the mosaic of strongholds for widely distributed species such as the key salmonids will enhance the integrity of larger systems. For wide-ranging fishes such as salmon, steelhead, and other migratory trouts, this includes protection of water quality and passage in migratory corridors as well as protection of spawning and rearing areas. Conservation and restoration of important habitats for key salmonids should provide habitat for associated species and will sustain important processes that influence structure and function within these systems. We have used existing information to identify important subwatersheds in the current distribution of the key salmonids. These subwatersheds should be incorporated into future conservation strategies, but they cannot be the only element of those strategies.

The diverse characteristics of the key salmonids and associated assemblages involve more than single subwatersheds. The full expression of life history in any species often involves whole river basins and a mosaic of habitats throughout those basins (Gresswell and others 1994; Healey 1994; Lichatowich and Mobrand 1995). It is also apparent from our analysis that although many subwatersheds support several species, few support spawning and rearing areas for more than one key salmonid. Any conservation strategy focused on protecting or restoring habitat for a single species or life-history form at the subwatershed scale will not provide for multiple species or complete communities. Frissell and others (1995) and Gresswell and others (1994) reach similar conclusions. Consideration of larger spatial and temporal scales would be an important aspect of any

effective conservation strategy for aquatic ecosystems. Conservation and restoration of subwatersheds that support the remaining populations are critical for short-term persistence. Conservation and restoration of habitat networks throughout larger subbasins, however, will be necessary for long-term stability, persistence and the full expression of biological diversity.

Restoration and management of watersheds only on Federal lands will not be sufficient. River corridors surrounded largely by private lands are a particularly important part of the habitat networks. Much of the overlap in species distributions occurs in the larger river corridors because many of the species range widely. For example, anadromous species use the entire system of rivers as migratory corridors and also for overwintering and short-term rearing. The connections and habitat provided by larger river systems are thus critical to the maintenance of anadromous populations. The construction of dams and reservoirs and their complex effects on migration and survival is viewed as the single greatest threat to the persistence of salmon and steelhead in the upper basins. Although much of the highest-quality habitat for anadromous fish probably remains in the Central Idaho Mountains, no strong populations persist there, due largely to passage mortality in migration corridors. These corridors provide a critical link maintaining the complex life histories of other species as well. Non-anadromous species that retain migratory life-history patterns such as bull, redband, Yellowstone cutthroat, and westslope cutthroat trout may migrate hundreds of kilometers annually. These species may move repeatedly between small rivers and headwater streams used for spawning and initial rearing and large rivers or lakes used for subadult rearing, overwintering or seasonal foraging. Bull, cutthroat, and redband trout persist in basins isolated from the larger rivers and lakes. Where connections are disrupted and the full expression of life histories is restricted, however, the persistence, resilience, and diversity of aquatic communities are limited.

Restoring or maintaining the integrity of migration corridors will be challenging. Lowland rivers and lakes integrate the effects of disturbance over huge areas under many ownerships. No single agency oversees the management of entire basins or has the ability to balance competing demands and uses (for example, irrigation, hydropower, recreation, housing, waste disposal, timber harvest). Habitats associated with lower-elevation and lower-gradient valley bottoms are more desirable for human development. Many of these areas are in private ownership and attempts to protect private properties have severed the ties between rivers and their floodplains. Channelization, riprapping, construction of levees, and elimination of riparian vegetation have dramatically simplified stream and river habitats and disrupted the natural processes that form and maintain those habitats (Johnson and others 1995). Areas that may have been critical seasonal habitats for some species have been eliminated or degraded.

Third, containment of non-native species in certain areas will benefit native species. We are not advocating wholesale eradication of introduced fishes. We do suggest, however, that land management agencies could work with state fishery management agencies to reduce or eliminate stocking of non-native and hatchery-reared fish in areas capable of supporting self-sustaining native species. Containment of introduced fishes will help with the first two approaches as well. Interestingly, the average Z values, our measure of native diversity and evenness, were significantly higher in areas with two or more strong populations of key salmonids. This suggests a meaningful relationship between introduced fishes and abundance of native species.

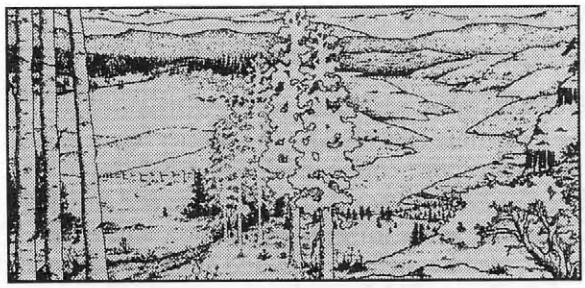
4. Although the integrity of aquatic systems is most easily maintained in watersheds having little or no human influence, evidence suggests that many species persist in some intensively managed areas. We found stronger fish populations in areas with minimal disturbance. But we also found that intensive land use did not necessarily eliminate all strong populations or areas of higher fish community integrity. The scope of this assessment precludes us from examining individual watersheds in detail. Thus, we cannot discern whether intensively managed areas that retain relatively healthy populations and communities are anomalies, regions where the effects on streams lag behind the change on lands, or are areas where intensive management and fish simply coexist. We therefore recommend a more careful examination of these areas.

There are many factors that contribute to the productivity of individual watersheds and systems of watersheds. Those watersheds that are intensively managed, yet support strong populations or areas of high integrity, should be among those of greatest concern. Watershed responses often lag behind management changes. The cumulative effects of land disturbance, for example, may not be evident in streams until triggered by low-frequency storm events. We suggest prioritization of these areas for detailed review of watershed conditions and trends. Such review could recognize populations at risk and highlight practices that could be used to benefit aquatic resources in other intensively managed areas.

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RARE AND SENSITIVE SPECIES: STATUS SUMMARIES

Narratives summarizing the status for 39 rare and sensitive species were prepared. These narratives are arranged in phylogenetic order and are divided as follows: Distribution and Status, Habitat Relationships, and Key Factors Influencing Status. Accompanying each narrative is a map that typically illustrates the probable historic and current distribution plus any major introduction sites mapped at the watershed level. The actual distributions of these species may include small portions of the watersheds and therefore, are overestimated on the figures. General categories of research and information needs are listed for each species in table 4.53 (see following section "Information and Research Needs."

These status narratives include a variety of narrowly distributed endemics, largely unknown species, and other native species that may be important and wide ranging but for which the assessment area represents a small portion of their range. The Sunapee char, an introduced species of special note, also is included. All these species are worthy of special management attention and several already receive protection under the Endangered Species Act. Resident freshwater threatened or endangered species are listed under the Endangered Species Act by the U.S. Fish and Wildlife Service, whereas the National Marine Fisheries Service has responsibility for listing anadromous fishes. Some rare and sensitive species are recognized as requiring special protection by the States of Oregon, Washington, Idaho, or Montana. Many are managed as sensitive species by the USDA Forest Service and/or USDI Bureau of Land Management. Several were considered by the U.S. Fish and Wildlife Service to be Category 2 Candidates for listing until a February 27, 1996 nationwide decision to delete all Category 2 taxa from Candidate species status.

Although we know less about the rare and sensitive species than the seven key salmonids, analyses of existing distribution and reviews of available literature provide important insights about common threats and appropriate management needs. Many of these taxa occur in isolated areas of the Columbia River Basin, in isolated subbasins of the Great Basin, or are restricted to the upper Klamath Basin. They typically occur in relatively depauperate subbasins, perhaps with only one or two native fish species present and therefore, may not be recognized in management strategies that focus on areas of high native species diversity. Many of these taxa occur in very restricted areas, often occupying one or two small habitat patches within subwatersheds. Consequently, broad or mid-scale assessments may not adequately describe their distributions.

White Sturgeon (*Acipenser transmontanus*)

White sturgeon were once widely distributed in the Columbia River basin. The species has been an important sport, commercial, and tribal resource. The Kootenai River (Idaho, Montana and British Columbia) white sturgeon population is listed as endangered by the U.S. Fish and Wildlife Service and the State of Idaho and as sensitive by the BLM. The Snake River white sturgeon is listed as a species of concern by the State of Idaho and as a sensitive species by Region 1 of the Forest Service.

Distribution and Status

Along the Pacific Coast, white sturgeon were found in accessible freshwater from the Aleutian Islands south to central California. The Columbia River represents one of three large river basins in the Pacific Northwest where white sturgeon reproduce. Historically, prior to dam construction, white sturgeon were anadromous and migrated within the Columbia River Basin up to impassable falls (map 4.35). The Kootenai River white sturgeon has been isolated from other white sturgeon populations since the last glacial age (Apperson and Anders 1991). The white sturgeon is restricted to 695 river kilometers in the Kootenai River Basin between Kootenai Falls, Montana downstream to Cora Linn Dam at Kootenay Lake, British Columbia, Canada. The Kootenai River white sturgeon have not successfully spawned in recent years. The current population, which has a no harvest restriction, has decreased to about 880 individuals (Apperson and Anders 1991). Snake River white sturgeon are found in the Snake River in Idaho up to Shoshone Falls, and in the Salmon River in Idaho likely upstream to the confluence of the East Fork Salmon River. The present distribution of Snake River white sturgeon has been fragmented into discrete subpopulations confined between mainstem dams (Hanson and others 1992). The Hells Canyon reach along the Oregon-Idaho border contains the highest densities of Snake River white sturgeon. In the Columbia River downstream from McNary Dam, on the Washington-Oregon border, the annual abundance of white sturgeon greater than 53 centimeters was 893,800 fish from 1986 to 1992. In contrast to the Snake and Kootenai rivers where all captured sturgeon must be released, a consumptive sturgeon fishery continues in the lower Columbia River.

Habitat Relationships

Substrate size and water velocity influence selection of spawning areas by white sturgeon. Spawning generally occurs in water over three meters deep and over cobble substrate. In the Columbia River system, reproduction has been greater during years of high flows compared with years of low flow (Hanson and others 1992). Spawning also occurs earlier and at lower temperatures during high flow years (Hanson and others 1992). Adults and juveniles prefer deep-pool habitat with a fine bottom substrate. Adults tend to move downstream in the summer and fall months and upstream in the winter and spring months. Fish tend to stay in shallower water during the spring and summer and move to deeper waters during the winter.

Key Factors Influencing Status

Hydropower dams on the Columbia and Snake rivers have prevented migration, fragmented riverine populations, and reduced the effectiveness of natural propagation (Hanson and others 1992). Dams have also reduced spawning success, by decreasing the amount of suitable spawning areas or creating poor incubation environments. In general, the length of time required to reach sexual maturity, typically 10 to 15 years, results in low rates of natural recruitment. Most reproductively capable fish are protected by harvest regulations based on fish length. The decrease in spring river flows below Libby Dam, Montana appears to have contributed to spawning failures of the Kootenai River population in recent years (Apperson and Anders 1991). Land management activities are considered a secondary impact to white sturgeon.

Map 4.35—Historical and current distribution plus introduced sites of white sturgeon.

Klamath Lamprey (*Lampetra similis*)

The Klamath lamprey (*L. similis*) is a parasitic form from the Klamath River of Oregon and California (Vladykov and Kott 1979). The Klamath lamprey is poorly understood, restricted in its distribution, and may be threatened with extinction.

Distribution and Status

The Klamath lamprey is one of five species of lampreys described from the Klamath Basin of northern California and south-central Oregon. The other forms include the Miller Lake lamprey (*L. minima*), a dwarf parasitic form that was endemic to Miller Lake, Oregon, and is now extinct (Bond and Kan 1973); the Modoc brook lamprey (*L. folletti*), a nonparasitic form known only from Willow Creek and the Lost River portions of the Klamath River drainage in Modoc County, California (Vladykov and Kott 1979); the Pit-Klamath brook lamprey (*L. lethophaga*), a more widely distributed nonparasitic form known from the upper Klamath drainage and the Goose Lake drainage in Oregon and California and the upper Pit River system in California (Hubbs 1971); and the widespread Pacific lamprey (*L. tridentata*). The Klamath lamprey is known from the Klamath River and upper Klamath Lake in Oregon (map 4.36) (Vladykov and Kott 1979). The Pacific lamprey reported from Copco Reservoir on the Klamath River in California may instead represent *L. similis* (Moyle and others 1989). Information about the status of the Klamath lamprey is lacking.

Habitat Relationships

Little is known about the specific habitat requirements of the Klamath lamprey. The species is parasitic, presumably on the larger trouts and suckers in the Klamath Basin.

Key Factors Influencing Status

The many dams, water diversions, and other modifications common to the upper Klamath River drainage are presumed to have disrupted the distribution and life history of this species. Many native fishes in the Klamath Basin, which would serve as hosts for the lamprey, have declined. Based on the restricted range and threatened status of many host species, the Klamath lamprey may be at high risk of extinction. Specific information is lacking.

River Lamprey (*Lampetra ayresi*)

River lamprey are anadromous and parasitic. They are rare and, according to the limited available literature, apparently migrate short distances inland compared with the Pacific lamprey.

Distribution and Status

The river lamprey is distributed along the Pacific Coast of North America from the Sacramento River, California north to Tee Harbor near Juneau, Alaska (map 4.37) (Kan 1975). In the Columbia River, the river lamprey has been reported from Bonneville Dam and locations downstream (Kan 1975). Very little is known on the status of this species.

Habitat Relationships

River lampreys require small, clear water streams for spawning, with ammocoetes (the larval form) living in silty backwaters of such streams (Moyle and others 1989). Known hosts for adults include smelt, herring, kokanee salmon, and coho salmon (Kan 1975). In Canada, the adults begin their spawning migration in freshwater between September and late winter after they have spent two years in the ocean (Beamish 1980). They spawn the following April to June, and subsequently die. At the appropriate age, the young begin to metamorphose in July but do not emigrate to the ocean until the following May to July (Beamish 1980).

Key Factors Influencing Status

Relative to Pacific lamprey, the river lamprey's tendency to use areas close to the coast may protect it to some degree from mortality associated with mainstem dam passage. The limited distribution of river lamprey relative to Pacific lamprey may increase their vulnerability. Information to assess that or other risks is not available.

Pacific Lamprey (*Lampetra tridentata*)

The Pacific lamprey is an anadromous and parasitic lamprey widely distributed along the Pacific Coast of North America and Asia. Traditionally, Pacific lamprey were an important ceremonial and subsistence resource for native peoples. In the assessment area, they occur in all waters that remain accessible to salmon and steelhead (Simpson and Wallace 1978). The Idaho Department of Fish and Game lists Pacific lamprey as a state endangered species.

Distribution and Status

Within the Columbia River Basin, Pacific lamprey are believed to have migrated to all waters accessible to anadromous salmonids (Simpson and Wallace 1978). Kan (1975) suggested that the primary consideration for presence of lamprey was access rather than distance from the ocean. Historic runs were large; in some years up to 400,000 lampreys were counted as they migrated past Bonneville Dam (Harrison 1995). Counts of lamprey passing Ice Harbor Dam totaled 40 in 1993 and 399 in 1994, compared with the 1960s when nearly 50,000 were counted annually (Harrison 1995).

Similar to other anadromous fishes, the distribution and abundance of Pacific lamprey has been reduced by construction of dams and water diversions as well as degradation of spawning and rearing habitat. Using the distribution of steelhead as an indicator, Pacific lamprey currently are blocked from entering more than 50 percent of their historic range (map 4.38). Consequently they are precluded from large areas, including upstream from Hell's Canyon Dam on the Snake River and Chief Joseph Dam on the Columbia River. Landlocked populations have been found in areas from which the anadromous form has been precluded (Wallace and Ball 1978), but they have not persisted and Beamish and Northcote (1988) concluded that metamorphosed lamprey were unable, in such areas, to survive to maturity.

Habitat Relationships

Pacific lamprey adults enter freshwater between July and September, and may migrate several hundred kilometers inland (for details of life history, see Scott and Crossman 1973). They do not mature until the following March. They spawn in sandy gravel immediately upstream from riffles between April and July and die soon after. Eggs hatch in two to three weeks and the ammocoetes spend up to the next six years in soft substrate as filter-feeders before they emigrate to the ocean. They remain in the ocean for 12 to 20 months before returning to freshwater to spawn. Diatoms appear to be a primary food supply for the ammocoetes.

Key Factors Influencing Status

The Idaho Chapter of the American Fisheries Society (IDAFS 1995) concluded that dams on the Snake and Columbia rivers, alteration of streams, and harvest of ammocoetes by bait fisheries are the most serious threats to the Pacific lamprey in Idaho. Pacific lamprey, similar to salmonids, are likely to be vulnerable to land disturbances that cause sedimentation in nursery streams. The ammocoetes depend on quality habitat in freshwater for up to six or seven years before they emigrate to the ocean. Such an extended period in freshwater makes them especially vulnerable to degraded stream conditions. Their anadromous life-history necessitates maintenance of access to spawning and rearing areas. Water quality consistent with robust diatom production may be a key factor for their continued success.

Map 4.36—Historical and current distribution of Klamath lamprey.

Map 4.37—Historical and current distribution of river lamprey.

Map 4.38—Historical and current distribution of Pacific lamprey.

Goose Lake Lamprey (*Lampetra tridentata* ssp.)

The Goose Lake lamprey is considered a subspecies of parasitic Pacific lamprey that were isolated in the Goose Lake basin during the early Pleistocene (Moyle and others 1989). Although it is a State of Oregon sensitive species, and a State of California species of special concern, it currently receives no special management attention.

Distribution and Status

The species is unique to the Goose Lake Basin of Oregon and Washington (map 4.39). In California, they are reported from Lassen and Willow creeks. In Oregon, they were found in Drews Creek, Drews Reservoir, Thomas Creek, Cottonwood Creek, and Cottonwood Reservoir (ODFW 1992). They also occur in Goose Lake. Beyond this, the extent of their distribution and abundance is unknown.

Habitat Relationships

Specific habitat requirements of the Goose Lake lamprey are unknown. The parasitic adults live for a time in Goose Lake, a shallow (less than 7 meters), turbid lake. Lake temperatures range from 1° to 24° C (Johnson and others 1985). They migrate to lake tributaries to spawn. The young remain in the tributaries for an unknown amount of time before they metamorphose and move to the lake. Requirements in nursery streams are thought to include gravel spawning areas and soft substrate for the filter-feeding ammocoetes.

Key Factors Influencing Status

Goose Lake dried in 1992 because of drought. Extended drought could lead to extinction of the species. Water diversions during the period that ammocoetes emigrate to the lake would likewise contribute to the demise of the species. The subspecies does not have a wide distribution and is therefore vulnerable to the effects of small population size and fragmentation. Declines of native hosts, particularly chub, sucker, and redband trout, would likely be detrimental to the lamprey.

Pit-Klamath Brook Lamprey (*Lampetra lethophaga*)

This brook lamprey completes its life-cycle in freshwater and is nonparasitic. It occurs in the Klamath and upper Pit river systems of northern California and south-central Oregon.

Distribution and Status

The Pit-Klamath brook lamprey is reported from the North Fork Pit, Pit, and Fall rivers, and Hat Creek, in California; the Sprague, North Fork Sprague, Sycan, and Williamson rivers, and Crooked and Meryl creeks in Oregon (map 4.40) (Hubbs 1971; Kan 1975).

Habitat Relationships

Metamorphosis may occur anytime between May and late October (Kan 1975) and neotenic ammocoetes are common. Spawners have only been found from March to May. The larval period extends for five or six years.

Key Factors Influencing Status

Factors influencing the habitat of the species have not been described. Stream alterations that reduce productivity for diatoms and other food items, and that increase water temperature would be likely to be deleterious for the species. The species is narrowly distributed and is therefore vulnerable to the effects of small population size and fragmentation.

Map 4.39—Historical and current distribution of Goose Lake lamprey.

Map 4.40—Historical and current distribution of Pit-Klamath brook lamprey.

Sockeye Salmon (*Oncorhynchus nerka*)

Sockeye salmon were once an abundant and widely distributed species in the Columbia River Basin and apparently also occurred in the Klamath Basin (Wydoski and Whitney 1979). Sockeye salmon were an important sport, commercial, and tribal resource. Native stocks have declined and a remnant population of sockeye salmon in the upper Snake River Basin in Idaho is federally listed as endangered. Sockeye salmon exhibit two dominant life history forms, the anadromous form and a resident form called kokanee.

Introduced and native kokanee salmon populations that now exist in lakes and reservoirs throughout the assessment area are viewed as one of the Basin's most important sport fishery resources (Rieman and Maiolie 1995; Rieman and Myers 1992). Kokanee salmon are a highly valued food fish and are also a key forage fish (Wydoski and Bennett 1981).

Distribution and Status

The historic range of sockeye salmon extended across the northern rim of the Pacific Ocean down the west coast of North America as far south as the Sacramento River in California (Burgner 1991). Anadromous sockeye salmon are now believed to be extinct south of the Columbia River Basin and the remaining runs represent the most southerly and longest migrating populations of the species in the world (Waples and others 1991a). The historic range included large segments of the Columbia River Basin where natural lakes and surrounding watersheds are connected by river systems to the Pacific Ocean (maps 4.41a and 4.41b). Eleven major watersheds and at least 24 lakes are believed to have supported native populations of sockeye salmon within the Columbia River Basin (Fulton 1970; Waples and others 1991a; Wydoski and Whitney 1979).

Historic runs of anadromous adults at the mouth of the Columbia River may have numbered more than two million before the turn of the century. Numbers are now consistently less than 100,000 fish. Today, only lakes Wenatchee and Osoyoos in the upper Columbia River produce significant numbers of anadromous sockeye (Mullan 1986). A single remnant population of anadromous fish remains in Redfish Lake in the upper Salmon River Basin, Idaho. The number of adults returning to Redfish Lake has ranged from zero to eight fish since 1990, and that population is now federally listed as endangered (Bevan and others 1994). An intensive, captive brood-stock program has been initiated to conserve the remaining population.

The resident form, kokanee salmon, still appears to be widely distributed throughout the Columbia River Basin. All of the historic rearing lakes still support some kokanee salmon although eradication programs and subsequent reintroduction of other stocks may have eliminated most if not all of the native fish from several lakes within the Stanley Basin (Chapman and others 1990). Nonnative kokanee salmon have been widely introduced to lakes and reservoirs throughout the Columbia River Basin. These introduced populations are now far more widely distributed than native populations were historically (map 4.41 a and b). Introgressive hybridization may have compromised the genetic integrity of many populations but no study of such effects has been conducted.

Habitat Relationships

Sockeye salmon exhibit some of the more complex life history patterns among Pacific salmon in that they often rely on both stream and lake environments for early rearing (Burgner 1991). Adults often spawn in lake inlet streams but lake shoal and outlet spawning also occurs. Sockeye salmon in the Columbia River Basin are typically late summer/fall spawners. Juveniles emerge from the gravel the following spring and move into the lake for one to two years where they feed on zooplankton before migration. Kokanee salmon will continue to rear for a total of three to five years before maturing.

Within the two primary life histories, there is wide variation in spawning, rearing, and maturation timing, site selection and duration. The indigenous distribution of kokanee salmon coincides with that of the anadromous form; natural kokanee populations have probably developed repeatedly from anadromous populations and not through dispersal of kokanee from other systems (Foote and others 1989). Non-migratory progenies of anadromous fish are known as residuals (Burgner 1991) and are believed to represent the transitional link between the two dominant forms. Native kokanee salmon still persist throughout much if not most of the historic range and thus represent an important component of the original biological diversity within the assessment area. Residual sockeye and kokanee salmon may also have the potential to support or even refound anadromous forms should change in the available habitat and migratory corridors allow (Rieman and others 1994). Conservation of all remaining native stocks, therefore, should be considered important regardless of whether they currently support anadromous returns.

Key Factors Influencing Status

Much of the decline in anadromous sockeye salmon can be attributed to dams blocking access to spawning and rearing streams in the early 1900s and to increased mortality of migrants caused by dams in the migratory corridors of the Snake and Columbia rivers constructed in later years (Fulton 1970; Mullan 1986; Nehlsen 1995). Available lake rearing habitat has been reduced from approximately 86,880 surface hectares to 4,400 surface hectares (Mullan 1986). Numbers of spawning sockeye were also seriously reduced by commercial fisheries around the turn of the century. Although fishing was important historically, there is no longer any legal harvest in the Columbia Basin for anadromous sockeye except a small American Indian fishery in the Priest Rapids, Washington pool and a recreational harvest in Lake Wenatchee, Washington when escapement goals are met. Ocean conditions probably account for some of the variation in annual returns and may influence productivity of stocks over long periods. Forest management may influence the quality of spawning habitats and the productivity of lake environments. Sockeye salmon are likely susceptible to factors that may increase sediment in spawning gravel and scour of redds. Factors influencing rearing lake environments, such as accelerated eutrophication, could also be important. Ultimately, however, it is unlikely that any substantial recovery of historic anadromous populations will occur without major improvements in conditions in the migratory corridors.

Overall, kokanee and sockeye salmon appear to be in little danger of extinction throughout their range. However, individual stocks are susceptible to loss. The anadromous component of sockeye is near extinction in Idaho's Stanley Basin. The introduction of exotic fishes, fishing, and habitat condition may be important influences on the relative productivity and survival of those populations but, in general, most populations appear to be relatively abundant. The loss of genetic integrity in native stocks, however, may represent an important loss of biological integrity and could compromise the potential for long-term persistence of wild populations or the refounding of anadromous runs. A basic inventory of the integrity and status of native stocks would be useful.

Map 4.41a—Historical and current distribution plus introduced sites of sockeye salmon.

Map 4.41b—Historical spawning and rearing areas of sockeye salmon.

Chum Salmon (*Oncorhynchus keta*)

Chum salmon have the widest distribution of any of the Pacific salmon in North America. In the Columbia River Basin, chum salmon were abundant in lower river tributaries and the mainstem Columbia River, where they supported tribal, sport, and commercial fisheries. Populations had dwindled to a point of minor importance by the 1950s (Fulton 1970). Because several populations are on the verge of extinction, the species is an Oregon state sensitive species (ODFW 1990). The American Fisheries Society lists the chum salmon in the lower Columbia River as at moderate risk of extinction (Nehlsen and others 1991).

Distribution and Status

Chum salmon have spawned and reared in streams from the Sacramento River in California to the arctic shore of Alaska and eastward to the Mackenzie River on the arctic coast of Canada (Bakkala 1970). In the assessment area, most chum salmon spawned in the lower tributaries of the Columbia River below Bonneville Dam (map 4.42). Major wild production areas include Grays Basin and Hardy and Hamilton creeks in Washington (Howell and others 1985a). Chum salmon were also distributed above Bonneville Dam in the lower portions of tributaries upstream to the Umatilla River in Oregon and the Walla Walla River in Washington (Nelhsen and others 1991). Chum salmon are essentially extinct in the Columbia River Basin above Bonneville Dam. Former spawning areas above Bonneville Dam included lower portions of the Little White Salmon River; Hamilton, Rock, and Herman creeks; and areas along the margins of river banks in the main Columbia River (Fulton 1970). Chum salmon are currently found only in the lower sections of tributaries entering the Columbia River below Bonneville Dam (Howell and others 1985a). Historical commercial harvest ranged from 450,000 to 3.9 million kilograms, peaking in 1928 at about 700,000 fish (Chaney and Perry 1976). Since 1978, commercial harvest has not exceeded 2,000 fish (ODFW and WDF 1981).

Chum salmon have also experienced similar declines coast-wide. No significant hatchery production of chum salmon occurs in the Columbia River.

Habitat Relationships

Most chum salmon spawn within the lower reaches of streams and frequently within the tidal zone. In the Columbia River Basin, spawning usually occurred a short distance upstream from the head of tidewater, in margins of mainstem rivers, and at the mouths of lower tributary streams. Clean, abundant gravel in these areas is needed for successful spawning. Water temperatures for spawning range from 4° to 16° C (Neave 1966). Eggs hatch between about 1.5 and 4.5 months after fertilization. Survival from egg to fry stage is usually less than 10 percent (Bakkala 1970). Survival is related to flows and temperatures during incubation. The greatest cause of egg mortality is fluctuating streamflows, dislodged eggs from shifting gravels, and sediments deposited on and in gravels impeding intragravel flows. Unlike most other anadromous salmonids, chum salmon fry enter saltwater soon after emergence and form schools in estuaries.

Key Factors Influencing Status

Dramatic declines in run size can be attributed to siltation and stream blockages from logging activities and inundation of spawning areas following construction of Bonneville Dam (Fulton 1970). Poor condition of chum populations is attributed to their sensitivity to poor water quality primarily caused by habitat degradation and loss from forest and agricultural practices, urbanization, and pollution; incidental over-harvest in mainstem fisheries directed at coho and chinook salmon; and competition with hatchery fish in streams (Nehlsen and others 1991).

Map 4.42—Historical and current distribution of chum salmon.

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Coho Salmon (*Oncorhynchus kisutch*)

Coho salmon are native to coastal streams of western North America and range throughout temperate waters of the northern Pacific Ocean. Prior to the 1900s, naturally produced coho salmon were widespread in the Columbia River basin, with a historical center of abundance in the lower Columbia River (Fulton 1970). Coho salmon supported tribal, commercial, and sport fisheries. Now there are essentially no naturally spawning fish in the basin. Because their naturally spawning numbers are low throughout their range in California, Oregon, and Washington, coho salmon have been petitioned for listing under the Endangered Species Act and are now under status review by the National Marine Fisheries Service.

Distribution and Status

Early literature, reports, and accounts reveal some major historical production areas for coho salmon in the middle and upper Columbia and Snake rivers (map 4.43) (Fulton 1970; Mullan 1984). The Yakima, Wenatchee, and Methow rivers in the upper Columbia River and the Grande Ronde River system in the Snake River were major natural production areas (Fulton 1970; Mullan 1984). Fulton (1970) and Mullan (1984) also report some substantial runs in the Hood, John Day, Entiat, Okanogan, and Spokane rivers. Other reports appear to verify that historic coho runs in the Snake River also occurred in the Clearwater, Lochsa, Touchet, Tucannon, and Walla Walla rivers (Fulton 1970; Schoning 1947b).[1,2] In the Grande Ronde River, the Wenaha, Wallowa, Minam, and Lostine rivers, and Catherine Creek historically supported runs of coho salmon. Other accessible tributaries in the Columbia and Snake River systems with low gradients and sufficient water in September through November probably supported small runs of coho salmon. The longest distance coho salmon are known to have migrated in the Columbia River was to the Spokane River, about 1,125 kilometers from the ocean (Fulton 1970).

Chapman (1986) estimated the peak 5-year average of adult coho salmon that annually entered the Columbia River before 1900 was 618,000 fish, of which somewhere around 30 percent or upwards of 200,000 fish spawned in the middle and upper Columbia and Snake rivers (Mullan 1984). Wahle and Pearson (1987) indicated that less than 25,000 coho salmon were spawning naturally in the Columbia River Basin by the early 1980s. This number remained the same into the late 1980s (CBFWA 1990). Naturally spawning fish included feral hatchery fish that spawned in streams near hatcheries, returns from hatchery outplants to streams away from hatcheries, and naturally produced fish. Currently, natural coho salmon production (including hatchery spawning fish) in the Columbia River Basin above Bonneville Dam occurs in the Wind, Big White Salmon, Klickitat, Yakima, and Wenatchee rivers in Washington and the Hood, Deschutes and Grande Ronde rivers and Lindsey, Viento, Mosier, Chenowith and Mill creeks in Oregon (Johnson and others 1991). The current abundance is less than 6 percent of historic abundance (Johnson and others 1991).

The in-river harvest of Columbia River coho salmon reached a peak of about 880,000 fish in 1925 (Beiningen 1976). Thereafter, an almost-continuous decline in the fishery occurred until the 1960s, when a widespread hatchery enhancement program was initiated. Since the 1960s, the vast majority of coho salmon returning to the Columbia River have been of hatchery origin (CBFWA 1990).

Habitat Relationships

Habitat requirements for coho salmon were reviewed by Bjornn and Reiser (1991). Coho salmon migrate upstream at water temperatures ranging from 7.2° to 15.6° C. Spawning and egg incubation occur at water temperatures from 4° to 13° C. Adults spawn in as sorted gravels. After

[1]Also, personal communication. 1995. Stacy Gebhards, Idaho Department of Fish and Game, Boise, Idaho.

[2]Also, personal communication. 1995. Chuck Huntington, Clearwater BioStudies, Inc., Portland, Oregon.

emergence, coho fry move into available rearing space, especially areas with lower velocities, such as stream margins and off-channel habitat. As fry grow, they rear in deeper pool habitats. Preferred summer water temperatures for rearing are 12° to 14° C, with upper lethal temperatures near 26.0° C. During winter rearing, young coho salmon seek areas with more cover, such as woody debris, root wads, and overhanging vegetation and lower velocity areas such as side channels, sloughs, and beaver ponds.

Key Factors Influencing Status

Human activities have profoundly influenced the past and present status of coho salmon in the mid and upper Columbia and Snake River systems. These activities have resulted in lost spawning and rearing habitat, migration delays, passage mortality, predation, diseases, water pollution, genetic introgression, and overfishing (Horner and Bjornn 1981). Habitat degradation has resulted from water withdrawals for irrigation, increased water temperatures caused by removal of riparian vegetation, and excessive sediment and simplification of stream channels from accelerated land use activities. The National Marine Fisheries Service has essentially determined that mid and upper Columbia and Snake River wild stocks of coho salmon are below levels necessary for long-term survival (Johnson and others 1991). Commercial exploitation, dams, and degradation of spawning and rearing habitat, beginning around the 1890s, dramatically reduced natural spawning populations and resulted in extirpations in much of the historical range. All middle and upper Columbia River and Snake River runs were drastically reduced or destroyed by construction of impassable mill dams, unscreened irrigation diversions, habitat loss, and over-harvest, prior to completion of the Grand Coulee Dam in 1941 (Mullan 1984). However, the advent of extensive artificial propagation in hatcheries "rebuilt" some runs to or above historic levels. In the process, coho salmon runs once dominated by naturally spawning fish have changed to predominately hatchery-maintained runs.

Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*)

Historically abundant and widespread, the coastal cutthroat trout is particularly sensitive to environmental disturbance and is now in decline throughout its historic range (Trotter 1989). The coastal cutthroat trout includes both anadromous and resident forms that support popular sport fisheries.

The American Fisheries Society identified all remaining populations of coastal cutthroat trout in the Columbia River as at high risk of extirpation (Nehlsen and others 1991). In July 1994, the National Marine Fisheries Service proposed to list the coastal cutthroat trout in the Umpqua Basin, Oregon as threatened. Listing was finalized in August 1996. Also in Oregon, it is listed as a state critical species by the Oregon Department of Fish and Wildlife and a sensitive species by the BLM.

Distribution and Status

Coastal cutthroat trout are distributed along the Pacific Coast from northern California's Eel River to Gore Point, Kenai Peninsula, Alaska (Behnke 1979). In Oregon and Washington, they extend to the east slopes of the Cascade Mountains and in British Columbia and Alaska to the crest of the coast range. Their distribution rarely extends inland more than 160 kilometers. This geographical pattern corresponds closely with the distribution of the coastal rain forest belt in the Pacific Northwest. In Oregon, coastal cutthroat trout are distributed in almost all rivers from the Winchuck River north into the Columbia River system (map 4.44). In the Columbia River Basin, coastal cutthroat trout resided in tributaries east to Fifteenmile Creek in Oregon and Rock Creek in Washington, including the Willamette Basin to its headwaters. The abundance of sea-run cutthroat trout in the lower Columbia Basin appears to have significantly declined in recent years. Although these populations are not routinely monitored, angler surveys have shown decreases from catches of around 5,000 fish in the 1970s to catches as low

Map 4.43—Historical and current distribution of coho salmon.

Map 4.44—Historical and current distribution plus introduced sites of coastal cutthroat trout.

as 50 in the 1980s. Effective as of 1994, all wild cutthroat trout caught in the Columbia River by anglers must be released unharmed.

Sea-run cutthroat trout are believed to be extirpated in the Wind and Klickitat rivers of Washington. The stocks in the Hood River of Oregon and Rock Creek in Washington are listed as at high risk of extinction. All populations in small tributaries in the lower Columbia Basin below Bonneville Dam are identified as at moderate risk of extirpation (Nehlsen and others 1991). Both anadromous and resident coastal cutthroat trout are present in the mainstem Hood River and its tributaries, including the East Fork. In the Fifteenmile Creek drainage, cutthroat trout are known to be present in Fivemile Creek and are thought to be present in Eightmile Creek.

Habitat Relationships

Coastal cutthroat trout exhibit diverse patterns in life history and migration. Populations of coastal cutthroat trout show marked differences in their preferred rearing environments (river, lake, estuary, or ocean), size and age at migration, timing of migrations, age at maturity, and frequency of repeat spawning. Four distinct life history patterns have been described for the subspecies: anadromous (sea-run) populations migrate to the ocean or estuary for usually less than a year before returning to freshwater; fluvial populations undergo in-river migrations between small spawning tributaries and main river sections downstream; adfluvial populations migrate between spawning tributaries and lakes or reservoirs; and nonmigratory (resident) forms occur in small headwater streams and exhibit little instream movement.

Spawning occurs in riffles 15 to 45 centimeters deep in pea-sized, clean gravel in low gradient stream reaches. Spawning sites are located near or in shallow areas of deep pools close to escape cover (Hunter 1973). Newly emerged fry move into low-velocity stream margins, backwaters, and side-channels adjacent to main channel pools and riffles (Moore and Gregory 1988). Selection of small tributaries for spawning and first-year rearing serves to isolate sea-run cutthroat trout and minimize their interactions with other salmonids.

There is evidence of negative interactions among juvenile cutthroat trout, coho salmon, and steelhead during this life history stage (Bisson and others 1988; Glova 1984, 1986) which may limit sea-run cutthroat trout population size. Generally in spring, young fish move downstream into mainstem rivers and, with the onset of winter freshets, often move back upstream into smaller tributaries. In the Columbia River, smolts remain in a large estuary during their first migration. The Columbia River plume provides a large, near-shore area for feeding in the ocean. Some sea-run cutthroat trout overwinter in salt water, but most return to freshwater in the same year they migrate (Johnston 1981).

Resident cutthroat trout are primarily drift feeders and reside at the head of pools (Wilzbach and Hall 1985). In forested streams, large woody debris creates productive habitat by forming pools, meanders, secondary channels, and undercut banks (Bisson and others 1987). Pools formed by large wood support more and older resident cutthroat trout, and also provide winter refugia during high flows (House 1995).

Campton (1981) and Campton and Utter (1987) found genetic differences among coastal cutthroat trout stocks at four locations in Washington. If this genetic variation holds true throughout the subspecies range, then the total subspecies gene pool could be composed of literally hundreds of genetically distinct breeding units (Trotter and others 1993).

Key Factors Influencing Status

There are three main factors that contribute to coastal cutthroat trout declines (Trotter and others 1993): present or potential destruction, modification, or blockage of habitat by logging, urban and rural development, or mainstem passage; overharvest from recreational fishing; and negative interactions with hatchery stocks and/or introduced species.

Lahontan Cutthroat Trout (*Oncorhynchus clarki henshawi*)

The Lahontan cutthroat trout is native to the Pleistocene Lake Lahontan Basin of northwestern Nevada, northeastern California, and a small adjacent portion of southeastern Oregon. This subspecies is federally listed as threatened pursuant to the Endangered Species Act throughout its native range. It has been introduced elsewhere in southeastern Oregon and eastern Washington.

Distribution and Status

Lahontan cutthroat trout are native to the McDermitt Creek drainage, a Quinn River tributary of the larger Lahontan Basin, in southeastern Oregon (map 4.45). In 1991, genetic analyses of cutthroat trout in Willow and Whitehorse creeks, also in southeastern Oregon, found the inhabitants to be genetically indistinguishable from *O. c. henshawi* (Williams 1991). During the 1970s, trout from Willow and Whitehorse creeks were introduced into Denio, Van Horn, Pike, Mosquito, Little McCoy, Big Alvord, Little Alvord, Cottonwood, and Willow creeks in the adjacent Alvord Basin. Surveys conducted in 1991 confirmed that Lahontan cutthroat trout still persist in many Alvord Basin streams.[3] Trout from Willow and Whitehorse creeks were also introduced into Guano Creek in 1957 (Hanson and others 1993). Lahontan cutthroat trout also have been introduced into Oregon's Mann Lake although recent information questions their genetic purity.[4] In addition, the Washington Department of Fisheries has widely introduced Lahontan cutthroat trout into eastern Washington.

[3]Personal communication. 1995. Wayne Bowers, Oregon Department of Fish and Wildlife, Hines, Oregon. Personal communication of unpublished data.

[4]Personal communication. 1995. Ron Wiley, Bureau of Land Management, Portland, Oregon.

Habitat Relationships

Optimal riverine habitat for Lahontan cutthroat trout is characterized as clear, cold water with an average maximum summer temperature of less than 22° C; an approximate 1-to-1 pool:riffle ratio; well-vegetated, stable stream banks; at least 25 percent of the stream area providing cover; a relatively stable water flow regime; and a relatively silt-free rocky substrate in riffle-run areas (USFWS 1993a).

Key Factors Influencing Status

Habitat degradation, especially loss of riparian vegetation, is identified as a key factor in declining Oregon stream populations. Loss of vegetation has resulted in stream temperatures that have far exceeded those considered optimal for the subspecies. Dissolved oxygen levels in such reaches are too low. Drought conditions coupled with extremely low temperatures during winter have caused stream segments to freeze completely. Loss of vegetation has resulted in the loss of forage organisms and cover (Hanson and others 1993). Excessive turbidity and sedimentation also contribute to habitat degradation problems because of their effects on food production, spawning areas, and feeding ability (Hanson and others 1993). Water diversions and the introductions of non-native salmonids are also key factors. Because native populations of Lahontan cutthroat trout in southeastern Oregon are naturally small and isolated, they are at risk. Many introduced populations are especially vulnerable because the number of founding fish was less than 30.

Map 4.45—Historical and current distribution plus introduced sites of Lahontan cutthroat trout.

Sunapee Char (*Salvelinus alpinus oquassa*)

The Sunapee char, a landlocked Arctic char endemic to Sunapee Lake, New Hampshire, was extirpated from New Hampshire in the mid-1900s as a result of competition with introduced species (Kircheis and others 1995). In 1925, prior to extirpation from Sunapee Lake, Sunapee char were introduced into two high elevation and fishless lakes in Idaho's Sawtooth Mountain Range (Kircheis and others 1995) where they established reproducing populations. The fish stocked in Idaho were not "rediscovered" until 1978 (IDFG 1991). To help protect the taxon, no further information on the location of introduction sites is provided.

The American Fisheries Society listed the Sunapee char and blueback trout (a phenotypically distinct form endemic to Maine) as threatened (Williams and others 1989). Because the subspecies is introduced, Idaho does not list it as a state species of special concern. However, protection of the fish and its habitat is suggested as a priority because of its unique genotype (IDFG 1991).

Sunapee char differ from other North American lacustrine char in their unique coloration, large size, and use of a mid-lake spawning shoal (Kircheis and others 1995). Kircheis and others (1995) recently examined the genetic identity of 17 Sunapee char collected from one Idaho lake. The samples displayed four haplotypes, three of them uniquely divergent from other landlocked arctic char and the other similar to a blueback char haplotype. The authors reported that the divergent portion of the Idaho char population represented a distinct, native population formerly in Sunapee Lake. Despite the unique haplotype, Kircheis and others (1995) recommended against using Idaho arctic char to restock New Hampshire waters because of the potential for dilution of the gene pool by brook trout, which were stocked in the Idaho lakes in the 1940s. The authors, however, presented no data assessing the degree of introgression with brook trout.

Pygmy Whitefish (*Prosopium coulteri*)

The pygmy whitefish may have been widely distributed across North America during the last ice age, however, once the glaciers receded only isolated populations remained. Little is known about the species in the southern range of its distribution, including Washington, Idaho, and Montana. The pygmy whitefish is listed as a Washington state monitor species.

Distribution and Status

The pygmy whitefish has a discontinuous distribution in the Columbia River system. No reports have found this species to be present below Grande Coulee Dam on the Columbia River (map 4.46). In Montana, the pygmy whitefish is found in Bull Lake and Lake MacDonald and their tributaries, Flathead, Little Bitterroot, Ashley, Swan and Seeley lakes and Hungry Horse Reservoir. In Washington, the fish has been reported in Diamond Lake near Spokane and Lake Roosevelt. In Idaho, the pygmy whitefish occurs in Lake Pend Oreille and Priest Lake. No estimates of abundance are available.

Habitat Relationships

The pygmy whitefish inhabits lakes and cold streams. All reported data are from lakes. In Canada, fish were found in depths ranging from 4.6 to 36.6 meters (McCart 1963). The upper limit may coincide with the depth of the warmer epilimnial water. Shallower distributions in some lakes may be the result of low dissolved oxygen levels on the bottom (McCart 1963). There is no evidence of horizontal or vertical movements or change in depth distribution in pygmy whitefish with seasonal changes (Scott and Crossman 1973).

Key Factors Influencing Status

Little is known about the distribution and abundance of the species or its ecology. One factor that may influence species abundance is chemical treatment of lakes. Increased eutrophication of lake environments, through nutrient additions from increased human development and sediment input from watershed practices, could negatively influence the species persistence. Lack of information on species distribution, abundance, and ecology at the southern edge of its range leads to a cautionary approach. If pygmy whitefish are isolated to a few lakes in the Columbia River Basin, species persistence is at risk.

Burbot (*Lota lota*)

The burbot, a freshwater member of the cod family and a popular sport fish, has a holarctic distribution that includes Alaska, much of Canada, and the northern portion of the United States from the Columbia River Basin to Maine (Scott and Crossman 1973). Within the assessment area, they are native to the Kootenai and Columbia rivers, and scattered deep lakes of eastern Washington, which represent the southern extent of their distribution in the Pacific Northwest. Burbot in the Kootenai River, Idaho, are listed as threatened by the State and as sensitive by Region 1 of the Forest Service.

Distribution and Status

In Washington, Wydoski and Whitney (1979) reported burbot from the Columbia River and deep lakes in the Columbia River Basin, including Kachess, Keechelus, Banks, and Cle Elum (map 4.47). In Idaho and the Columbia River drainage of Montana, burbot are native only to the Kootenai River system, where they provided a popular winter game fishery until numbers began to decline in 1965 (Simpson and Wallace 1978). According to the Idaho Chapter of the American Fisheries Society (IDAFS 1995), Idaho Fish and Game personnel could fill trap nets set for burbot and individual anglers could catch up to 50 per night during the 1950s. Traditional Idaho spawning tributaries included Deep, Snow, Caribou, Parker, Smith, Mission, Boundary, and Myrtle creeks. Stocking of burbot in Clark Fork River, Montana, has resulted in introduced populations in the Clark Fork drainage of Idaho and Montana as well as in Lake Pend Oreille.

Habitat Relationships

Burbot prefer clear, cold water (15.6° to 18.3° C) lakes or large rivers. In summer, they move into deeper pools or hypolimnion areas of lakes. Spawning occurs in midwinter, typically in water between 0.6° and 1.7° C. Young burbot may occur in shallow areas of lakes, large rivers, or smaller cold water streams. As burbot increase in size, they prefer deeper water and become nocturnal.

Key Factors Influencing Status

Populations of burbot in the Kootenai River dropped precipitously in numbers following completion of Libby Dam in Montana and associated changes in the river's hydrograph (IDAFS 1995). In the Pacific Northwest, dam construction typically leads to collapse of burbot populations below the dams, although populations may persist in the reservoirs. Impoundments and changes in river hydrographs appear to disrupt historic spawning patterns and result in reduced recruitment (IDAFS 1995). Most burbot populations in the Columbia River drainage suffer from reduced recruitment, low population densities, and fragmented populations.

Sand Roller (*Percopsis transmontana*)

The sand roller is an uncommon, poorly understood species that is endemic to larger rivers of the Columbia River system. It is a species of special concern in Idaho, and a monitor species in Washington.

Distribution and Status

Historic distribution has not been fully documented but sand roller were known to occur from the Columbia River at Horseshoe Island Slough (about 40 kilometers from the mouth of the Columbia River) upstream to West Bar south of Wenatchee on the Columbia River and in the Snake River to the

lower Clearwater River in Idaho (map 4.48) (Gray and Dauble 1979). The sand roller is currently uncommon throughout its range. Within its historic range in the assessment area, it occurs in the Yakima River upstream to Ellensburg and the Umatilla and Walla Walla rivers (Pratt and Whitt 1952). It is unlikely that the fish presently occurs in Idaho. Because of its seclusive behavior during the day, the sand roller is a difficult species to sample and may be more abundant than it appears. Little information is available to assess its current range and population size.

Habitat Relationships

Sand rollers seem to prefer large rivers in areas with low water velocities. Because of their seclusive nature, large numbers of sand rollers have only been observed when they enter shallow open waters to feed at night. During the day, they inhabit quiet areas near exposed roots and undercut banks with depths greater than 15 meters.

Key Factors Influencing Status

Several non-native predators now occupy waters in the historic and current ranges. Walleye, smallmouth bass, channel catfish, and native squawfish are known to prey on sand rollers. For instance, sand rollers were found to be the primary food of walleyes between 350 and 550 millimeters in length (Poe and others 1991). Alterations of larger rivers may degrade habitat preferred by the native species.

Northern Roach (*Hesperoleucus symmetricus mitrulus*)

The northern roach is native to Oregon and California and was classified as a subspecies of the California roach in 1948 (Murphy 1948). The California roach occurs in the Sacramento River Basin (Moyle 1976). The northern roach is currently listed as sensitive by the BLM and as sensitive (peripheral/rare) in Oregon.

Distribution and Status

Historically, the northern roach was found in the upper Pit River system and tributaries to Goose Lake (map 4.49) (Moyle 1976). In the Goose Lake Basin, the fish was known only from tributaries in the Oregon side, although the actual extent of their historic distribution is poorly known. They were known to occur in Cottonwood, Drews, and Muddy creeks and were thought to be introduced in Deep and Mud creeks in the Warner Valley (ODFW 1992). Outside the Goose Lake Basin, the distribution of the northern roach has been reduced in the Pit River system (Moyle and Daniels 1982). Surveys conducted in 1983 and 1988 revealed a limited distribution of the northern roach, with populations still occurring in Thomas and Dent creeks and possibly Cottonwood Creek.[5] Northern roach have also been introduced as bait fish into Summer and Harney lakes and tributaries of the Chewaucan River (Bills 1977). The northern roach was abundant in Spring Creek, tributary to Cottonwood Creek, but is rare in other areas. Presently, populations are considered stable (ODFW 1992).

Habitat Relationships

Northern roach are generally found in small, intermittent streams with silty bottoms and containing frequent isolated pools. Water temperatures ranged from 5.5° C in March to 29° C in July. Spawning occurs from March to June (Moyle 1976). Fry remain in interstitial spaces until they are free-swimming and then move into shallow areas with moderate flow and gravel or rubble substrate.

Key Factors Influencing Status

Northern roach in the Goose Lake Basin are very rare. Their rarity and apparent lack of use of the lake limit their ability to recolonize extirpated streams. Conditions that would negatively affect existing stream populations include loss of surface water during extreme drought, timing of water diversions, construction of reservoirs, and introduction of non-native fishes.

[5]Personal communication. 1995. Jack Williams, Bureau of Land Management, Boise, Idaho. Personal communication of unpublished data.

Map 4.46—Historical and current distribution of pygmy whitefish.

Map 4.47—Historical and current distribution plus introduced sites of burbot.

Map 4.48—Historical and current distribution of sand roller.

Map 4.49—Historical and current distribution of northern roach.

Alvord Chub (*Gila alvordensis*)

Alvord chub are endemic to the Alvord Basin of southeastern Oregon and northwestern Nevada. The American Fisheries Society considers the Alvord chub to be a species of special concern (Williams and others 1989).

Distribution and Status

The Alvord chub was described in 1972 based on specimens collected from Trout Creek in the Alvord Basin, Harney County, Oregon (Hubbs and Miller 1972). The species is restricted to the Alvord Basin of southeastern Oregon and northwestern Nevada, where it is widely distributed within springs, creeks, and lakes (map 4.50). Williams and Bond (1983) reported Alvord chubs from 16 localities within the basin, including Serrano Pond, Trout Creek, Alvord Lake, and Pueblo Slough in Oregon, as well as Bog Hot Creek, Bog Hot Reservoir, Thousand Creek Spring, Thousand Creek, Continental Lake, Warm Spring, Dufurrena Ponds, Gridley Springs, and West Spring in Nevada. The Alvord chub may be absent from the pluvial lake remnants of Alvord and Continental lakes during drier years. The current distribution of this species has apparently changed little during the past 100 years except for a recent report of Alvord chubs in Juniper Lake, Oregon (Bond 1974), where they were introduced and subsequently disappeared, and the extirpation of the Alvord chub population from Thousand Creek Spring.

Habitat Relationships

Within the Alvord Basin, the Alvord chub occurs in a wide variety of available habitats such as isolated springs, cool- and warm-water creeks, reservoirs, and lakes. Within the principal creek systems in the Alvord Basin, Trout Creek in Oregon and the Thousand-Virgin Creek system in Nevada, chubs occur commonly in the mid and lower elevation sections, but are rare or absent entirely from high elevations. Within spring systems, the Alvord chub occupies a variety of spring habitats except springs with water temperatures above 31°C. Alvord chubs are absent from Bog Hot Springs, which is fishless, and from Borax Lake, which is occupied by the Borax Lake chub (*G. boraxobius*).

Key Factors Influencing Status

Alvord chubs appear capable of occupying a wide range of habitat conditions as long as relatively clean water persists that is free of introduced species. The Alvord chub has been eliminated from Thousand Creek Spring because of the presence of introduced guppies (*Poecilia reticulata*). Alvord chubs are absent from some ponds at Dufurrena, which are dominated by introduced centrarchids (Williams and Bond 1983). Introductions of non-native fish and diversion of stream flows pose the greatest immediate risk to populations. Maintenance of the integrity of aquifers that feed surface waters in the Alvord Basin is critical to the long-term persistence of this species.

Borax Lake Chub (*Gila boraxobius*)

The Borax Lake chub is a small cyprinid fish restricted to the Borax Lake ecosystem of southeastern Oregon. Because of its restricted distribution and threats to its remaining habitat, it is listed as an endangered species by the U.S. Fish and Wildlife Service and State of Oregon.

Distribution and Status

This species is known only from Borax Lake and associated waters in Harney County, Oregon (map 4.51). The Borax Lake chub is a sister taxon of the Alvord chub (*Gila alvordensis*) from which it became isolated as the waters of pluvial Lake Alvord receded (Hubbs and Miller 1972; Williams and Bond 1980). The Borax Lake chub occurs in Borax Lake, its associated outflows including Lower Borax Lake, surrounding marsh, and pools.

Map 4.50—Historical and current distribution of Alvord chub.

Map 4.51—Historical and current distribution of Borax Lake chub.

From 1986 to 1988, population estimates for the Borax Lake chub ranged from 3,934 to 13,319 depending on the year and season (Williams 1995).[6,7] Based on water conditions, hundreds of chubs also may occur in outflow creeks and, during wet years, up to a few thousand also may occur in Lower Borax Lake.[6,7]

Habitat Relationships

The Borax Lake chub is restricted to the thermal waters of Borax Lake and its outflows. Waters flow out from the elevated rim of Borax Lake in many directions, but more typically to the southwest, where they enter a marsh and then flow into Lower Borax Lake (a reservoir). Reproduction is limited to Borax Lake; Borax Lake chubs in other habitats gain access through interconnected outflows and marshes. In Borax Lake, the species occurs throughout the lake except in hot spring inflows, where temperatures exceed approximately 34° C.

Key Factors Influencing Status

Threats of geothermal energy exploration and manipulation of surface flows from Borax Lake were the primary factors that resulted in the 1980 listing of the species by emergency provision under the Endangered Species Act. Changes in thermal flows that enter the lake could cause slight temperature increases or decreases that would be detrimental to the species. Alterations in surface flows from Borax Lake could isolate subpopulations adjacent to the lake causing their desiccation. Because of the restricted size of the lake, threats also exist from introductions of chemicals or nonnative species. Protection of the fragile salt crusts that maintain water level at Borax Lake is also critical (USFWS 1987). Livestock grazing and physical damage from off road vehicles and humans are the primary risks to shoreline salt crusts. The species is also at risk because of its highly restricted range and specialized habitats.

[6]Also, personal communication. 1995. Jack Williams, Bureau of Land Management, Boise, Idaho. Personal communication of unpublished data.

[7]Also, The Nature Conservancy. 1995. Unpublished data. Portland, OR: The Nature Conservancy.

Catlow Tui Chub (*Gila bicolor* ssp.)

Catlow tui chub are endemic to the Catlow Valley of southeastern Oregon. Because of their restricted distributions and threats to remaining habitat, the subspecies is considered of special concern by the American Fisheries Society (Williams and others 1989).

Distribution and Status

Historically, Catlow tui chubs occurred in three streams (Threemile, Skull, and Home creeks) that drain the west flank of the Catlow Rim and in Rock Creek along the western edge of Catlow Valley (map 4.52) (Bills 1977; Kunkel 1976). The Catlow tui chub has a restricted range, but appears to be locally abundant in streams and in Threemile Reservoir. An exception is Rock Creek, where only a few were found in 1994.[8]

Habitat Relationships

Little is known about the habitat relationships of the Catlow tui chub. Their preference for low gradient reaches of Skull, Threemile, and Home creeks suggests an affinity for low velocity habitats, which is typical of most tui chubs. They also appear to be well-adapted to Threemile Reservoir, at the downstream end of Threemile Creek. Catlow tui chubs occur in streams occupied by redband trout (Kunkel 1976).

Key Factors Influencing Status

Diversions of creek flows for irrigation reduce Catlow tui chub habitat. The low gradient reaches that it prefers are also subject to degradation from livestock overgrazing. Because of the Catlow tui chub's restricted distribution, disturbances such as drought or fire and human land use practices place populations at risk.

[8]Oregon Department of Fish and Wildlife. 1995. Unpublished data. Hines, OR: Oregon Department of Fish and Wildlife.

Map 4.52—Historical and current distribution of Catlow tui chub.

Continue

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Oregon Lakes Tui Chub (*Gila bicolor oregonensis*)

The Oregon Lakes tui chub, as defined here, is endemic to the Abert Lake Basin of south-central Oregon (Bills 1977). Remaining populations are classified by the State of Oregon as vulnerable. The American Fisheries Society lists the Oregon Lakes tui chub as a species of special concern (Williams and others 1989), although they use the common name XL Spring tui chub for this form.

Distribution and Status

The Oregon Lakes tui chub complex, as originally described by Snyder (1908), consisted of tui chub populations in five isolated basins of south-central Oregon: Silver, Summer, Abert, Alkali, and Warner. The pioneering work of Bills (1977) demonstrated that morphological divergence had occurred among these long-isolated populations and he recognized that the complex of tui chubs actually consists of four subspecies. Only populations in the Abert Lake Basin are retained in *Gila bicolor oregonensis*. They occur in XL Spring to the north of Abert Lake and in the Chewaucan River (map 4.53). Abert Lake is, in general, fishless but records of chubs exist, presumably in areas of spring or river inflow (Snyder 1908). No changes between historic and current distributions are known although the Abert Lake Basin has not been adequately sampled.

Habitat Relationships

In general, tui chubs occupy a wide variety of habitats (Moyle 1976). In the Abert Lake Basin, the Oregon Lakes tui chub inhabits springs, rivers, and ditches. The Oregon Lakes tui chub is absent from higher gradient portions of the Chewaucan River system.

Key Factors Influencing Status

Agricultural practices, including ditching and diverting stream flows as well as livestock grazing, are the principal factors influencing the distribution and abundance of this subspecies. No recent surveys of habitats occupied by the Oregon Lakes tui chub are known. Thus, any additional, recent factors influencing its status are unknown. The introduction of non-native fishes also threatens the continued existence of this subspecies. The type locality population, at XL Spring, is particularly vulnerable to loss because of its restricted habitat.

Summer Basin Tui Chub (*Gila bicolor* spp.)

The Summer Basin tui chub is endemic to springs and outflows in the Summer Basin of south-central Oregon. The form was considered of uncertain taxonomic status and possibly extinct by Bills (1977) during a thorough review of the Oregon tui chub complex in southern Oregon. Summer Basin tui chubs were rediscovered in 1985. This subspecies is listed as a C1 Candidate by the U.S. Fish and Wildlife Service and as endangered by the American Fisheries Society (Williams and others 1989).

Distribution and Status

Historically, the Summer Basin tui chub occurred at various localities within Summer Basin, including springs at the Summer Lake Post Office, Ana River, and source springs of the Ana River (map 4.54) (Snyder 1908). Collections in these localities during the 1960s and 1970s indicated divergence from the form that was native to the Summer Basin, a result of numerous applications of fish toxicants and transplants of chubs from adjacent basins (Bills 1977). The native form was considered extinct until rediscovered from a small, previously unsampled spring system on the west side of the Summer Lake bed in 1985.[9] The subspecies now occupies a small portion of its historic range.

Habitat Relationships

Habitat relationships are poorly known because habitats in the Summer Basin have been greatly modified and the fish were eliminated from much

[9]Personal communication. 1995. C.E. Bond and J.E. Williams, Oregon State University, Corvallis, Oregon. Personal communication of unpublished data.

Map 4.53—Historical and current distribution of Oregon Lakes tui chub.

Map 4.54—Historical and current distribution of Summer Basin tui chub.

of its range prior to surveys. Historically, the Summer Basin tui chub appears to have occurred in a variety of spring and creek systems in the basin.

Key Factors Influencing Status

Fishes in Ana Springs, its outflow and associated reservoir have been repeatedly poisoned to rid the area of nongame fish in favor of game species. Such efforts along with subsequent transplants of tui chubs from adjacent basins apparently eliminated the native tui chub from the Ana River system. Additional transplants of non-native fishes appear to have eliminated the native form from springs and ditches in the Post Office area. The remaining population occurs in small, isolated springs in the southern portion of Summer Basin. During brief surveys in 1985, habitats of the remaining population were threatened by livestock grazing and water diversions. It is uncertain whether the subspecies continues to persist in its restricted habitat. Primary threats include habitat degradation by livestock, water diversions, and introductions of non-native species. Drought, fire, and other disturbances also could threaten this subspecies.

Sheldon Tui Chub (*Gila bicolor eurysoma*)

The Sheldon tui chub was described from specimens collected from Fish Creek, Washoe County, Nevada (Williams and Bond 1981). This subspecies, which occurs sporadically in the mostly arid Guano Basin of southeastern Oregon and northwestern Nevada, is listed as a species of special concern by the American Fisheries Society (Williams and others 1989).

Distribution and Status

The Sheldon tui chub is restricted to isolated waters of the Guano Basin of southeastern Oregon and northwestern Nevada (map 4.55). Within Guano Basin, the subspecies has been reported from Fish Creek on the Sheldon National Wildlife Refuge, Washoe County in Nevada, and Piute and Guano creeks, Lake County in Oregon (Hubbs and Miller 1948, Williams and Bond 1981). Sheldon tui chubs apparently are extremely rare in Guano Creek and have only been collected there twice.[10]

Habitat Relationships

The Sheldon tui chub occurs in those portions of Fish and Piute creeks described as small, turbid desert streams with abundant aquatic and riparian vegetation. During drought years, the chubs may be restricted to isolated pools in intermittent stream sections. The Sheldon tui chub typically is absent from downstream reaches, which often dry during summer months. When water is abundant, chubs also may occur in terminal lakes and reservoirs of these streams as suggested by the discovery of skeletal remains of Sheldon tui chub in Swan Lake Reservoir, which is the terminal water body on Fish Creek (Williams and Bond 1981).

Key Factors Influencing Status

All streams where the Sheldon tui chub occur could be described as "marginal" in reference to their small and often intermittent nature. Grazing by livestock apparently has limited the amount of available habitat by reducing riparian vegetation and limiting soil water retention, which leads to drying of additional stream segments during summer and autumn (Williams and Bond 1981). Reductions in stream flow due to overgrazing and water diversion appear to be the primary threat to this subspecies. Because of the species restricted range and small habitat size, such factors will exacerbate risks associated with environmental stochasticity, such as drought. Although introduced fish have not been documented from water inhabited by the Sheldon tui chub, any introductions could be detrimental to this subspecies.

[10]Personal communication. 1995. J. Williams, Bureau of Land Management, Boise, Idaho. Personal communication of unpublished data.

Hutton Tui Chub (*Gila bicolor* spp.)

The Hutton tui chub, collected as early as 1908, has been found in only two surface flow areas of Hutton Spring, Oregon. The Hutton tui chub was listed as threatened in 1985 by the U.S. Fish and Wildlife Service. It is also considered threatened by the American Fisheries Society (Williams and others 1989).

Distribution and Status

Hutton tui chubs still inhabit their historical locations (map 4.56). The subspecies is restricted to Hutton Spring and a small nearby spring in the Alkali Lake Basin of south-central Oregon (Bills 1977). In 1977, population estimates were 300 at Hutton Spring and 150 at the unnamed spring.

Habitat Relationships

The Hutton tui chub lives its entire life in spring habitats. Little is known about their habitat requirements, with the exception that dense aquatic vegetation is needed for spawning and rearing of young.

Key Factors Influencing Status

The habitat of the Hutton tui chub, along with that of the Foskett speckled dace, are the most restricted of any fish in the assessment area. Because of their limited distribution and small population size, Hutton tui chubs are at risk. A hazardous waste dump at Alkali Lake threatens to contaminate surface floodwater, groundwater, and air at Hutton Spring. Persistence of the Hutton tui chub is threatened by catastrophic events to spring sources, pollution from toxic chemicals, vandalism, introduction of non-native species, and no natural sources of recolonization.

Leatherside Chub (*Gila copei*)

The native range of the leatherside chub in Utah and Wyoming consists of the eastern and southern parts of the Bonneville Basin in rivers draining into the Great Salt Lake. In Idaho, the species is presumed to occur naturally as a result of pluvial discharges from the Bonneville Basin into the Snake Basin. Its current distribution in Idaho may, in part, also be due to its release as a bait fish. The leatherside chub is presently listed by the BLM as a sensitive species, and by the Idaho Department of Fish and Game as a species of special concern, Category C undetermined status.

Distribution and Status

In 1934, Carl Hubbs made the first reported collection of leatherside chub in Idaho.[11] The leatherside chub was collected in the 1970s in the Raft River and Goose Creek tributaries of the Snake River and the Little Wood River, all in Idaho (map 4.57).[12] In 1995, leatherside chubs were collected from Trapper, Goose, and Beaver Dam creeks, all part of the Goose Creek drainage near the Nevada-Utah border.[13] Otherwise, because of a lack of surveys, their current status is unknown.

Habitat Relationships

Little is known about the habitat requirements of leatherside chub. They typically occur in cool to cold creeks and rivers, with adults residing in pools and riffles and young inhabiting brushy, quiet pockets near the shoreline. Water quality ranges from clear to occasionally turbid. Leatherside chub are typically found associated with gravel substrate, but they also use all substrate sizes.

Key Factors Influencing Status

The most significant threat to the leatherside chub is loss of habitat caused by development of irrigation projects in the 1930s. However, habitat losses have and continue to occur from overgrazing of livestock, mining, timber harvest, and road construction.[14] Predation and competitive interactions from the stocking of exotic game species may also affect leatherside chub populations. However, the threat from these introductions is not known.

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[11]University of Michigan Museum of Zoology. 1995. Unpublished collection records.

[12]Personal communication. 1995. F. Partridge, Idaho Department of Fish and Game, Jerome, Idaho.

[13]Personal communication. 1995. B. Horton, Idaho Department of Fish and Game, Boise, Idaho.

[14]Personal communication. 1995. F. Partridge, Idaho Department of Fish and Game, Jerome, Idaho.

Map 4.55—Historical and current distribution of Sheldon tui chub.

Map 4.56—Historical and current distribution of Hutton tui chub.

Map 4.57—Historical and current distribution of leatherside chub.

Foskett Speckled Dace (*Rhinichthys osculus* spp.)

The Foskett speckled dace is an undescribed subspecies restricted to springs in the Coleman Valley of southeastern Oregon. The dace is federally listed as threatened and as vulnerable by the State of Oregon. The American Fisheries Society also lists the Foskett speckled dace as threatened (Williams and others 1989).

Distribution and Status

The Foskett speckled dace historically was known only from Foskett Spring, located along the west side of Coleman Lake bed in Lake County, Oregon (map 4.58) (Bond 1974). Coleman Lake is dry except during years of exceptional rainfall. During 1979, dace from Foskett Spring were transplanted into Dace Spring, located 1.5 kilometers south of Foskett Spring to create a second population. The population in Dace Spring had reproduced and appeared to be established (Williams and others 1990), but has recently become extirpated.[15] Although the watershed that contains Coleman Lake extends into Nevada, the dace does not occur in that state. Total population size is approximately 2,000 in Foskett Spring (Bond 1974).

Habitat Relationships

Foskett Spring is a small, cool-water (approximately 16° to 17° C) spring. The Foskett speckled dace are abundant in the small spring pool and associated outflow until surface flow disperses and disappears near the edge of Coleman Lake. The species were also abundant at Dace Spring, including an adjacent cattle trough located just outside the fenced area. No other fish has been reported from Coleman Valley.

[15]Personal communication. 1995. Alan Munhall, Bureau of Land Management, Lakeview, Oregon.

Key Factors Influencing Status

Foskett speckled dace need adequate surface flows free of non-native species to persist. Because of the restricted flows, habitats can be easily disturbed by visitor use, livestock grazing and reduction of riparian vegetation. Habitats also could be disturbed by significant increases in vegetation, which could choke the spring system or reduce surface flows. Because of its small size, Foskett Spring could be easily disturbed by changes in flows resulting from surface or subsurface disturbance. Both springs are fenced and protected from livestock grazing by the BLM.

Lost River Sucker (*Deltistes luxatus*)

The Lost River sucker, one of four native suckers in the Klamath Basin of California and Oregon, was the most important food fish of Modoc and Klamath tribes in the Klamath Lake Region (Andreasen 1975b; USFWS 1993b). As a result of low numbers, reduction in spawning and rearing habitat, and poor adult recruitment, the U.S. Fish and Wildlife Service listed the Lost River sucker as endangered in 1988. In 1994, 185,000 hectares of stream, river, lake, and shoreline were proposed as critical habitat for the Lost River sucker by the U.S. Fish and Wildlife Service.

Distribution and Status

The Lost River sucker historically occurred in the Lost River and upper Klamath River systems of northern California and southern Oregon, including Clear, Tule, Lower Klamath, Sheepy, Agency, and Upper Klamath lakes and their tributaries (map 4.59) (USFWS 1993b). Currently, Lost River sucker populations and available habitat have been greatly reduced. Lost River suckers currently are found in Upper Klamath and Tule lakes and Clear Lake Reservoir, with possible populations in Sheepy Lake and Iron Gate Reservoir. Recruitment of juvenile Lost River suckers to adult classes is poor, resulting in populations of older suckers and few new spawning individuals (USFWS 1993b).

Map 4.58—Historical and current distribution of Foskett speckled dace.

Map 4.59—Historical and current distribution of Lost River sucker.

Habitat Relationships

Suckers, as bottom dwellers, are sensitive to low near-bottom dissolved oxygen levels (Buettner and Scoppetone 1990). In spring and summer, they seek refuge from poor water quality conditions and can be found at spring fed areas in lakes. During spawning, adults move from lake habitats to larger tributary streams or adjacent spring systems. Adult Lost River suckers spend little time in spawning tributaries of lakes. Juveniles are found along the bottom of gently sloping lake shorelines, in water less than 50 centimeters in depth.

Key Factors Influencing Status

Loss of spawning and rearing habitat has been the largest impact on Lost River sucker populations. Dams, livestock grazing, ditching, tilling, diking, and wetland loss have reduced historical habitat by up to 90 percent. Agriculture and forestry practices have increased nutrients and chemical contaminants, thereby reducing dissolved oxygen levels, disrupting food chains, and minimizing aquatic organism survival. Introductions of nonnative fish species have increased predation on larval Lost River suckers (USFWS 1993b). Low populations, habitat fragmentation, poor adult recruitment, loss of spawning and rearing habitat, and water quality degradation threatens the persistence of the Lost River sucker.

Warner Sucker (*Catostomus warnerensis*)

The Warner sucker is endemic to the Warner Basin of south-central Oregon and an adjacent area of Nevada. The species was federally listed as threatened by the U.S. Fish and Wildlife Service in 1985. The state of Oregon also recognizes the species as threatened.

Distribution and Status

The Warner sucker historically was restricted to lake habitats and their tributary streams in Warner Valley (map 4.60). Accounts of early settlers documented large Warner sucker populations, including major spawning runs of "redhorse" up tributaries as recently as the 1930s (Andreasen 1975b). Three relatively permanent lakes, Hart, Crump, and Deep, provide primary habitat for the Warner sucker (Williams and others 1990). During wet years, the species also occurs in ephemeral lakes in the north end of the valley. Five perennial streams provide spawning habitat: Snyder, Honey, Deep, Twelvemile, and Twentymile creeks (Coombs and others 1979). All these habitats are in south-central Oregon, except a small portion of Twelvemile Creek, which flows from California into Nevada and then north into Oregon. Warner suckers have been collected from the Nevada and Oregon portions of Twelvemile Creek but not the upstream, higher-gradient California sections. During extreme drought conditions of the early 1990s, some Warner suckers were transplanted from drying habitats in Warner Valley to an area near Summer Lake, Lake County, Oregon, where they still persist.

Habitat Relationships

Historically, the Warner sucker probably inhabited a wide variety of marsh, slough, lake, and stream habitats in the valley. Studies during the 1970s (Coombs and others 1979) documented the presence of both lake and resident stream populations of Warner suckers. The species also occurs in larger irrigation ditches and shallow, ephemeral lakes.

Key Factors Influencing Status

Historically, the lakes and streams of Warner Valley were interconnected by slough and marsh areas which allowed Warner suckers broad access to a variety of habitats. Draining of wetlands coupled with installation of numerous irrigation diversion structures on lower reaches of tributaries greatly fragmented the distribution of the species and precluded access to many historic spawning areas as well as access to inflowing streams as lakes dried during drought periods. During 1992, for example, Hart Lake completely dried and nearly eliminated the species. Water diversion practices

Map 4.60—Historical and current distribution plus introduced sites of Warner sucker.

also can be detrimental to any juveniles that drift downstream and are diverted into fields. Degradation of riparian zones also has reduced this species' numbers. Bank erosion has widened channels, reduced cover, and increased sedimentation rates. Large populations of non-native species, particularly centrarchids and ictalurids, occur in lake habitats and appear to prey on young Warner suckers as they return from spawning areas (Williams and others 1990). During 1987 and 1989 surveys in Warner Valley, suckers comprised only 2.5 percent of fishes collected, whereas introduced crappie (*Pomoxis* spp.) and brown bullheads (*Ameiurus nebulosus*) accounted for 38.0 percent (Williams and others 1990). Poor recruitment continues to threaten the existence of the Warner sucker. Spawning areas are very limited because of poor access as described above. The relatively small number of larvae produced each year may fall prey to introduced predatory fishes. Overgrazing by livestock reduces riparian vegetation and further intensifies effects during drought periods.

Goose Lake Sucker (*Catostomus occidentalis lacusanserinus*)

The Goose Lake sucker, a subspecies of the more widespread Sacramento sucker (*Catostomus occidentalis*), is endemic to the Goose Lake Basin of south-central Oregon and northeastern California. The Goose Lake sucker is a Forest Service Region 6 sensitive species, and a State of Oregon sensitive species.

Distribution and Status

The subspecies is found in Goose Lake and many of its larger tributaries (map 4.61) (Moyle and others 1989). Goose Lake suckers were collected during the 1980s from Corral, Long Branch, Badger-Cloud, Davis, Lassen, and Willow creeks in Modoc County, California, and Augur, Bauers, Thomas, Cox, Cottonwood, Fall, Dry, Drews, Dog, and Hay creeks in Lake County, Oregon.[16] The subspecies also has been collected from Cottonwood Reservoir, Dog Lake, and Goose Lake. Spawning fish migrate from Goose Lake into Lassen, Willow, Thomas, Dry, and Cottonwood creeks (King and Hansen 1966; also, see previous footnote). The actual abundance of Goose Lake suckers is unknown, although they are locally common in many streams where they occur. In 1992, the population in Goose Lake was eliminated, at least temporarily, when drought caused the lake to dry completely. However, this was not the first time the lake had become desiccated. Recolonization is expected to occur naturally.

Habitat Relationships

Very little specific habitat information is available on the Goose Lake sucker. Two life history patterns are present in the Goose Lake Basin: a resident stream form, and a lake form that ascends tributary streams during spring spawning runs. Goose Lake is a large, shallow, and alkaline natural lake where bottom sediments are easily suspended by winds that create turbid conditions. Lake temperatures vary with ambient conditions and range from 1° to 24° C (Johnson and others 1985). Spawning habitat in lower Willow Creek is characterized by a complex of cobble-pebble-gravel with moderate to swift current.[17] In streams during summer, Goose Lake suckers seem to prefer pool habitats, with young of year rearing in shallows.

Key Factors Influencing Status

Historically, Goose Lake provided refuge to a relatively diverse native fish fauna free of non-native species that occur in tributary streams and elsewhere. Lower reaches of major tributary streams served as refuges to lake-dwelling Goose Lake suckers during drought periods. Irrigation diversions and physical barriers disrupted this pattern and compounded risk to this subspecies during periods of naturally reduced water availability. Many stream habitats have been degraded by agricultural practices. Overgrazing by livestock and resulting loss of riparian vegetation, increased

[16]Personal communication. 1995. J. Williams, Bureau of Land Management, Boise, Idaho.

[17]Personal communication. 1995. J. Williams, Bureau of Land Management, Boise, Idaho. Personal communication of unpublished data.

Map 4.61— Historical and current distribution of Goose Lake sucker.

water temperature, and increased sedimentation are common problems along the lower reaches of Goose Lake tributaries. Non-native fishes occur in many stream systems occupied by the Goose Lake sucker, but the extent of their impact on Goose Lake sucker populations is unknown. In 1994, a new non-native species, the fathead minnow (*Pimephales promelas*), was collected in Willow Creek.[18] The effect of this species on the native fish fauna is uncertain, but fathead minnows dominate in many parts of the nearby Klamath Basin, where they have been broadly introduced. Stream populations also may face increased risk from stochastic events because of their small population size.

Shortnose Sucker (*Chasmistes brevirostris*)

The shortnose sucker is endemic to the Klamath Basin of south-central Oregon and northern California. They were a primary food source for the Klamath Indians and provided a popular sport fishery on tributary streams until populations decreased substantially during the early 1980s. They are federally listed as endangered by the U.S. Fish and Wildlife Service because of low population numbers, reduction in spawning and rearing habitat, and poor recruitment. The species also is listed as endangered by the State of Oregon. In 1994, the U.S. Fish and Wildlife Service (U.S. Government 1994) proposed critical habitat for the shortnose sucker that consists of 185,000 hectares of stream, river, lake, and shoreline areas.

Distribution and Status

Shortnose suckers are endemic to the Upper Klamath Basin and were known to be locally abundant in lake habitats and, during spawning runs, in tributaries (map 4.62). Documented occurrences include the Upper Klamath and Agency lakes system and the Lost River system, including Tule Lake. Within the Upper Klamath Lake system, primary spawning habitats include the Williamson, Sprague, and Wood rivers. The species has suffered large reductions in numbers and range (Andreasen 1975b; USFWS 1993b). Remaining populations appear to be restricted to Upper Klamath Lake and tributaries, Klamath River downstream to Iron Gate Reservoir, and Clear Lake Reservoir and its primary tributary, Willow Creek. The species also may occur in Gerber Reservoir, which may be the result of an introduction (USFWS 1993b). Riverine spawning of the Upper Klamath Lake population is restricted to the lowermost reaches of the Williamson and Sprague rivers because of a diversion dam on the Sprague River at Chiloquin, Oregon.

Habitat Relationships

Members of the family Catostomidae are primarily bottom-dwelling fishes although the nearly terminal mouth of the shortnose suggests adaptation for more mid-water lake habitats. During recent years, occurrences in lake habitats appear to be primarily influenced by adults seeking improved water quality conditions. Adult shortnose suckers spend relatively little time during spawning periods in riverine habitats. Larvae are surface oriented and tend to occur in shallow, shoreline habitats.

Key Factors Influencing Status

Factors leading to the decline of the shortnose sucker are multiple and complex. Like the Lost River sucker, the lack of recruitment is probably the greatest threat to its continued existence. The influence of numerous non-native fishes in Upper Klamath Lake is presumed to be negative because of the potential for competition or predation on larval and juvenile suckers. Non-native species may be a primary factor causing the lack of recruitment observed in Upper Klamath Lake and other lake habitats. Draining of marshes, channelization, and dams have been major factors contributing to loss of habitat and the decline of the shortnose sucker. Replacement of wetlands

[18]Personal communication. 1995. Paul Chappell, California Department of Fish and Game, Redding, California.

Map 4.62— Historical and current distribution of shortnose sucker.

surrounding the lakes with farms has resulted in pollution and hypereutrophication of lake habitats with resulting fish kills from poor water quality. Low population numbers, habitat fragmentation, poor adult recruitment, loss of spawning and rearing areas, and water quality degradation threaten the persistence of this species. The risk increases as the decrease in genetic diversity from habitat fragmentation makes populations more susceptible to environmental change. Also as spawning populations become smaller and the amount of spawning area decreases, the species becomes more susceptible to hybridization and introgression with remaining Lost River and Klamath largescale suckers, which spawn in the same areas.

Klamath Largescale Sucker (*Catostomus snyderi*)

The Klamath largescale sucker is one of four members of the family Catostomidae native to the Klamath Basin of south-central Oregon and northern California. The species provided a staple food for the Klamath Indians and a major sport fishery as recently as 1980. It occurs in many of the same habitats and shares many of the same threats as the shortnose and Lost River suckers. The Klamath largescale sucker is classified by Region 6 of the Forest Service as a sensitive species.

Distribution and Status

The Klamath largescale sucker is native to the Upper Klamath Lake drainage in south-central Oregon and to the Lost River system of Oregon and California (map 4.63) (Andreasen 1975b; Moyle and others 1989). Within the Upper Klamath Lake system, the species is known from Upper Klamath Lake, Agency Lake, Williamson River, Sprague River, Sycan River, Wood River, and Sevenmile, Fourmile, Odessa, and Crystal creeks. Klamath largescale suckers also may occur in the Klamath River between Upper Klamath Lake and Copco Reservoir. Populations of all the lake-dwelling and big river sucker species (Klamath largescale, Lost River, and shortnose) in the Klamath Basin have declined greatly compared with their historic abundance. Klamath largescale suckers have been virtually eliminated from the Lost River system since at least the early 1970s (Contreras 1973).

Habitat Relationships

Upper Klamath and Agency lakes harbor lake-dwelling populations of Klamath largescale suckers that ascend major tributaries during spring for spawning. Unlike the Lost River and shortnose suckers, however, Klamath largescale suckers also occur as resident riverine populations in the Williamson, Sprague, and Sycan rivers. While adult largescale suckers are oriented to bottom substrates of lakes and rivers, larvae are surface oriented and are found over gravel and cobble substrates of rivers (Buettner and Scoppettone 1990). In lakes, juvenile Klamath largescale suckers tend to congregate along the bottoms of gently sloping shorelines.

Key Factors Influencing Status

The historic marshes and interconnected waterways common to the Klamath and Lost rivers have been nearly completely modified and replaced by major irrigation projects. These projects have drained wetlands, channelized streams, and diverted large amounts of water for irrigation. Nearly one-third of the wetlands in the Klamath Basin were eliminated by the Klamath Reclamation Project and many more areas were inundated by reservoirs. Including degradation and loss from intensive grazing by livestock, ditching, tilling, and diking, total wetland loss approximates 75 to 90 percent of historical extent. As a result of these factors, habitats have been fragmented, access to historic spawning areas has been blocked, and remaining lakes have suffered from hypereutrophication and massive blooms of toxic blue-green algae. Modified habitats in the Klamath Basin now support large numbers of non-native fishes, which cause further decline in native sucker numbers through predation on young. The Lost River,

Map 4.63— Historical and current distribution of Klamath largescale sucker.

Continue

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shortnose, and Klamath largescale suckers are all at risk because of lack of recruitment and adult susceptibility to hybridization and introgression among the species. As populations become smaller and spawning areas become increasingly modified and restricted in area, the likelihood of hybridization increases.

Wood River Bridgelip Sucker (*Catostomus columbianus hubbsi*)

The native range of the bridgelip sucker (*Catostomus columbianus*) in the assessment area is the Snake River drainage downstream from Shoshone Falls, Idaho and the Columbia River drainage to British Columbia. The Wood River in Idaho supports an isolated population that is "nearly 100 percent distinct" from other bridgelip sucker populations and has been described as a discrete subspecies (Smith 1966). Smith reported that the distinctness of the Wood River population suggests that it may warrant full species status upon further evaluation. The subspecies will be reviewed for listing by the Idaho Department of Fish and Game.

Distribution and Status

The holotype of the Wood River bridgelip sucker was collected from Fish Creek, tributary to the Little Wood River, in 1934 by Carl Hubbs (Smith 1966). Other specimens were collected from the mainstem Big Wood and Little Wood rivers. Electrofishing surveys of the Big Wood River since 1986 have captured bridgelip suckers that are presumed to represent this subspecies (Thurow 1990).[19] No comprehensive surveys have been completed. Therefore, the subspecies distribution and abundance are uncertain. Presumed distribution is shown in map 4.64.

Habitat Relationships

Little is known about the biology of the bridgelip sucker in the Wood River but it is believed to resemble that of other members of the species (Simpson and Wallace 1978). In general, bridgelip suckers differ from most other suckers by inhabiting streams with colder, swifter water and rocky substrate (Scott and Crossman 1973). Fish likely mature after age-2 and spawn in late spring. Maximum size is about 25 centimeters.

Key Factors Influencing Status

The status of Wood River bridgelip suckers will likely be influenced by the same factors that affect the status of other native fish species in the Wood River drainage. Alteration of habitat by residential and agricultural development, including irrigation withdrawal, overgrazing by livestock, and introductions of non-native species are likely to be detrimental to the viability of this subspecies.

Torrent Sculpin (*Cottus rhotheus*)

The torrent sculpin inhabits rivers and streams in the Puget Sound and Columbia River drainages in the states of Oregon, Washington, Idaho, Montana, and in British Columbia (Maughan 1976). The torrent sculpin is listed as a sensitive species by the Forest Service in Region 1 and as a species of special concern by the Montana Department of Fish, Wildlife, and Parks.

Distribution and Status

Historically, the torrent sculpin was found throughout tributaries of the mid- and upper Columbia River Basin, overlapping range with the shorthead sculpin. In Oregon and Washington, the torrent sculpin has been found in the Yakima, Entiat, and Palouse rivers and tributaries of the upper Deschutes River (map 4.65) (Wydoski and Whitney 1979). In Idaho, the torrent sculpin has been found in the Kootenai, Pend Oreille, Spokane, Clearwater, Salmon, St. Maries, upper Clark Fork, and Palouse river drainages and in the Snake River below Shoshone Falls (Simpson and Wallace 1978). MacPhee (1966) also found the torrent sculpin in Rochat Creek, a tributary to the St. Joe River. Although the current status is unknown, the present range probably remains

[19]Also personal communication. 1995. F. Partridge, Idaho Department of Fish and Game, Jerome, Idaho.

Map 4.64— Current distribution of Wood River bridgelip sucker.

Map 4.65— Current distribution of torrent sculpin.

similar to the historic range. When found, the torrent sculpin was in low numbers compared with the shorthead sculpin (MacPhee 1966).

Habitat Relationships

The torrent sculpin is primarily a benthic stream species but also occurs in lakes (Wydoski and Whitney 1979). In streams, they inhabit swift, cool, clear riffles with a stable bottom of scattered rubble, gravel, and boulder substrate (Simpson and Wallace 1978). Torrent sculpin were found only where rock substrate was present. Spawning, which occurs in riffle areas with rubble or boulder substrate, starts in early spring and lasts to late April.

Key Factors Influencing Status

The torrent sculpin is probably susceptible to land use practices (for example, livestock grazing, road construction, and mining) and climatic events that degrade water quality and diminish its natural habitat. Pollution, increased water temperatures, and sedimentation are the major potential negative impacts to sculpin populations.

Shorthead Sculpin (*Cottus confusus*)

The shorthead sculpin inhabits rivers and streams in the Puget Sound and Columbia River drainages in the states of Oregon, Washington, Idaho, Montana, and in British Columbia (Bailey and Bond 1963). The shorthead sculpin is listed by the Forest Service as sensitive and by the Montana Department of Fish, Wildlife, and Parks as a species of special concern.

Distribution and Status

In the assessment area, the shorthead sculpin is found in the upper reaches and tributaries of the Deschutes, Yakima, Wenatchee, and John Day river systems in the lower Columbia River Basin and the Snake, Spokane, Pend Oreille, and Kootenai River drainages in the mid and upper Columbia River Basin (map 4.66) (Bailey and Bond 1963). In the mid-Columbia River Basin, the species has been collected in the Coeur d'Alene and St. Joe river systems in Idaho (Maughan 1976), and in the upper Columbia in the Flathead, Little Blackfoot, and Blackfoot river systems in Montana and the Flathead River in British Columbia (Bailey and Bond 1963). In the Snake River drainage, the species occurs in the mainstem and tributaries of the Grande Ronde and Imnaha river systems in Oregon and the Clearwater, Salmon, Boise, Owyhee, Big Lost, and Little Lost rivers and Birch, Medicine, and Beaver creeks in Idaho (Maughan 1976). In 1994, surveys found shorthead sculpin in the upper Deschutes drainage in Oregon, the upper and lower Kootenai, Yaak, and Fisher rivers in Montana, the upper Yakima in Washington, and the upper and South Fork Coeur d'Alene, and Little Lost rivers, and Birch Creek in Idaho.[20]

Habitat Relationships

The shorthead sculpin prefers riffle areas and small coldwater rivers and streams (Bowler 1974). It has been collected in emergent grasses and slow-moving waters along shorelines and in backwaters. Spawning, which occurs in riffle areas with a rubble/boulder substrate, starts in early spring and lasts to late April.

Key Factors Influencing Status

The shorthead sculpin is probably susceptible to land use practices (for example, timber harvest activities, road construction, and mining) and/or climatic events that degrade water quality. Pollution, increased water temperatures, and sedimentation are the major potential negative impacts to sculpin populations. Once stream populations are eliminated, sculpin are poor recolonizers from adjacent areas as compared with trout.

[20]Personal communication. 1995. Lori Leatherbury, Forest Service, Boise, Idaho.

Map 4.66— Current distribution of shorthead sculpin.

Pit Sculpin (*Cottus pitensis*)

Pit sculpin were historically widespread in the Pit River system, from the Goose Lake Basin to the Sacramento River (Moyle 1976). In Oregon, the Pit sculpin is currently listed as sensitive by the Forest Service and BLM, and as a peripheral/rare species by the Oregon Department of Fish and Wildlife.

Distribution and Status

In Oregon, the extent of the historical distribution of Pit sculpin in the Goose Lake Basin is unknown. However, the sculpin was recorded both historically and recently (1979), and can still be found, in a few tributaries of Goose Lake, specifically Cottonwood and Drews creeks (map 4.67) (Long and Bond 1979; ODFW 1992). Pit sculpin also were recorded historically in Thomas Creek, Oregon, but surveys in 1983 and 1988 yielded no sculpin.[21] The Pit sculpin has never been found in Goose Lake. In California, the Pit sculpin is still widespread throughout the Pit River system and has recently been found in Lassen, Gold, and Willow creeks, all tributaries of Goose Lake. The Pit sculpin, where found, tends to be rare.

Habitat Relationships

Pit sculpin are not known to migrate. They are a benthic species found mainly in small, cold water tributaries (Moyle 1976). They show a strong preference for riffle habitat with small gravel substrate (Moyle 1976).[22] In the winter, they use the interstices among large gravels and cobbles during near-freezing and ice formation periods. They occupy water that ranges in temperature from 6.5° C in March to 18.8° C in June.[23]

[21]Personal communication. 1995. J. Williams, Bureau of Land Management, Boise, Idaho. Personal communication of unpublished data.

[22]Personal communication. 1995. J. Williams, Bureau of Land Management, Boise, Idaho. Personal sommunication of unpublished data.

[23]Personal communication. 1995. J. Williams, Bureau of Land Management, Boise, Idaho. Personal communication of unpublished data.

Factors Influencing Status

The main reasons for the Pit sculpin's current status are its rarity and limited amount of available habitat. Pit sculpin are limited in their ability to recolonize a stream once extirpated, this is especially true in the Goose Lake Basin because of the apparent lack of use of the lake. Because of their inability to recolonize, catastrophic events, loss of habitat, extreme droughts, and introductions of exotics could all lead to extirpation of individual stream populations. Extreme drought events and loss of stream habitat may have been factors limiting the current distribution of Pit sculpin in the Goose Lake Basin. Past management, such as livestock grazing, timber activities, and road building, has negatively affected sculpin habitat by increasing siltation (ODFW 1992). Loss of perennial, cool, spring-fed stream reaches, which act as refuge sites during extreme droughts, also has affected status.

Slender Sculpin (*Cottus tenuis*)

The distribution of the slender sculpin is restricted to the Upper Klamath Basin in Oregon, upstream of Klamath Falls. The slender sculpin is listed as a sensitive species by Region 6 of the Forest Service and as a species of special concern by the American Fisheries Society (Williams and others 1989).

Distribution and Status

The sculpin was historically distributed in the Upper Klamath and Agency lakes and their tributaries. Recorded distributions, between 1934 and 1976, are the lower Williamson and Sycan rivers, South Fork and mainstem Sprague and Wood rivers and Odessa, Denny, Crystal Camporee Spring, Crooked, Fort, and Sevenmile creeks (map 4.68) (Ford and Thomas 1993). The current status of slender sculpin is not well known, but sampling by Oregon State University and the Forest Service in 1992 found slender sculpins in sections of the Wood River and Larkin, Crystal, Crooked, and Fort creeks, and Fourmile Springs (Ford and Thomas 1993).

Map 4.67— Historical and current distribution of pit sculpin.

Map 4.68— Historical and current distribution of slender sculpin.

Habitat Relationships

Slender sculpins reside in both lake and stream environments and use a variety of habitat types. They are found in detritus, mud, sand, gravel, and rubble substrate and occupy pools, riffles, and glides (Bond 1963). Similar to other sculpins, they prefer low water temperatures and high dissolved oxygen levels. The upper lethal temperature is 31° C and dissolved oxygen concentrations less than four parts per million are generally avoided (Bond 1963).

Key Factors Influencing Status

The very restricted distribution of this species suggests very specific habitat needs or preferences. Changes in habitat features and water quality would likely result in population declines. The effects of introduced predators and potential competitors, now prevalent in the Upper Klamath Basin, are not known. So little is known of the distribution, life history, and habitat needs of slender sculpins that assessing their status or understanding the precise effects of human activities is difficult.

Margined Sculpin (*Cottus marginatus*)

The margined sculpin is the only freshwater fish confined entirely to the middle Columbia River drainage in the northern portion of the Blue Mountains of eastern Washington and Oregon. Due to its limited range, the species is currently listed as a BLM tracking species, a State of Oregon vulnerable species; and a State of Washington monitor species.

Distribution and Status

The historic distribution of margined sculpin has not been studied in detail, mainly because it overlaps the distribution of Paiute sculpin and is difficult to identify in the field. The most comprehensive study on the distribution of margined sculpins (Lonzarich 1993) revealed that they occur in the mainstem of the Tucannon and mainstem and tributaries of the Walla Walla (Washington) and Umatilla (Oregon) rivers (map 4.69). In the Walla Walla River Basin, they are found in the North and South forks, the Touchet River including the North, South and Wolf forks, and Pine, Dry, Mill, Couse, and Cottonwood creeks. In the Umatilla Basin, they are found in the McKay River and East Birch, Pearson, Johnson, Rail, and Butler creeks. Although confined to streams in the Blue Mountains, the species is abundant within this range.

Habitat Relationships

Lonzarich (1993) found that the margined sculpin prefers pools and glides with low velocity water flowing over cobble and gravel substrate. While it appears tolerant of variable habitat conditions, relatively little is known about this species. Most sculpin species prefer relatively low water temperatures. In Oregon, the margined sculpin is often found in association with rainbow trout, speckled dace, longnose dace, and Paiute sculpin (Wydoski and Whitney 1979).

Key Factors Influencing Status

The restricted distribution of the margined sculpin makes it especially vulnerable to environmental changes. Land management activities could lead to the rapid decline in margined sculpin population numbers and status. Major potential effects from these activities include reduced amounts of preferred pool habitat, habitat fragmentation, increased water temperatures, loss of streamside vegetation, increased water velocities, and increased sedimentation. Lonzarich (1993) noted the degraded condition from grazing and logging in the Touchet River, particularly the South and Wolf forks. Also, Oregon Department of Fish and Wildlife (1992) cited potential impacts from agricultural chemicals, heavy sedimentation, and toxic material spills as reasons for listing the species.

Map 4.69— Historical and current distribution of margined sculpin.

Wood River Sculpin (*Cottus leiopomus*)

The Wood River sculpin is endemic to the Wood River drainage in south-central Idaho. The Wood River sculpin is currently listed as a State of Idaho species of special concern and as a sensitive species by the BLM and Region 4 of the Forest Service.

Distribution and Status

The Wood River sculpin was first collected from the Little Wood River near Shoshone, Idaho in 1893 (map 4.70) (Gilbert and Evermann 1895). Historically, the range of Wood River sculpin consisted of all permanent, interconnected waters from the falls on the Malad River at Interstate 84 in Idaho upstream into the Little Wood and Big Wood rivers and their tributaries (Simpson and Wallace 1978). It is likely that the Wood River sculpin was the only sculpin present in the drainage. The Wood River sculpin was more widely distributed in the drainage historically than at present.[24] However, no basin-wide inventories have been conducted to determine its present range accurately. Inventories conducted on 26 streams in the drainage from the 1970s to 1990s found sculpins at 40 locations but not at 8 locations.[25] Where found, sculpin were common to abundant.

Habitat Relationships

The Wood River sculpin has similar habitat requirements as other sculpins found in Idaho (Merkley and Griffth 1993). The Wood River sculpin seems to select fast water riffles with boulder, cobble, and gravel substrate. In some streams, sculpins make limited use of overhanging banks and beaver ponds. In the Big Wood River, sculpins were found seasonally in ephemeral side channels with suitable cobble and boulder substrates.

[24]Wallace, R.L. University of Idaho. 1995. Letter dated September to B. Reininger, Idaho Department of Fish and Game, Jerome, Idaho.

[25]Personal communication. 1995. F. Partridge, Idaho Department of Fish and Game, Jerome, Idaho. Personal communication of unpublished data.

Key Factors Influencing Status

The most significant threat to Wood River sculpin is the loss of habitat caused by development of irrigation projects in the Wood River drainage and by floodplain encroachment. Habitat destruction from irrigation projects includes stream dewatering, flooding of stream channels by reservoir construction, and formation of migration barriers. Non-native fish introductions have also occurred. These introductions have created adverse effects on the population, including predation, competition, potential hybridization with Paiute sculpin, and potential introduction of disease. Most habitat loss occurred on private lands prior to the 1930s, with additional habitat loss resulting from overgrazing in the upper Big Wood River. More recently, sculpin habitat has been degraded by agriculture and residential development within the floodplain.

Shoshone Sculpin (*Cottus greenei*)

The Shoshone sculpin is endemic to springs along the Snake River in the Hagerman Valley of south-central Idaho. Because of its restricted range and the development pressures on spring systems, the Shoshone sculpin is classified as threatened by the American Fisheries Society (Williams and others 1989), as a State of Idaho species of special concern, and as a sensitive species by the BLM.

Distribution and Status

Shoshone sculpins are restricted to portions of the Snake River in south-central Idaho that contain spring systems (map 4.71). Wallace and Griffith (1982) reported the species from 49 locations within 25 spring systems in the Hagerman Valley. Most locations are along the north bank of the river in the Thousand Springs formation of Gooding County. Two localities along the south side of the river in Twin Falls County contained Shoshone sculpin. Shoshone sculpin also were collected from Billingsley Creek, a tributary of the Snake River near Hagerman. Many spring and stream systems in the region contain the more

Map 4.70— Historical and current distribution of Wood River sculpin.

Map 4.71— Historical and current distribution of Shoshone sculpin.

common mottled sculpin (*C. bairdi*). Results of a recent Idaho Chapter American Fisheries Society Workshop (IDAFS 1995) indicate some population loss but an overall "fairly stable" population status during the past decade.

Habitat Relationships

Shoshone sculpin are found only in association with spring outflows. Highest population densities occur near the headwaters of springs and lower densities occur with decreasing influence of spring water on water quality (Wallace and Griffith 1982). Younger sculpins prefer areas with more plant cover and fewer large rocks than do older Shoshone sculpins. Both juvenile and adult Shoshone sculpins prefer relatively low water velocities (less than 20 cm per second) with temperatures near 15° C (Wallace and Griffith 1982).

Key Factors Influencing Status

Shoshone sculpins are dependent on maintenance of the natural integrity of spring flows. The numerous spring systems that are located along the Snake River provide a valuable, but finite resource. Diversion of spring water has caused dewatering of Shoshone sculpin habitat in many areas (Wallace and Griffith 1982). Spring waters are used for a variety of purposes, including aquaculture facilities, hydropower operations, and agriculture. These practices have diverted, dried, and polluted springs. Various private and Federal fish hatcheries also serve as sources of non-native invertebrates, fishes, diseases, and parasites.

Malheur Sculpin (*Cottus bairdi* spp.)

The Malheur sculpin is endemic to the Harney Basin of southeastern Oregon. This undescribed subspecies is listed as a sensitive species by the State of Oregon.

Distribution and Status

The Malheur sculpin is endemic to streams in the Harney Basin, including the Silvies and Blitzen river systems (map 4.72). Historic distribution includes the Blitzen River and tributary streams on the Steens Mountain, the Silver Creek drainage, the Silvies River and tributary streams, and the isolated drainages of Poison and Rattlesnake creeks. The sculpin in the Harney Basin is considered by Bailey and Bond (1963) and Bond (1974) to represent an undescribed relative of the mottled sculpin in the Snake River drainage. Within the Silvies Basin, Bisson and Bond (1971) reported the Malheur sculpin from the mainstem Silvies River, Scotty Creek, and Emigrant Creek. According to the BLM (1992), Malheur sculpin occur on BLM-administered lands in the upper Silvies River and Emigrant, Yellowjacket, Hay, Myrtle, and Sawtooth creeks in the Silvies Basin. Historic collections suggest that the subspecies was broadly distributed within its range. Bond (1974) reported that the subspecies has been extirpated from the Rattlesnake Creek subbasin.

Habitat Relationships

Very little is known about the life history of the Malheur sculpin, but it is assumed to be comparable to that of other mottled sculpins, *Cottus bairdi*. According to Bond (1974), the Malheur sculpin requires cool-water streams with large gravel or rubble substrates for cover and spawning. It requires water temperatures below 26° C, with high dissolved oxygen and very low turbidity. Given these characteristics, the Malheur sculpin can occupy small headwater streams and larger rivers, such as the lower Blitzen River.

Key Factors Influencing Status

Malheur sculpin appear to be very sensitive to changes in water quality, including increases in temperature, sediments, and turbidity. Aquatic habitat and water quality conditions are considered poor in the upper Silvies River because of elevated water temperature, silt loads, and livestock grazing; and poor on Hay and Yellowjacket creeks because of elevated water temperature, silt loads, and timber harvesting (BLM 1992). On Emigrant Creek, BLM (1992) rated water quality condition as fair and aquatic habitat condition as good but considers both conditions to be declin-

Map 4.72— Historical and current distribution of Malheur sculpin.

ing because of siltation, high water temperature, and upstream impacts from livestock grazing and logging. Biotic interactions are not specifically known, but the occurrence of the Malheur sculpin would appear to be negatively correlated with presence of introduced warm-water fishes such as catfish and centrarchids, which are more tolerant of turbid water conditions. Elevated water temperature, increased turbidity, and sediment transport caused by activities such as livestock grazing, road construction, and timber harvest activities are detrimental to the sculpin and have been cited by the BLM (1992) as causes for the decline of Malheur sculpin populations in the mainstem Silvies, Hay, Yellowjacket, and Emigrant creeks within the Silvies Basin.

Conclusions

Approximately 50 percent of the native fish taxa in the assessment area has exhibited significant declines compared with historic levels. Presently, 45 of the 88 native fish taxa (51%) in the assessment area are identified as threatened, endangered, sensitive, or of special concern by state or Federal agencies or by the American Fisheries Society. Eleven fish taxa are formally listed as threatened or endangered under the Endangered Species Act. The following important concepts have emerged from our review of historic and current distributions of rare fish and existing literature.

1. Many of these taxa are vulnerable to anthropogenic effects and stochastic events because of their restricted range and fragile habitat requirements. Four cyprinid fishes are restricted to one or two small spring systems: Borax Lake chub, Summer Basin tui chub, Hutton tui chub, and Foskett speckled dace. Several other species appear to be extremely rare, but their precise status is unclear. These species include the Klamath lamprey, Goose Lake lamprey, Lost River sucker, and shortnose sucker. The spring-dwelling fishes, such as the Borax Lake chub and Hutton tui chub, occupy unique desert habitats that are easily disturbed by off-road vehicles, livestock grazing, or other surface disturbances. Spring aquifers and associated substrates also may be degraded from over-withdrawal of groundwater, geothermal exploration, or other subsurface drilling. Many spring habitats of the Shoshone sculpin have been lost because of aquaculture facilities and small hydropower operations. Such species require protection of remaining habitat if the species are to persist.

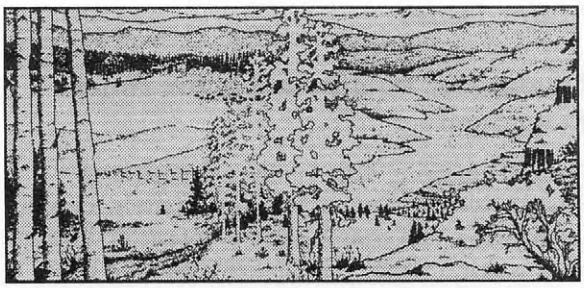
2. Many of these taxa are subject to increased likelihood of extinction or extirpation as environmental variability combines with low population sizes. The native lake-dwelling suckers of the Klamath Basin (shortnose, Lost River, and Klamath largescale) have declined to the extent that hybridization among the species may be occurring within restricted, remaining spawning areas. Water quality in Upper Klamath and Agency lakes has severely reduced the distribution of native fishes and has caused fish mortality in the past. Drought exacerbates problems of water quality in the lakes. In the Warner Valley, the threatened Warner sucker was nearly eliminated during the drought of the early 1990s by a combination of the desiccation of lake habitats and the diversion dams that prevented access to lower sections of remaining tributaries. The species survived largely through temporary transfer of individuals to the Summer Basin. Drought caused similar problems to the Goose Lake lamprey when Goose Lake dried in the early 1990s.

3. Many of these taxa are poorly understood and in need of study and rigorous monitoring efforts. We know very little about the lampreys (with the possible exception of the Pacific lamprey), the northern roach, the leatherside chub, most of the tui chubs, the Foskett speckled dace, the Wood River bridgelip sucker, and the Malheur sculpin. Several of these taxa, for example the Hutton tui chub and the Foskett speckled dace, have long been recognized as distinct at the subspecific level yet lack formal scientific descriptions. Monitoring of habitat and populations is essential if management is to respond to factors that threaten the persistence of the narrowly distributed endemics.

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ISSUES AND OPPORTUNITIES

In the introduction to their influential paper describing the status of 214 Pacific salmon stocks from California, Oregon, Idaho, and Washington, Nehlsen and others (1991) describe Pacific salmon as being at a crossroads:

> In the 1990s, native anadromous Pacific salmon (*Oncorhynchus* spp.) are at a crossroads, the habitats of these once wide-ranging fishes are severely curtailed, many stocks are extinct, and many remaining stocks face a variety of threats.

Unfortunately, Pacific salmon are not the only aquatic resource at a crossroad. As described in earlier sections, many other fish taxa are threatened by developmental activities within the Basin that affect aquatic habitats. Aquatic ecosystem integrity is degraded in much of the Basin; however, many important elements of functioning aquatic systems remain. Native species still appear to dominate many waters, and important population strongholds and regions of high biological integrity are found in watersheds under federal management. These areas are critical to short-term conservation and long-term rehabilitation of ecologically functional aquatic systems throughout the Basin. Restoring aquatic integrity is a challenge that extends well beyond the 1990s.

The emerging paradigm of ecosystem management is a new way of doing business to solve current forest, watershed, and aquatic health issues on federal lands. An assumed goal of ecosystem management is to maintain or rehabilitate the integrity of aquatic ecosystems and to provide for the long term persistence of native and desirable non-native fishes and other species (Grumbine 1994). Achieving this goal will require the maintenance or rehabilitation of a network of well-connected, high-quality habitats that support a diverse assemblage of native species, the full expression of potential life histories and dispersal mechanisms, and the genetic diversity necessary for long-term persistence and adaptation in a variable environment. Watershed rehabilitation and the development of more ecologically compatible land-use policies are required to ensure the long-term productivity of many systems. Ecosystem management, then, implies managing to reestablish more complete or natural structure, function, and processes whenever possible. Identical goals in terrestrial ecology and the inextricable link between terrestrial and aquatic systems suggest that management efforts in one should benefit the other. The challenge is to coordinate management of terrestrial and watershed systems rather than work at cross purposes.

In this section we examine some major issues involved with ecosystem management and fishes and provide a context for conservation and rehabilitation opportunities. The four issues examined are: 1) catastrophic wildfire and active forest restoration; 2) the role of federal land management in managing anadromous fishes; 3) the effect of roads on sedimentation and fishes; and 4) stronghold watersheds relative to unroaded areas. We then provide a synthesis and discussion of a spatial context for application of the ideas emerging from our assessment, conservation biology, and the ecosystem goals. We consider several scales: the broadscale (subbasins within the context of the entire Basin), the mid-scale (within a subbasin context), and the fine-scale (riparian habitat conservation area widths and functions and cumulative watershed effects).

Major Issues

Catastrophic Wildfire and Active Forest Restoration

A major emerging issue involves the threat of catastrophic wildfire and efforts to actively restore the structure and composition of forests to diminish this threat. Since past timber harvest activities have contributed to degradation in aquatic ecosystems, emphasis on timber harvest and thinning to restore more natural forests and fire regimes represents a risk of extending the problems of the past.

Wildfire has historically been one of the most important and pervasive agents of disturbance on the landscape. The historical pattern of fire frequency and severity within the Basin was a complex mosaic that reflected variation in vegetative cover types and structure, climate and weather, and terrain. Current fire regimes may vary substantially from the historical pattern (Landscape Dynamics, Chapter 3). In forested areas, fire suppression and timber management practices are believed to be the principal causes of disrupted natural fire regimes in many areas. The most prevalent change has been a shift toward more severe fires, as fire suppression has permitted a buildup of fuels. Fire suppression has also increased connectivity of larger stands that are susceptible to insect and pathogens, further contributing to fuel loadings. Past timber management has compounded these problems in some areas by promoting large, even-aged stands, altering forest composition, and favoring higher stand densities. Active timber harvest and thinning are now proposed as primary methods for restoring and recomposing forests (Johnson and others 1995).

It can be argued that the change in fire regime may pose a new threat to the integrity and persistence of aquatic communities and species. Although we do not view wild fire as a particular threat to healthy aquatic ecosystems, depressed and strongly isolated populations could be vulnerable to the effects of intense or very large fires.

Wildfires influence aquatic ecosystems both directly and indirectly. Direct effects include heating or abrupt changes in water chemistry (Minshall and others 1989; McMahon and de Calesta 1990). Indirect effects include changes in hydrologic regime, erosion, debris flows, woody debris loading and riparian cover (Swanson and Lienkaemper 1978; Brown 1989; Megahan 1991; Bozek and Young 1994). Intense fires and related events have killed fish (Bozek and Young 1994) and caused local extinctions (Propst and others 1992; Rinne, 1996). In addition, more extreme fires may have an important influence on the diversity of habitats at watershed and subbasin scales. Since fires burning over large areas are likely to influence more habitats simultaneously, the spatial and temporal diversity in habitat condition and population dynamics we believe important to the stability and persistence of species and populations could be compromised by more extreme events. Such effects might be particularly important where populations and habitats are already degraded. Large and intense fires could threaten some populations that are seriously depressed or isolated.

Given the potential negative consequences of severe wildfires on aquatic communities, pursuing strategies that reduce risks of fire with all haste might seem prudent. But there are other facets to this story. First, historical fires were a natural and important part of the disturbance regime for terrestrial and aquatic systems (Reeves and others 1995). Large fires supplied woody debris and magnified the affect of hydrologic events and debris flows that transported coarse substrates to stream channels. These processes may well have provided the materials that maintained productive habitats for fish and other organisms (Swanson and others 1990; Reeves and others 1995). Second, proposed efforts to reduce fuel loads and stand densities often involve mechanical treatment and the use of prescribed fire. Such activities are not without their own drawbacks — long-term negative effects of timber harvest activities on aquatic ecosystems are well documented (see this chapter; Henjum and others 1994; Meehan 1991; Salo and Cundy 1987). Thus, managers face a

dilemma. To do nothing invites potential loss due to uncontrolled wildfires. Reducing fuels involves methods that also may degrade aquatic systems.

We suggest that to resolve this dilemma, one must look at the mechanisms through which fish populations respond to wildfire. In a recent study, Rieman and others (in press) identify two factors that were important in fish population recovery following a large wildfire: 1) refounding of populations through dispersal from local refuges; and 2) refounding through complex life history and overlapping generations.

In studies of recolonization in fish populations following major disturbance and defaunation, internal refuges, that is, sites that protect portions of the population during the disturbance, can promote rapid recolonization of affected areas within a stream. Recovery is often evident in a few years (Meffe and Sheldon 1990; Niemi and others 1990; Yount and Niemi 1990; Lamberti and others 1991; Detenbeck and others 1992; Bayley and Osborne 1993) or even weeks (Sheldon and Meffe 1995). The benefits of spatially redundant and complex habitats to the persistence and resilience of populations are well established in theory (den Boer 1968; Poff and Ward 1990; Sedell and others 1990) and building empirical evidence (Pearsons and others 1992; Rieman and others, in press). The presence of refuges allows populations to compensate for habitat losses, in part through recolonization but also through mechanisms that may be triggered or enhanced by the disturbance event (Bisson and others 1988; Minshall and others 1989). For example, Rieman and others (in press) observed high densities for young-of-the-year redband trout in several reaches affected by intense fires or subsequent channel disruptions precipitated by fire. Although habitats have been lost or degraded through debris flows, increased sediment deposition, and scour following the fires, habitats are also being created through the influx of large debris. The preexisting and resulting complex of habitats seem to allow fishes to persist and perhaps even prosper under these dynamic conditions.

A complex of life-history patterns also provides temporal and spatial hedges against local extinction following catastrophic disruption. Maintenance of that complexity may be critical to the persistence of many populations. As an example, Rieman and others (in press) argue that refounding of a bull trout population in a tributary influenced by the fires discussed above was dependent on the presence of a migratory life history. Gross (1991) and Thorpe (1994) have proposed that the expression of multiple life-history strategies as a mechanism stabilizing populations in variable environments. That expression may also lead to full exploitation of, and be dependent upon, a complex of available habitats (Healey 1994; Lichatowich and Mobrand 1995) and historical patterns of disturbance. The diverse life histories of many native salmonids within the assessment area are discussed in preceding chapters. The existence of complex life histories, such as mixed migratory behaviors and overlapping generations, could be the expression of strategies that have emerged because of the disturbance of fire and associated hydrologic events. Species like bull trout that are associated with cold, high elevation forests have probably persisted in landscapes that were strongly influenced by low frequency, high severity fire regimes. In an evolutionary sense, many native fishes are likely well acquainted with large, stand-replacing fires. If the expression of life-history patterns does reflect the template of historically available habitats (see Healey 1994; Thorpe 1994) and if the spatial and temporal complexity of habitats is lost, the expression of complex life histories may be lost as well.

Both pathways that we have suggested for the short-term recovery of populations influenced by fires reinforce the importance of spatially diverse and complex habitats. Complex landscapes not only produce a mosaic of burn effects, they also create a mosaic of pre-fire stream habitat conditions that provide important refuges within the burn perimeter. That same pattern of stream habitats, the size of the watersheds, and the connection of the watersheds to a larger river basin are likely important in the full expression of life

history. Strong, well-distributed populations appear to have a high potential for recovery following intense wildfires. Depressed populations inhabiting marginal or degraded habitat may lack the resiliency to deal with catastrophic disturbance adequately.

The chronic and widespread nature of timber harvest and other human related disturbance has led to a loss of spatial complexity of stream environments that ultimately is reflected in the loss of diversity and distribution of populations and life histories (see this chapter; Frissell and others 1993; Reeves and others 1995). Attempts to minimize the risk of large fires by expanding timber harvest risks expanding the well-established negative effects on aquatic systems as well. The perpetuation or expansion of existing road networks and other activities might well erode the ability of populations to respond to the effects of fire and large storms and other disturbances that we cannot predict or control (National Research Council 1996).

There is growing interest in use of intensive forest management to reestablish more natural landscape patterns and disturbance regimes, but the risks and benefits of that management vary across the landscape. Forest-health treatment projects have been justified from all perspectives including reducing the risk of extirpation for sensitive aquatic species. Undoubtedly, a point exists where the risk of fire outweighs the risk created by management. Management creates risks of somewhat known magnitude, timing, and extent, whereas wildfire potential is less known in each of these respects. The point at which risks are equal needs to be discovered through careful evaluation and scientific study. It appears that the consequences of large fires are dependent on habitat conditions and the inherent resiliency of local populations. Risks of fire are likely most important for aquatic ecosystems that have been seriously degraded and fragmented. Watersheds that support healthy populations may be at greater risk through disruption of watershed processes and degradation of habitats caused by intensive management than through the effects of fire.

The Role of Federal Lands in Managing Anadromous Fishes

Earlier we surveyed a number of historical changes across the Basin that have influenced aquatic ecosystems and contributed to declines in fish populations and ecological integrity. Changes are due to hydroelectric development, flood control, irrigated agriculture, hatcheries, ocean and in-river harvest, and finally, degradation of freshwater spawning and larval and juvenile rearing habitats. The cumulative effects of many of these changes are readily apparent in the distributions and status of naturally reproducing anadromous salmonids. Freshwater habitat degradation is the one most prominently influenced by the Forest Service and BLM, which administer much of the remaining habitat used for spawning and larval and juvenile rearing by anadromous fishes.

Both steelhead and stream-type chinook have most of their few remaining strong populations in subwatersheds on federal land (70% and 88% respectively). More than ninety percent of remaining bull trout and westslope cutthroat trout subwatersheds with known or predicted strong populations are on Forest Service and BLM administered lands (table 4.49). The recovery of depressed populations will depend strongly on management of federal lands as 50 to 76 percent of species with depressed populations occupy federal land. Only ocean-type chinook are less influenced by federal land management since they occupy larger stream systems that are more influenced by private lands, irrigation withdrawals, and dams.

Federal land management has an effect on anadromous salmonids. Numerous published studies describe the negative effects of land-use activities on habitat conditions and link habitat conditions to survival and productivity of anadromous fishes. Meehan (1991) and Murphy (1995), for example, provide excellent comprehensive overviews of this topic. The survival differences between pristine and degraded habitats for egg and juvenile fish can be dramatic. Scully and others (1990) show that egg-to-parr survival for chinook salmon in

Table 4.49— Current population status of seven key salmonids in the Basin and their relationship to habitat provided by Forest Service- and BLM-administered land.

Species	Percent of Historical Range Occupied	Percent of Occupied Range Classed as Strong	Percent of Strongholds in Wilderness	Percent of Strongholds on FS/BLM	Percent of Depressed on FS/BLM	Sensitive to FS/BLM Land Uses
Bull trout	44	13	55	95	82	Yes
Yellowstone cutthroat	66	35	19	70	46	Yes
Westslope cutthroat	85	25	44	94	65	Yes
Redband	64	22	8	56	58	Yes
Steelhead	46	1	9	70	61	Yes
Stream-type chinook	28	<1	50	88	77	Yes
Ocean-type chinook	29	15	0	20	25	minor influence

degraded streams with high sand content was less than one eighth that exhibited in low-sand areas. A large literature documents anthropogenic effects on other life stages (National Research Council 1996). A collection of papers in Schwiebert (1977), for example, documents numerous problems in the Columbia River Basin that still apply 20 years after publication. Our summary, described in earlier sections, supports a scientifically credible view that is emphasized repeatedly in the literature: habitat change due to land use is pervasive and at times dramatic, but impacts are not evenly distributed across the landscape. High-quality areas remain that are capable of supporting anadromous fishes at near-historical levels.

Given the other factors affecting these fishes, the precise magnitude of the loss to anadromous fishes that is due to degradation of spawning and rearing habitats is not known. Similarly, although positive responses to habitat improvement are expected, no precise estimate of the magnitude of the expected benefit is possible. The complexity of interactions across life stages confounds even the best of studies. For example, the debate over the efficacy of juvenile salmon transportation focuses not so much on the survival through the transportation process *per se*, but rather on the latent effect that transportation has on post-release smolt survival and adult returns. Similar questions could be raised regarding early rearing. For example, do juvenile fishes from degraded habitats exhibit the same migration and early marine survival as those from better habitats? Research in British Columbia suggests not (Hartman and Scrivener 1992). In the absence of empirical studies, stock-recruitment models that incorporate habitat conditions suggest that declines in habitat productivity can have a disproportionate effect on total population size. Thurow and Burns (1992) present an example for Idaho streams where a 20 percent loss in habitat productivity results in more than a 50 percent reduction in adult numbers, while a 50 percent reduction in habitat productivity causes extirpation.

The reason the effects of spawning and rearing habitat changes are difficult to measure precisely concerns the compensatory nature of fish-habitat relations. This compensation is also a reason why high-quality habitat is so vital to maintaining and rebuilding populations where they still exist or are strong. When the number of spawning adults declines as it has in recent years, the adults can choose areas offering the best conditions. Similarly, juveniles can spend their time in the better habitats with reduced competition for resources. The net result is that the number of smolts produced per adult can actually increase as the number of spawners declines. As long as the amount and distribution of high-quality habitat available remains proportional to the number of spawners and in locations used by the fishes, the apparent productivity of the population will remain fairly constant. Thus, detecting a historical decline in habitat conditions over a period when numbers of spawning adults are declining may be impossible as well, if one looks only at the number of smolts produced per adult. This is the situation in the Snake River subbasins above Lower Granite Dam. During and after construction of the federal dams in the lower Snake River (post 1970), numbers of returning adult chinook salmon declined dramatically compared to run sizes in the 1950s and 1960s (Petrosky and Schaller 1992). The declining numbers of adult salmon do not permit an adequate test of the hypothesis that habitat conditions changed during the same time period. Such a test would require a return to historical levels of spawning adults that predate the dams.

A study conducted by Lee and Rieman (1996) using the Stochastic Life-Cycle Model (SLCM) examined the effects of habitat quantity, habitat quality, and downstream passage survival on a hypothetical population of chinook salmon. The SLCM was developed by Lee and Hyman (1992) to simulate the life cycle of anadromous salmonids. It is designed to mimic the basic mechanisms regulating populations of Pacific salmon, while capturing some of the intra-annual and interannual variation inherent in these populations. The SLCM was designed for population viability assessments and has been used in recent years by the National Marine Fisheries Service and the Bonneville Power Administration.

The study illustrated the relative effects of simultaneously varying incubation success, parr carrying capacity, and downstream passage survival. Incubation success refers to the proportion of eggs produced that are successfully deposited in the redd and survive to emergence from the gravel. It can be viewed as an indicator of habitat conditions in terms of both spawning and incubation conditions (Bjornn and Reiser 1991). Parr capacity refers to the maximum number of parr or juvenile fish that an area can support. It reflects both habitat quality and quantity, but was used to measure habitat quantity only, assuming quality remained constant. Downstream passage survival refers to the proportion of the smolts that leave natal streams or rearing areas and survive migration to the estuary. Again, passage survival many reflect many things, but was of use to index the effects of changes in the hydroelectric system.

Lee and Rieman (1996) examined eleven levels of incubation success (15% to 65% in 5% increments) in combination with three levels each of parr capacity (50, 100, and 150 thousand) and downstream passage survival (35%, 45%, and 55%). All other parameters, such as fecundity, ocean survival, maturity rates, etc., were held constant at reasonable values for an upriver Columbia Basin stream-type chinook population.

Lee and Rieman (1996) found that the probability of persistence responded to changes in incubation success and passage survival in a way that was consistent across different levels of parr carrying capacity. As passage survival decreased, the level of incubation success required to ensure population persistence increased. Increasing parr capacity had no apparent effect on the relationship. Furthermore, the drop from certain persistence to certain extinction was fairly abrupt. Halving the incubation success (say from 50% to 25%) was sufficient to cause certain extinction of an apparently robust population, regardless of the passage survival or parr carrying capacity.

While all three factors affected population numbers through time, habitat quantity had a measurable effect on mean run size, but only beyond a certain threshold combination of passage survival and incubation success. In practical terms, this suggests that increasing the amount of available habitat (parr capacity) without any increase in quality (incubation success) would have no discernable effect on the chances of the population persisting through time. Alternatively, more habitat of lower quality is less advantageous in terms of population persistence than less habitat of higher quality.

Because of the habitat and population losses associated with dams, only the most productive populations may retain the resilience to persist in the face of natural and human caused disturbance. Any changes in the environment that influence survival and productivity of remaining stocks, including improvements in rearing habitats, harvest, predation, and mainstem passage, will improve chances for persistence in stochastic environments (Emlen 1996; National Research Council 1995). Simply put, with current conditions in migrant survival, many stocks are at serious risk. The differences between those that persist and those that do not will include chance events and the survival and productivity of the stocks as they are largely influenced by freshwater habitats. Without substantial improvement in migrant survival, securing and restoring the quality of freshwater habitats may make the critical difference in persistence for many of the remaining populations. In the short term, conservation and/or rehabilitation of habitats available to or directly associated with remaining populations will be key. In the long term, assuming mainstem conditions are resolved, it will be necessary to conserve and restore broader habitat networks to support the full expression of life histories and species (this chapter; Lichatowich and Mobrand 1995; National Research Council 1995). Rehabilitation of depressed populations cannot rely on habitat improvement alone but requires a concerted effort to address causes of mortality in all life stages. These include freshwater spawning, rearing, juvenile migration, ocean survival, and adult migration.

To prevent extinction of the anadromous fishes in the Snake River subbasins and maintain population resiliency until other causes of mortality are reduced, it is essential that existing high-quality habitats be maintained. To ensure recovery, the amount of high-quality habitat available must remain proportional to the number of returning adults and in appropriate areas, so that there is no net loss in productivity as adult numbers increase. Returning adult numbers can fluctuate over a broad spatial range and from year to year much more rapidly than habitat conditions can improve. Thus, to realize the benefits of improved migration and ocean survival, there must be maintenance of good quality habitats and populations as well as increases in the distribution of high-quality spawning and early rearing habitats. Improved federal land management is crucial to this task.

Effects of Roads on Sedimentation and Fishes

The relationship of roads to intensity of land use and adverse impacts on aquatic habitats has been discussed in several recent studies and publications (Naiman and others 1992; Spence and others 1995; Meehan 1991). The discussion often centers around three themes: 1) the belief that road building practices have improved in the last decade to the point we need not worry about the effects of roads on aquatic systems; 2) the legacy of past road building is so vast and road maintenance budgets so low that the problems will be with us for a long time; and 3) the belief that the correlation of road density to fish habitat and fish population is not strong.

Increases in sedimentation are unavoidable even using the most cautious logging and roading methods. Improvements in road-construction and logging methods, however, can reduce erosion rates and sediment delivery to streams. The amount of sedimentation or hydrologic alteration from roads that streams can tolerate before there is a negative response is not well known, but general effects of sediments on fishes are known. Sediment loads that exceed natural background levels can fill

pools, silt spawning gravels, decrease channel stability, modify channel morphology, and reduce survival of emerging salmon fry (Burton and others 1993; Everest and others 1987; MacDonald and others 1991; Meehan 1991; Rhodes and others 1994).

Rice (1992) documented an 80 percent reduction in mass erosion from forest roads and about a 40 percent reduction in mass erosion from logged areas in northern California due to improvements in forest practices beginning in the mid 1970s. Megahan and others (1992) used the BOISED sediment yield production model to evaluate the effects of historical and alternative land management in an Idaho watershed (within the South Fork Salmon River). They reported that present day management practices, properly implemented, have the potential of reducing sediment yield by about 45 to 90 percent compared with yields caused by the historical land use in their study watershed. However, using the improved road design currently practiced by the Boise National Forest, total accelerated sediment yields were still 51 percent over natural sediment yields. These improved road designs plus maximum erosion mitigation led to 24 percent increases over natural yields. Helicopter logging resulted in 3 percent increases over natural yields, and wildfire increased sediment yield about 12 percent over natural levels (Megahan and others 1992).

Megahan and others (1995) evaluated the effects of helicopter logging and prescribed burning on south-facing slopes of headwater drainages in the Idaho batholith, using paired watersheds monitored from 1966 to 1986. Average annual sediment yields showed a statistically significant increase of 97 percent persisting for the 10 years of post-treatment study following logging and burning. Accelerated surface erosion occurred primarily as a result of the prescribed burning but not the helicopter logging, because burning resulted in the majority of bare soil exposure and connection of affected area to streams. Surface erosion rates in the logged and burned areas were about 66 times greater than those on undisturbed slopes. The conclusion is that current Best Management Practices (BMPs) can reduce sediment yields compared with historical practices. But there is a continued risk of increased sedimentation from forest management that will occur particularly if such activities as road building and timber harvest are to take place.

The legacy of past road building within the Basin is enormous. The FEMAT report (1993) noted that federally managed forest lands within the range of the northern spotted owl contain about 180,000 kilometers of roads, a major portion of which constitutes potential threats to riparian and aquatic habitats, mostly through sedimentation. An estimated 250,000 stream crossings (about 1.25 per kilometer) are associated with that road system, and a significant number of culverts are thought to be unable to withstand storms with a recurrence interval greater than 25 years (FEMAT 1993). Our road analysis indicated that over 205,000 kilometers of roads exist on Forest Service and BLM lands in the Basin. We expect that there are a large number of stream crossings, with higher densities of stream crossings in steep highly dissected terrain and lower densities in drier and flatter terrains. We also expect that many of the culverts or stream crossings may not function well in flood events with recurrence intervals greater than 25 years, like their westside counterparts identified in FEMAT. Even with adequate culvert size, lack of maintenance of a road network of this size would lead to significant road drainage problems.

The ability of the Forest Service and BLM to conduct road maintenance has been sharply reduced because funds for maintenance as well as timber purchaser conducted maintenance have declined. This is resulting in progressive degradation of road drainage structures and functions causing erosion rates and potential for erosion to increase (Furniss and others 1991). Most of the problems are with older roads that are located in sensitive terrain and roads that have been essentially abandoned but not adequately configured for longterm drainage. Applying erosion prevention and control treatments to high-risk roads can

drastically reduce risks for future habitat damage and can be both effective and cost-effective. In watersheds that contain high quality habitat and have only limited road networks, large amounts of habitat can be secured with small expenditures to apply "storm-proofing" and "decommissioning" activities to roads (Harr and Nichols 1993).

Given the sheer magnitude of the area of federal forests with moderate to high road densities, the job of road maintenance will be expensive. As most road networks have not been inventoried to determine influence on riparian or aquatic resource goals and objectives, there is a need to complete inventories, especially where listed or threatened fish are of concern.

Much of our previous discussion and results point to negative consequences that often accompany roads. The effects associated with roads reach beyond their direct contribution to disruption of hydrologic function and increased sediment delivery to streams. Roads provide access, and the activities that accompany access magnify the negative effects on aquatic systems beyond those due solely to roads themselves. Activities associated with roads include fishing, recreation, timber harvest, livestock grazing, agriculture, and others. Roads also provide avenues for stocking non-native fishes. Unfortunately, we do not have adequate broad-scale information on many of these attendant effects to accurately identify their component contributions (Hicks and others 1991). Thus, we are forced to use roads as a catchall indicator of human disturbance.

In preceding sections we presented results based on two analyses. Each of these analyses supports the general conclusion that increasing road density is correlated with declining aquatic habitat conditions and aquatic integrity. Our results clearly show that increasing road densities and their attendant effects are associated with declines in the status of four non-anadromous salmonid species. They are less likely to use moderate to highly roaded areas for spawning and rearing, and if found are less likely to be at strong population levels. There is a consistent and unmistakable pattern based on empirical analysis of 3,327 combinations of known species' status and subwatershed conditions, limited primarily to forested lands managed by the Forest Service and BLM.

The declines in population status of the non-anadromous salmonids should be viewed as an indication of the types of responses that may be experienced by other native species in similar habitats. Those most like the non-anadromous key salmonids in distribution or habitat requirements would be expected to show the most similar responses. This would include the anadromous species such as steelhead, stream-type chinook salmon, and Pacific lamprey that broadly overlap in range with the non-anadromous salmonids and utilize many of the same habitats for significant portions of their life. There are no logical reasons to expect anadromous fishes to be immune to the effects of habitat change from roads evident in the non-anadromous species. Other species, including sculpins, dace, and some suckers also have considerable overlap in range and may follow similar trends in population abundance and distribution.

Stronghold Watersheds and Unroaded Areas

Most aquatic conservation strategies acknowledge the need to identify the best habitats and most robust populations to use as focal points from which populations can expand, adjacent habitat can be rehabilitated, or the last refugia of a species can be conserved. At issue is whether habitat criteria or population presence and status are better indicators for such special fish emphasis watersheds. Unroaded areas potentially represent areas in which biophysical processes are still operating unimpeded from major human disturbances. Many resource managers believe that management activities in unroaded areas will increase the risk to aquatic and riparian habitat and limit the potential to achieve aquatic conservation strategy objectives. However, not all of the unroaded areas in the Basin are located in areas that are essential to reconnecting habitats and populations.

In this section, we examine several attempts to identify different special emphasis watersheds for fish. These include the Section 7 and High Priority Watersheds in the Snake River Basin, bull trout watersheds as part of the Inland Native Fish Strategy (INFISH) implementation plan, PACFISH watersheds outside of the high priority watersheds, as well as the FEMAT key watersheds in the Northern and Southern Cascades. In addition, we discuss a population status watershed approach that incorporates the use of information on excellent habitat, strong populations, and major unroaded areas.

Special emphasis areas which provide for high quality habitat and stable populations are a cornerstone of most species conservation strategies. Concern for the continued viability of salmonids on federally managed forest lands has led to establishment of the concept of "key watersheds" in which high priority is given to protecting stream habitat (Reeves and Sedell 1992; FEMAT 1993). The goal for these watersheds is to maintain the best of habitats and fish populations, and generally watersheds are chosen that have the highest potential for rehabilitation. For instance, a total of 162 key watersheds was designated that cover 8.7 million acres or approximately one third of the federal land within the range of the northern spotted owl (FEMAT 1993). These refugia were widely distributed across the landscape and were 48 to 70 percent unroaded and/or in wilderness. The designation of the key watersheds was based on rule sets that were simple. These were watersheds that: (1) were larger than 15 square kilometers and had relatively high quality water and fish habitat, or had the potential of providing high quality water and fish habitat with the implementation of rehabilitation efforts; and (2) contained habitat for potentially threatened stocks of anadromous salmonids or other potentially threatened fish species. These watersheds function as freshwater refugia for species or stocks that are currently at low population levels and also as source areas of individuals to recolonize streams that may develop more favorable conditions.

Our assessment identified 1,693 subwatersheds with strong populations of at least one of seven key salmonids within the entire Basin regardless of ownership or management class. They occupied 27 percent of the Forest Service and BLM lands in the entire assessment area. Not unlike FEMAT, our population status review generally found strong populations to be most likely in less disturbed subwatersheds. The spatial context of remaining habitats and local populations may be critical to persistence of these remnant systems. Emphasis on maintenance and rehabilitation of habitat in the Basin is tied to the importance of maintaining biodiversity and stable populations, not just habitat and watershed conditions.

The ecological importance of unroaded areas has been highlighted in this report as well as in other reports (FEMAT 1993; Henjum and others 1995). Unroaded areas have the potential to maintain natural processes unaltered by land management activities and may be important refugia for strongholds of salmonids. We examined the overlap of areas predicted to be unroaded (both within and outside of designated wilderness areas) with stronghold subwatersheds and the other important conservation watershed efforts within the Basin (tables 4.50a-c). We further examined the proportion of strongholds by fish species (seven key salmonids) contained within each of the six efforts identifying special emphasis watersheds (table 4.51).

Designated wilderness and areas predicted to be unroaded are important anchors for strongholds throughout the Basin (map 4.73). Strongholds on Forest Service and BLM lands are 58 percent predicted unroaded. Subatersheds with strongholds in the Central Idaho Mountains and the Snake Headwaters reflect the large amounts of wilderness and National Park System lands, with the largest amounts of predicted unroaded spaces in the Basin. Many predicted unroaded areas in the Lower Clark Fork and Northern Glaciated Mountains are adjacent to isolated and fragmented strongholds.

Table 4.50a—Percent of special emphasis watersheds (identified by various assessments) containing unroaded area on Forest Service and BLM administered lands within the Interior Columbia Basin Ecosystem Management Project EIS areas.

	Eastside EIS Area			Upper Columbia Basin EIS Area		
Special Emphasis Watershed	Percent Unroaded Inside Wilderness	Percent Unroaded Outside Wilderness	Percent Unroaded	Percent Unroaded Inside Wilderness	Percent Unroaded Outside Wilderness	Percent Unroaded
Subwatersheds with Known and Predicted Strongholds [1]	28	13	41	32	37	68
Section 7 Watersheds (Snake River Basin) [2]	32	19	52	33	32	65
High Priority Watersheds (Snake River Basin) [3]	48	11	59	40	39	79
PACFISH Watersheds outside High Priority [4]	27	9	37	33	15	48
INFISH (Bull Trout) Watersheds [5]	15	26	41	32	28	60
FEMAT Key Watersheds [6]	29	11	40	NA	NA	NA

[1] Developed by the Interior Columbia Basin Ecosystem Management Project.

[2] USDC National Marine Fisheries Service. 1994. Critical habitat designation for Snake River sockeye salmon, Snake River spring/summer chinook salmon and Snake River fall chinook salmon on December 28, 1993 (58 FR 68543).

[3] Stelle, William Jr. 1995. August 4 letter to the National Marine Fisheries Service.

[4] Developed as part of the Interior Columbia Basin Ecosystem Management Project.

[5] USDA Forest Service. 1995. Inland Native Fish Strategy. Volume 12. Located in Supervisor's office at the Idaho Panhandle National Forest, Coeurd'Alene, ID.

[6] Forest Ecosystem Management Assessment Team. 1993. Forest ecosystem management: an ecological, economic, and social assessment.

Known and predicted strongholds cover 40 percent of Forest Service administered lands and 4 percent of BLM administered lands. Thus, 27 percent of Forest Service and BLM lands contain the biological building blocks necessary to maintain and rehabilitate fish populations in the Basin. Areas predicted to be unroaded occupy 41 percent of area with known and predicted strongholds in the Eastside EIS area (table 4.50a). One third of this area is outside of wilderness. Sixty eight percent of known and predicted strongholds in the Upper Columbia Basin EIS area is in unroaded condition, of which 37 percent is outside of wilderness. Our assessment at the subwatershed scale, using population presence, absence, and strength (strong and depressed), is the most comprehensive effort to characterize conditions and identify important areas for fishes to date in the Basin. More than eight million hectares of Forest Service and BLM managed land are occupied by stronghold subwatersheds which contain a large area of unroaded land (about 4.7 million hectares or 58 percent).

Table 4.50b— Hectares of unroaded area in special emphasis watersheds identified by various assessments, on Forest Service and BLM administered lands within the Interior Columbia Basin Ecosystem Management Project EIS areas.

	Eastside EIS Area			Upper Columbia Basin EIS Area		
Special Emphasis Watershed	Unroaded Hectares Inside Wilderness	Unroaded Hectares Outside Wilderness	Total EEIS Unroaded Hectares	Unroaded Hectares Inside Wilderness	Unroaded Hectares Outside Wilderness	Total UCRBEIS Unroaded Hectares
Subwatersheds with Known and Predicted Strongholds [1]	820,229	364,113	1,184,342	1,643,658	1,899,967	3,543,626
Section 7 Watersheds (Snake River Basin) [2]	280,710	165,306	446,016	1,494,053	1,441,251	2,935,304
High Priority Watersheds (Snake River Basin) [3]	193,807	44,702	238,508	730,226	726,926	1,457,152
PACFISH Watersheds outside High Priority [4]	224,508	77,403	301,911	96,504	43,702	140,205
INFISH (Bull Trout) Watersheds [5]	32,601	59,202	91,803	1,053,237	921,433	1,974,670
FEMAT Key Watersheds (Eastern Cascades) [6]	280,710	105,404	386,114	NA	NA	NA

[1] Developed by the Interior Columbia Basin Ecosystem Management Project.

[2] USDC National Marine Fisheries Service. 1994. Critical habitat designation for Snake River sockeye salmon, Snake River spring/summer chinook salmon and Snake River fall chinook salmon on December 28, 1993 (58 FR 68543).

[3] Stelle, William Jr. 1995. August 4 letter to the National Marine Fisheries Service.

[4] Developed as part of the Interior Columbia Basin Ecosystem Management Project.

[5] USDA Forest Service. 1995. Inland Native Fish Strategy. Volume 12. Located in Supervisor's office at the Idaho Panhandle National Forest, Coeurd'Alene, ID.

[6] Forest Ecosystem Management Assessment Team. 1993. Forest ecosystem management:: an ecological, economic, and social assessment.

While unroaded areas are significantly more likely to support strong populations, strong populations are not excluded from roaded watersheds. There are several possible reasons for this coexistence: 1) the inherent productivity of some areas allows fish populations to persist despite disturbances linked to roads; 2) real or detectable effects on fish populations may lag behind the initial physical effects in watersheds which have been roaded in the last several years; and/or 3) the scale of the subwatershed (8,000 hectares on average) at which strong populations are identified may mask a potential disconnect between the real locations of strongholds and roads (which are identified at one square kilometer pixels). This issue of scale would be resolved with a mid-scale or subwatershed analysis. The fact that strong salmonid populations can coexist in many roaded areas provides

Table 4.50c— Total hectares of special emphasis watersheds identified by various assessments, on Forest Service and BLM administered lands within the Interior Columbia Basin Ecosystem Management Project EIS areas

Special Emphasis Watershed	Total Eastside EIS Hectares	Total Upper Columbia Basin EIS Hectares
Watersheds with Known and Predicted Strongholds [1]	2,892,803	5,195,385
Section 7 Watersheds (Snake River Basin) [2]	853,531	4,453,258
High Priority Watersheds (Snake River Basin) [3]	402,114	1,837,465
PACFISH Watersheds outside High Priority [4]	824,129	290,210
INFISH (Bull Trout) Watersheds[5]	224,708	3,293,817
FEMAT Key Watersheds [6]	955,934	NA

[1] Developed by the Interior Columbia Basin Ecosystem Management Project.

[2] USDC National Marine Fisheries Service. 1994. Critical habitat designation for Snake River sockeye salmon, Snake River spring/summer chinook salmon and Snake River fall chinook salmon on December 28, 1993 (58 FR 68543).

[3] Stelle, William Jr. 1995. August 4 letter to the National Marine Fisheries Service.

[4] Developed as part of the Interior Columbia Basin Ecosystem Management Project.

[5] USDA Forest Service. 1995. Inland Native Fish Strategy. Volume 12. Located in Supervisor's office at the Idaho Panhandle National Forest, Coeurd'Alene, ID.

[6] Forest Ecosystem Management Assessment Team. 1993. Forest ecosystem management:: an ecological, economic, and social assessment.

opportunities to determine the reasons why, and may prove instructive for both watershed restoration and future road building. It is not prudent, however, given current information to assume that because roads and fishes coexist in some watersheds they will in others. In general, greater short-term or long-term watershed and ecological risks are associated with entering an unroaded area than with proceeding cautiously with management activities in roaded areas to close and obliterate existing roads. The data strongly suggest a closer examination of the stronghold subwatersheds and their roaded condition.

As an outcome of Section 7 consultation and PACFISH direction, the Forest Service, BLM and National Marine Fisheries Service identified 54 high priority watersheds in the Snake River. These watersheds were intended to identify the best spawning and rearing habitats for the federally listed chinook salmon which currently has few strongholds in the Columbia River Basin, none of which are in the Snake River. These watersheds totaled approximately 2.2 million hectares accessible to anadromous fish. The Eastside EIS area contains 18 percent and the Upper Columbia Basin EIS area contains 82 percent of the total area of these watersheds. Subwatersheds with strongholds occupy 56 percent of the area in high priority watersheds.

Private land in special emphasis watersheds is usually situated in low gradient, unconstrained valley stream reaches which were historically important areas of high habitat complexity for spawning and rearing habitat (for example, approximately 12 percent of high priority watersheds are in private land). This small percentage of area belies the magnitude of its importance within forested special emphasis watersheds. Historically the best quality habitat during drought periods and winter was generally at lower elevations and

Table 4.51— Percent of special emphasis watersheds within the current range of key salmonids.

Special Emphasis Watershed	Status	Bull trout	Westslope cutthroat	Yellowstone cutthroat	Redband	Steelhead	Ocean-type Chinook	Stream-type Chinook
Section 7 Watersheds - Snake R.		58	75	0	60	39	50	60
High Priority Watersheds	Absent	25	40	0	30	24	32	31
PACFISH: outside high priority		5	2	0	10	3	10	5
INFISH (Bull Trout) Watersheds		18	10	0	15	23	1	22
FEMAT Key Watersheds		5	4	0	7	5	17	3
Section 7 Watersheds - Snake R.		53	62	0	66	81	74	83
High Priority Watersheds	Present-	39	33	0	37	47	18	56
PACFISH: outside high priority	Depressed	13	4	0	5	13	0	16
INFISH (Bull Trout) Watersheds		37	38	0	20	18	0	19
FEMAT Key Watersheds		2	1	0	3	4	14	5
Section 7 Watersheds - Snake R.		73	63	0	51	23	0	0
High Priority Watersheds	Present-	70	36	0	41	23	0	22
PACFISH: outside high priority	Strong	10	10	0	17	73	0	100
INFISH (Bull Trout) Watersheds		32	31	0	14	0	0	0
FEMAT Key Watersheds		4	11	0	4	0	30	0
Section 7 Watersheds - Snake R.						83	0	84
High Priority Watersheds	Migration					35	0	34
PACFISH: outside high priority						7	0	5
INFISH (Bull Trout) Watersheds						11	0	11
FEMAT Key Watersheds						0	0	2

Map 4.73—Designated wilderness and predicted unroaded areas overlaid on known and predicted strong populations of seven key fish species in the Basin.

often in larger streams which can support more complex life forms (large and small fishes of different age classes). Private lands can play an important ecological role in sustaining or restoring different ecosystem and rehabilitating certain fish populations.

In examining the area of various special emphasis watersheds and the proportion of subwatersheds included in each effort conditional on species and population status (table 4.51), delineation of stronghold watersheds provides a robust and extensive area from which any conservation strategy could proceed. Since too few watersheds exist with strong anadromous fish populations, watersheds with depressed anadromous fish are essential to anchor a conservation strategy.

Opportunities for Conservation

In the last three years 15 aquatic conservation strategies or assessments have been completed in the Pacific Northwest and Alaska (table 4.52). The 15 strategies represent contributions from agencies (6); university scientist panels (4), forest industry (1), environmental groups (2), private consulting contracts (1), and a coalition of tribes (1). The approaches range from an acknowledged attempt to build the best ecosystem strategy in the world (Clayoquot Sound Scientific Panel 1995) to a riparian inputs maintenance plan (National Forest Resource Council 1995). All but the Clayoquot Sound Scientific Panel (1995) were developed for the Columbia River Basin or parts of the Basin.

That at least 15 independent assessments and strategies exist for the Pacific Northwest is an indication of the difficulties of the agencies and interested parties to work together to develop a common management plan. However, the similarity in the conclusions drawn by each strategy is also an indication of the clarity about some of the problems and solutions being addressed:

- All strategies (except Fish 2000) discuss the concept of connectivity of habitats and metapopulation theory and their importance as integral components of an aquatic conservation strategy.
- All assessments emphasize the need to examine problems at multiple scales and that the social and institutional contexts are important.
- All strategies (except Fish 2000) make the same cumulative effects arguments.
- All strategies discuss moving from single species management to ecosystem management approaches while including provisions for rare elements.
- A common assumption is that federally administrated lands bear the responsibility of sustaining biological diversity.

An element common to each of the studies is an acknowledgment that the current management of aquatic and riparian ecosystems is insufficient to maintain the processes and functions of these systems. Each study attempted to provide a strategy that took conservation of aquatic resources one step further than the then-current state in light of identified problems. In general, all strategies were based on similar concepts, identified the same suite of factors and processes as concerns, and proposed mitigation that included essentially the same suite of planning and protective measures. The differences lay primarily in the specifics of what was recommended, the implementation strategy (if any), and the approach.

There appears to be a consistent assumption that activities will continue to occur within watersheds that are incompatible with maintaining biodiversity and natural processes and functions. Therefore, the common approach is to develop a strategy that mitigates or isolates the negative impacts, whether that is to allocate resources within a watershed (concept of riparian habitat conservation areas) or whether it is to dedicate whole watersheds where the highest management goal is to maintain that area of biodiversity.

With the human population of the Basin growing at about 1.9 percent annually, the challenge is readily apparent. Current and future efforts to save natural populations of both resident and anadromous salmonids, such as conservation measures,

Table 4.52— Assessments on aquatic and riparian systems in the Pacific Northwest conducted during the last five years.

Aquatic and Riparian Assessments
Botkin, D.B., K. Cummins, T. Dunne, H. Regier, M. Sobel, L. Talbot, and L. Simpson. 1995. Status and Future of Salmon of Western Oregon and Northern California: Findings and Options. Research Report 951002, The Center for the Study of the Environment, P.O. Box 6945, Santa Barbara, California 93106.
Clayoquot Sound Scientific Panel. 1995. Sustainable Ecosystem Management in Clayoquot Sound: Planning and Practices.
CRITFC. Columbia River Intertribal Fish Commision 1995. *Wy-Kan-Ush-Mi Wa-Kish-Wit*: Spirit of the Salmon, The Columbia River Anadromous Fish Restoration Plan of the Nez Perce, Umatilla, Warm Springs and Yakama Tribes. Volume I.
Henjum, M. G., J.R. Karr, D.L. Bottom, D.A. Perry, J.C. Bednarz, S.G. Wright, S.A. Beckwitt, and E. Beckwitt. 1994. Interim Protection for Late-Successional Forests, Fisheries, and Watersheds: National Forests East of the Cascade Crest, Oregon and Washington. Bethesda, MD: The Wildlife Society:129-168.
McGreer, D.J. 1995. National Forest Riparian Aquatic Habitat Management Strategy (Fish 2000). National Forest Resource Council. Lewiston, Idaho.
Moyle, P. B. 1995. Water and Life in the Sierra Nevada: Status and Trends of Aquatic Organisms and Habitats. Final Report Sierra Nevada Ecosystem Project. Davis, CA.
Murphy, M. L. 1995. Forestry impacts on freshwater habitats and anadromous salmonids in the Pacific Northwest and Alaska: requirements for protection and restoration. NOAA Coastal Ocean Program. Decision Analysis Series No.7. NOAA Coastal Ocean Office, Silver Spring, MD.
Nelson, C., ed. 1995. Key Elements for Ecological Planning: Management Principles, Recommendations, and Guidelines for Federal Lands East of the Cascade Crest in Oregon and Washington. A report to the Columbia Basin Ecosystem Management Project. May 19, 1995. Columbia River Bioregion Campaign, Science Working Group, 41 South Palouse Street, Walla Walla, Washington 99362.
Pacific Rivers Council. 1994. Management Recommendations for Aquatic Conservation in Eastern Oregon and Washington. Pacific Rivers Council, 921 SW Morrison #531, Portland, Oregon 97205.
Spence, Brian C.; Lomnicky, Gregg A.; Hughes, Robert M.; Novitzki, Richard P. 1995. An Ecosystem Approach to Salmonid Conservation, Volume I: Technical Foundation. Report to the National Marine Fisheries Service, Environmental Protection Agency, and Fish and Wildlife Service. ManTech Environmental Research Services Corp. Corvallis, OR.
USDA Forest Service; USDI Bureau of Land Management 1994. Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl.
USDA Forest Service; USDI Bureau of Land Management. 1995. Decision Notice/Decision Record, FONSI, EA, Appendices for the Interim Strategies for Managing Anadromous Fish-Producing Watersheds in Eastern Oregon and Washington, Idaho, and Portions of California (PACFISH), USDA Forest Service and USDI Bureau of Land Management.
USDA Forest Service; US Fish and Wildlife Service. 1995. Environmental Assessment Inland Native Fish Strategy.
USDA Forest Service Regions 1, 4, and 6. 1991. Columbia River Basin Anadromous Fish Habitat Management Policy and Implementation Guide (PIG).
USDC National Marine Fisheries Service. 1995. Proposed Recovery Plan for Snake River Salmon.

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improved land use practices, reduced competition from hatchery stocks, improved dam passage, and better riparian protection on all lands, could be undermined by continued regional population and economic growth.

A Broad-scale Context

An assumed goal of ecosystem management is to maintain or restore the integrity of aquatic ecosystems and to provide for the long term persistence of native and desirable non-native fishes and other species. Achieving this goal will require the maintenance or restoration of a network of well-connected, high-quality habitats that support a diverse assemblage of native species, the full expression of potential life histories and dispersal mechanisms, and the genetic diversity necessary for long-term persistence and adaptation in a variable environment. The concept of key watersheds has been used to identify areas that represent critical components of the mosaic that need to be conserved in the short term. In many cases, however, focus on a fixed set of high-quality watersheds will not meet the goals for healthy, functional aquatic ecosystems because they are too few and poorly distributed, and because natural succession and disturbance processes may preempt long-term productivity in fixed sites. Watershed rehabilitation and the development of more ecologically compatible land-use policies are required to ensure the long-term productivity of many systems. The next step then, implies more than a system of watershed reserves; it implies managing watersheds to reestablish more complete or natural structure, function, and processes. Again, the challenge is to work with the management of terrestrial systems rather than at cross purposes.

To assist in developing a more interdisciplinary dialogue, we developed a simple classification of subbasins throughout the Basin. The classification scheme provides a spatially explicit description of aquatic issues, needs, and opportunities that can be associated with similar descriptions for terrestrial ecosystems. It is not intended to be rigid. Rather, the classification is based on the integration of current data with local, qualitative knowledge of watershed connectivity and other conditions. This classification scheme may be useful as a tool for identifying the opportunities and conflicts that are likely to emerge from the multiple priorities and objectives inherent in ecosystem management.

Inherent in our classification is a template for prioritizing needs and opportunities for conservation and active rehabilitation. Several strategies have been proposed for the development of habitat networks designed to conserve species and aquatic biological diversity (Doppelt and others 1993; Frissell and others 1993; Moyle and Sato 1991; Reeves and Sedell 1992; Rieman and McIntyre 1993). A general consensus of these reports is that conservation and rehabilitation should focus first on the best remaining examples of aquatic biological integrity and diversity. Clearly, effectiveness of any conservation strategy improves with more detailed information regarding the distribution and composition and condition of aquatic communities. Earlier in this report we began the identification of unique or particularly important watersheds and basins. The data are most useful for considering patterns and important areas at the scale of the entire assessment area. These data provide a starting point for finer scale evaluations (such as within subbasins), but local information must be used to validate and extend these results. It will be particularly important to include information for aquatic organisms (that is, plants, invertebrates, amphibians) that could not be addressed in our analysis. We emphasize that this classification scheme is preliminary and should not be used for prescription of management activities without further refinement.

Most of the information used in our subbasin classification scheme is presented in preceding sections of this report. In particular, we relied heavily on the distributional maps of salmonid strongholds and our derived measures of community structure. We also looked closely at human influences when considering opportunities and

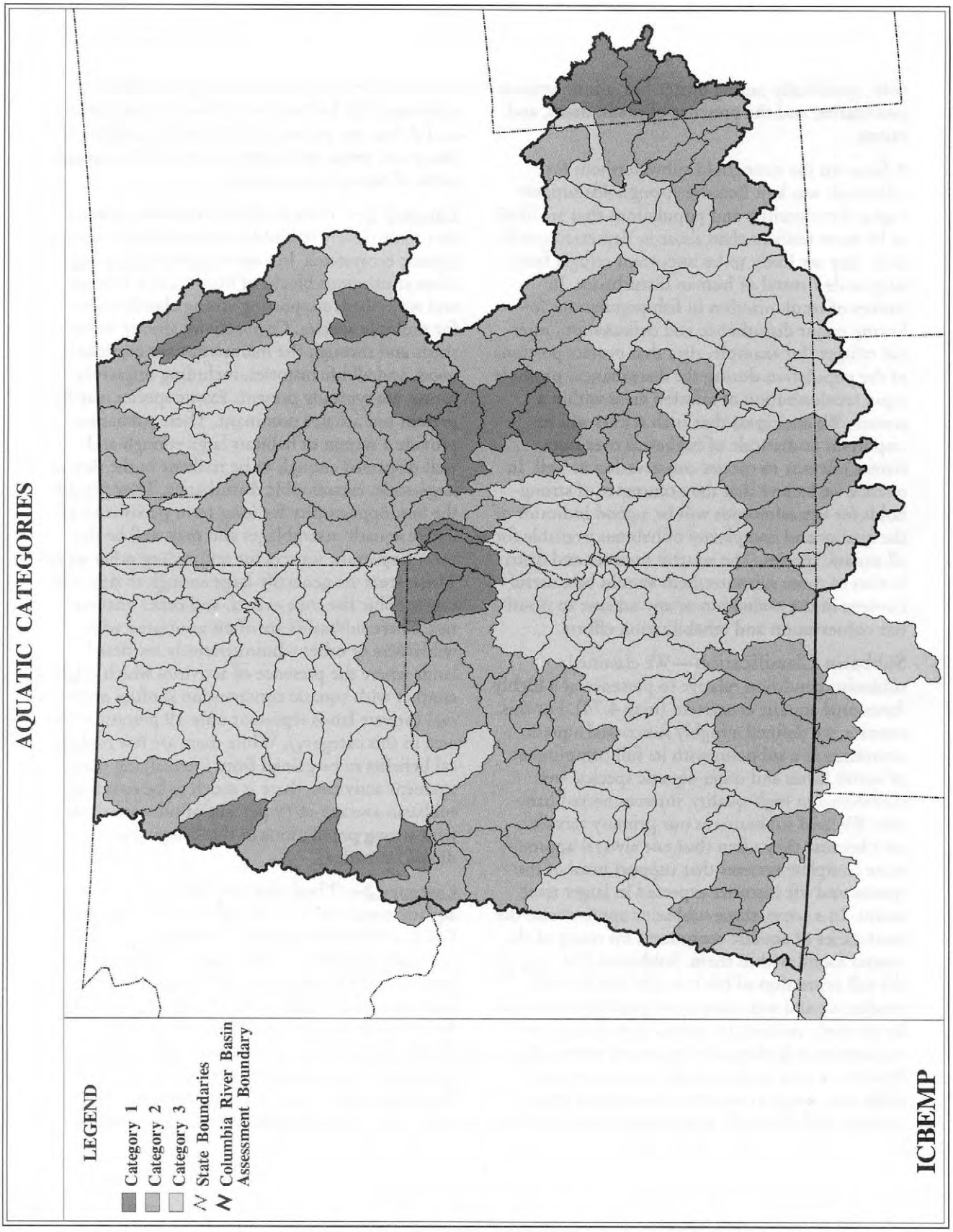
risks, specifically noting ownership, administrative boundaries, and the presence of roads, dams, and mines.

A focus on the stronghold subwatersheds for salmonids was key. Because strongholds support higher fish densities and populations that are likely to be more resilient than those in depressed condition, they are likely to be important refugia from large-scale natural or human disturbance. In studies of recolonization in fish populations following major disturbance and defaunation, internal refuges (for example, sites that protect portions of the population during the disturbance) promote rapid recolonization of affected areas within a stream. We anticipate that such effects will be important at the scale of subbasins over time frames relevant to species conservation as well. In essence we believe that the occurrence of strongholds for key salmonids will be a good indicator of the quality and complexity of habitats available for all aquatic species. The relative number and distribution of those subwatersheds should be a useful element in the evaluation of any scheme to prioritize conservation and rehabilitation efforts.

Subbasin Classification—We classified subbasins condition relative to presence of a highly functional aquatic ecosystem (map 4.74). For this exercise, we defined a highly functional aquatic ecosystem as a subbasin with its full compliment of native fishes and other aquatic species, well distributed in high-quality, interconnected habitats. We used subbasins as our primary sample unit because they often (but not always) approximate complete systems that support most of the species and life histories expected in larger river basins. In a sense, these subbasins approximate the boundaries of aquatic ecosystems for many of the species found within them. Subbasins that support the full expression of life histories and possess productive and well-connected populations should be relatively resilient to natural disturbances anticipated over biologically important time scales. Persistence over evolutionarily important time scales may imply connection across even larger systems, and obviously anadromous species require a connection to the ocean through multiple subbasins. We believe that subbasins represent a useful, but not exclusive boundary for analysis of issues and needs and opportunities in the management of aquatic ecosystems.

Category 1— These subbasins represent systems that most closely resemble natural, fully functional aquatic ecosystems. In general they support large, often continuous blocks of high-quality habitat and watersheds supporting strong classifications for multiple species. Connectivity among watersheds and through the mainstem river corridor is good, and all life histories, including migratory forms, are typically present. Exotic species may be present but are not dominant. These subbasins provide a system of habitats large enough and well-dispersed enough to be resilient in the face of large-scale, catastrophic disturbance. They provide the best opportunity for long-term persistence of native aquatic assemblages and may well be the most important sources for refounding other areas. These areas are generally large enough to deal with catastrophic fire, rare events, and other uncertainties. These subbasins are often associated with wilderness or other administratively restricted lands where the presence of activities which might conflict with aquatic conservation is often minimal (private lands represent only 19 percent of the area in this category). While there are few ecological benefits to be gained from intensifying management activities, there is much to be risked (a subbasin average of 79 percent of subwatersheds with strong populations in this category is predicted unroaded).

Category 2— These subbasins support important aquatic resources, often with subwatersheds classified as strongholds for one or multiple species scattered throughout. The most important difference between Category 1 and Category 2 is an increased level of fragmentation that has resulted from habitat disruption or loss. These subbasins clearly have a substantial number of watersheds where native species have been lost or are at risk for a variety of reasons. Connectivity among watersheds may still exist or could be restored



Map 4.74- Classification of subbasins. Category 1 reflects the most robust populations and habitats; Category 2 reflects fewer strongholds and greater isolation within a subbasin, but with a potential to restore an interconnected network of adjacent strongholds; and Category 3 reflects few, perhaps no strongholds which have little potential for reconnection (through rehabilitation) with other strongholds to create a larger network of stronghold watersheds.

through the mainstem river system, such that maintenance or rehabilitation of life-history patterns and dispersal among watersheds is possible. Reestablishing the necessary mosaic of habitats will often require conservation of existing high quality sites as well as the rehabilitation of whole watersheds that still support remnant populations. Private lands represent 32 percent of area in this category. These subbasins often fall in some of the more intensively managed landscapes and have some of the most extensive road networks. They also have the greatest need and opportunity for restoration of structure and composition of vegetation communities.

In many cases there may be an opportunity to accomplish watershed rehabilitation while conducting forest treatments. For example, where extensive road networks already exist, treatments might be focused over a relatively short period allowing road removal upon completion (a subbasin average of 48 percent of strongholds in this category is already predicted unroaded). Because watersheds requiring very conservative approaches to protect key resources are often scattered rather than contiguous, intensive forest management might be prioritized and focused in the area around them, thereby minimizing risks. The opportunities to explore and experiment with watershed restoration through active manipulation or through attempts to produce more episodic disturbance followed by long periods of recovery (Reeves and others 1995) are most likely to exist in these subbasins. Conceivably, these subbasins offer the greatest opportunity for positive solutions across multiple resource issues.

Category 3— These subbasins may have some subwatersheds supporting key salmonids classified as strong or have other important aquatic values (such as threatened and endangered species, narrow endemics, introduced or hatchery supported sport fisheries). In general, however, these watersheds are strongly fragmented by extensive habitat loss or disruption throughout the component watersheds and most notably through disruption of the mainstem corridor. Major portions of these subbasins (43 percent of the area in this category) are often associated with private and agricultural lands not managed by the Forest Service or BLM. Although important and unique aquatic resources exist, they are most often localized. The opportunity for restoring connectivity among watersheds, the full expression of life histories, or other large-scale characteristics of fully functioning and resilient aquatic ecosystems are very limited or nonexistent. Because the remaining aquatic resources are often strongly isolated, the risks of local extirpation may be high. While conservation of the remaining strongholds or other aquatic resources is important, land use activities can occur in the rest of the subbasin with less risk to critical resources (a subbasin average of 26 percent of strongholds in this category is predicted unroaded). Because these subbasins are often associated with large areas of non-Federal land, conservation of the remaining productive areas may result in a disproportionate contribution from Federal land management agencies.

The preceding classification scheme considers both the need and opportunity for conservation and rehabilitation of more functional aquatic ecosystems at the subbasin scale. The approach is simplistic and based entirely on information regarding the status of fishes. Other important considerations that might refine judgments regarding those needs and opportunities include the risks to aquatic ecosystems from mechanical disturbance that varies with geology, climate, and topography.

The concept that risk increases in mechanically disturbed environments is supported by the findings that habitat and population conditions are inversely related to the amount of roads present. Such effects may include a general simplification and degradation of habitats but also an increase in the frequency and magnitude of disturbance events. Those effects may be more important in some landscapes than others. For example, Columbia River Basalt geology is inherently more stable and less erodible than Idaho Batholith geology (Andre and Anderson, 1961; Wallis and Willen 1963), and therefore less risk to aquatic

ecosystems from mechanical disturbance can be inferred in the basalt geology. Sensitivity to disturbance may influence both the urgency and necessity of conservation and rehabilitation activities. Our classification scheme was intended only to convey a logic in determining management opportunities. The application and refinement of that scheme could include important physiographic elements as well as a finer resolution.

Application at the Mid Scale

At the mid-scale level, the focus is on single subbasins or a small group of adjacent subbasins. Many of the important issues at the broad scale are equally important at the mid scale, and vice versa. One such issue involves metapopulation dynamics. Metapopulations are a collection of populations or demes, each vulnerable to local extirpation but potentially supported or recolonized through dispersal from surrounding populations (Hanski 1991). Metapopulation ideas seem relevant for fishes, especially the salmonids (Bisson and others 1996; Rieman and McIntyre 1993, 1995; Rieman and others 1993) that show local population structuring through strong homing tendencies and the potential for dispersal through straying (Quinn and others 1991). Increased spatial structuring and associated dynamics may be particularly important for fishes persisting in increasingly fragmented environments. Metapopulation dynamics are still poorly understood, however, and there is little empirical evidence to guide conservation or active management of such processes or structures. The idea of creating or supporting spatial and temporal patterns of disturbance consistent with these larger scale dynamics is conceptually and theoretically appealing (Reeves and others 1995; Bisson and others, 1996). We still lack the understanding, however, to support broadscale and intensive manipulation of systems with that intent.

We know little about the spatial and temporal dynamics of species at scales larger than stream reaches, yet we clearly recognize processes acting among reaches, watersheds, and even river basins strongly influence the dynamics, persistence, and diversity of populations and species (Rieman and McIntyre 1993, 1995, 1996; Bisson 1995; Frissell and Bayles 1996). Conservation of genetic diversity clearly implies conservation of populations and habitats across their full range of distribution (the entire Basin area for some species) (Leary and others 1993; Lesica and Allendorf 1995). Conservation of species, life-history, and phenotypic diversity may imply conservation of populations and habitats across entire subbasins or basins (Healey 1994; Lichatowich and Mobrand 1995). For example, earlier we showed some overlap in the distribution of salmonids within 6th-field subwatersheds, but few of those subwatersheds support strong populations of more than two species while subbasins may support as many as six. Rieman and McIntyre (1995) demonstrated that the consistent occurrence of local populations of bull trout is associated with suitable watersheds larger than 5,000 hectares. Rieman and McIntyre (1996) found that local populations of bull trout distributed among a collection of similar sized watersheds throughout a much larger subbasin may fluctuate independently even though they share common migratory and rearing environments. Rieman and others (in press) argue that the persistence of bull trout in Rattlesnake Creek, an 8,000 hectare watershed, following a catastrophic fire was dependent upon a migratory life-history that required access to the much larger Boise River Basin (300,000 hectares). The full diversity of life-history forms for westslope cutthroat trout or chinook salmon are associated with areas comparable to or larger than whole subbasins (Rieman and Apperson 1979; Lichatowich and Mobrand 1995).

The implication, is that effective conservation of aquatic diversity and resilience will require the maintenance of complex habitats and networks of those habitats at multiple scales. That is not likely to happen if management activities continue to result in a chance pattern of habitats like that left by historical management practices. In many cases, the best remaining habitats are clumped in headwaters, with the most degraded conditions found

at lower elevations and often on private lands. In other cases, productive areas may extend throughout a subbasin but are represented by scattered watersheds in a matrix of more severely degraded conditions.

Securing existing habitats and subwatersheds that support the strongest populations and highest native diversity and integrity is a high priority in applying any conservation principles at the subbasin scale. Within areas emphasized for aquatic systems, addressing and fixing existing threats to watershed processes without adding new ones is a next step. A third step could be the extension of favorable conditions into adjacent watersheds creating a more secure, larger, or more contiguous network of suitable or productive habitats. The fourth step could be the extension of good habitats into more poorly represented parts of a subbasin. The existing distribution of species and life histories, and their potential to colonize or support newly available or rehabilitated environments, will provide the framework for the selection or prioritization of watersheds for conservation and rehabilitation.

Further research is necessary to develop management techniques that mimic natural disturbance regimes and the temporal and spatial dynamic relevant to the evolution of aquatic ecosystems (see Reeves and others 1995). Meanwhile, however, conservation and rehabilitation of a broader network of complex habitats will preserve options for the future.

Example Within a Subbasin—As a way of better illustrating the above concepts, we provide an example of how this might be done at the subbasin level. It is our intent to provide an illustration of the logic that could be applied, not to provide a specific guide for any subbasin or subwatershed.

The hypothetical subbasin for our example is a member of our aquatic Category 2. We selected a Category 2 subbasin because we expect the most variability in management priorities as well as the highest need and opportunity for active rehabilitation in this category. The subbasin supports wild native populations of westslope cutthroat, bull, and redband trout, steelhead, and stream-type chinook salmon, several other native species, and introduced populations of brook trout and Yellowstone cutthroat trout. Two lakes that historically supported sockeye salmon retain kokanee that may be remnant, residualized sockeye. Human activities including mining, timber harvest, and roading have substantially altered watershed characteristics and the condition of fish populations. Several subwatersheds still support relatively strong local populations of the salmonids, and mainstem rivers still function as wintering areas and migratory corridors for each of these species. The subbasin still supports a core of important habitats for native species and retains important components of the connectivity and life histories found in the historical system (fig. 4.25a-c).

We indexed the location of the best remaining habitats by describing the known strong subwatersheds for the native salmonids and by describing the distribution of the rare/sensitive species. Three non-anadromous species were strong in some subwatersheds. Anadromous salmonids are not considered strong in any of the subwatersheds. Wild, indigenous stocks of both chinook salmon and steelhead spawn in the subbasin, however. We considered wild anadromous salmonid production areas to be of equal status to subwatersheds supporting strong populations of the other salmonids. Hatchery-influenced chinook salmon (progeny of hatchery reared or mixed wild and hatchery parentage that naturally spawn) also spawn in the subbasin; however, we did not consider their spawning and rearing areas to be of equal concern to wild populations because they are supported, in part, by artificial production.

Subwatersheds that supported two or more species strongholds, spawning areas for wild salmon and steelhead, or kokanee were categorized as "Type 1". Type 1 subwatersheds were clustered in three areas of the subbasin. These subwatersheds currently support much of the biological diversity in the subbasin (fig. 4.25d).

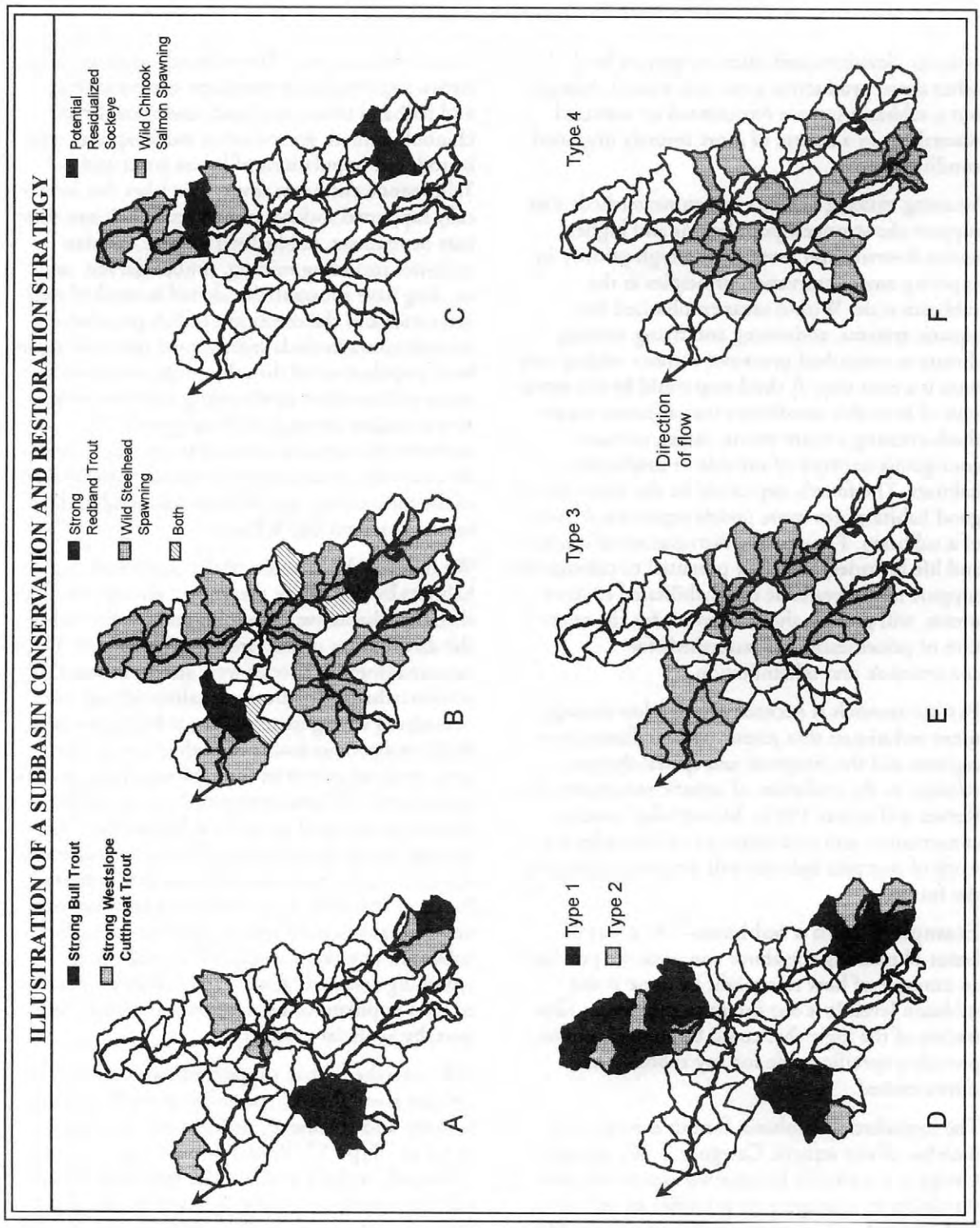


Figure 4.25—Illustration of a subbasin approach to conservation and rehabilitation of native fishes.

We considered the second type of subwatershed, Type 2, as those that supported important habitats either adjacent to or likely to influence the Type 1 subwatersheds. In this case we selected subwatersheds that created larger blocks of habitat contiguous with the Type 1 subwatersheds (fig. 4.25d).

Our third type of subwatershed, Type 3, were those that: 1) contained at least one strong population of a key salmonid, a spawning area for wild salmon or steelhead, or a rare/sensitive fish species; or 2) supported spawning and rearing habitat for two or more native key salmonids; and 3) were not closely associated with other currently productive areas (fig. 4.25e). Excepting redband trout, none of our Type 3 subwatersheds supported strong populations. Several supported populations of bull trout in headwater reaches of the subwatershed suggest that core areas for rebuilding bull trout populations are present. Most Type 3 subwatersheds supported spawning and rearing habitats for wild steelhead, natural stream-type chinook salmon, bull trout, and westslope cutthroat trout. Most Type 3 subwatersheds remained connected to larger portions of the subbasin, suggesting that rehabilitation of both fluvial and resident trouts might be feasible.

The remaining subwatersheds Type 4 (fig. 4.25f) were those that currently support no known strong populations, no spawning areas for wild anadromous salmonids, no rare/sensitive fish species, and do not directly influence subwatersheds that do. Although these areas are currently judged to support no priority populations, many retain multiple native species. Type 4 subwatersheds may be less critical to short and intermediate term persistence of key species and are less likely to contribute to the larger system than those considered above.

Potential Opportunities—Effective conservation and watershed rehabilitation efforts coupled with progress in improving salmon and steelhead migration corridors could restore a more complete and functional aquatic ecosystem. In Type 1 subwatersheds actions to secure and rehabilitate the watershed and riparian processes that maintain and create habitats in these systems would be especially important to the conservation of biological diversity and function in the subbasin. Because many of these subwatersheds may already be in relatively good condition, significant benefits may be realized with relatively small investments. Focusing conservation and rehabilitation activities in Type 2 subwatersheds could build larger networks of important habitats, add to the spatial extent and potential diversity of habitats, and influence the condition of important mainstem spawning and wintering habitats further downstream. Type 3 subwatersheds may represent important habitats in the future, and would benefit from focused management activities that allowed long-term recovery of habitat conditions. Long-term watershed rehabilitation would be slower in Type 4 subwatersheds, and initial investments might be less effective than in other areas. Type 4 systems could be good places on which to focus experimental and active management that has unproven or uncertain risks for aquatic systems.

Areas where fish information is lacking may require special treatment. An appropriate approach in areas where status of important native fishes is unknown might be to emphasize collection of adequate data prior to adding any additional risk from management actions.

The subwatershed types outlined above are presented simply to illustrate the application of conservation biology principles that might be used to develop fish/aquatic needs and opportunities to assist in the first stage of planning for ecosystem management at a subbasin scale. The classification of subwatersheds might be modified by information on distribution of other species or specific issues for the species we did consider. For example, many subbasins may not currently support strong salmonid populations, wild anadromous fish, or rare/sensitive species. In those areas, the logic for classifying subwatersheds might include those areas retaining the largest numbers of native species.

Fish conservation priorities might also be modified by risks and opportunities associated with the legacy of, and sensitivity to, natural and mechanical disturbance. Geologic and climatic setting,

topographic features, existing road networks, watershed condition, anticipated risks of existing or planned activities, and conflict or convergence with other resource management goals will provide finer resolution. Watershed and habitat conditions will strongly influence conservation and rehabilitation potential and will make some systems better candidates for rehabilitation activities than others. In our analysis of subwatershed types for example, we did not incorporate trends in habitat condition, but only the existing condition as inferred from the current known distribution and status of fishes. Had we considered trends, some areas that were classified based on fish status might be elevated to higher priorities for rehabilitation if particularly important risks existed. Similarly, areas judged to be of lower emphasis for conservation and rehabilitation based solely on fish status, may become higher priorities for rehabilitation when integrated with other resources (terrestrial species concerns for example) especially if habitats are already trending toward restoration. Areas trending toward less capability to produce fish or aquatic diversity might be either too severely altered to feasibly restore or very high priority for rehabilitation, depending upon the degree of fragmentation or isolation in populations, Endangered Species Act concerns, relative risks involved, and sensitivity of the species involved.

The location and condition of a subwatershed may also be critical for assessing its importance to the overall subbasin. For example, if a lower emphasis area is severely degraded and it lies directly upstream from and influences a critical spawning and rearing area for several species, managers may choose to emphasize its rehabilitation because it will directly improve conditions in the critical habitat downstream.

Implementation of watershed conservation and rehabilitation activities will obviously be constrained by management commitment and resources. The basin and subbasin scale scheme presented here can assist planning and prioritization of activities at larger scales. We do not consider all subbasins described as "Category 2" to be the same; their inherent differences should play an important role in determining the urgency and nature of conservation and rehabilitation activities that occur within the subwatersheds. The current condition of a subbasin and the inherent environmental variability and sensitivity of the composite subwatersheds to disturbance may dictate the urgency of management actions. For example, watersheds in the Central Idaho batholith that lie in erodible soils and are subject to high intensity thunderstorms, or those in the belt geologies of northern Idaho that are subject to frequent rain on snow events represent highly variable and sensitive environments for aquatic organisms. Fragmentation and disruption of habitats in these systems could pose much greater risks for sensitive species than in more stable environments. Such risks might imply a greater urgency to secure critical habitats and to rehabilitate habitat networks and watershed processes in some subbasins than others.

Application at a Fine-Scale: Riparian Areas and Cumulative Watershed Effects

Aquatic and riparian systems are easily affected by land management activities surrounding them. In general, there is little controversy over the need to provide buffers to maintain ecological function. The controversy is over the width of the buffers, the extent and type of activities which can occur within them, and the purposes for these activities. Riparian Habitat Conservation Areas (RHCA) are portions of watersheds where riparian dependent resources receive primary emphasis and management activities are subject to specific standards and guidelines (PACFISH 1994). Forest plans and forest practice rules regulate two major features of RHCA: their width and the kind and amount of activity that can take place within them. Evaluating the effectiveness of RHCAs to protect and manage riparian areas is difficult because of the complexity of the ecological function of such areas and the extended time over which impacts can occur and ecosystems might need to recover. The

RHCA must be wide enough to maintain ecological function at the small watershed level and limit disturbance near streams. At issue is the size of RHCAs and the function they provide throughout a stream network to reduce sedimentation and limit potential losses of aquatic biodiversity and habitat. We also address cumulative watershed effects (CWE) models which purport to account for the total amount of CWE quantitatively and limit CWE that may accumulate as a result of management activities or natural events such as wildfire and floods.

Riparian Area Management—Four biophysical principles underlie any evaluation of a riparian management strategy: 1) a stream requires predictable and near-natural energy and nutrient inputs; 2) many plant and animal communities rely on streamside forests and vegetation; 3) small streams are generally more affected by hillslope activities than are larger streams; and 4) as adjacent slopes become steeper, the likelihood of disturbance resulting in discernable in-stream effects increases.

Importance of Energy Inputs to Streams—First, stream and riparian organisms need energy (leaves, wood, organic carbon) and nutritional inputs to sustain their biological functions. An understanding of the influence of riparian vegetation on streams is fundamental to understanding the function and effectiveness of RHCAs. Streams are intricately connected physically, chemically, and biologically to their riparian zones (Murphy and Meehan 1991; Naiman and others 1992; Gregory and others 1991). Roots of streamside vegetation stabilize banks, retard erosion, and affect nutrients in groundwater. Root systems, in combination with large woody debris, provide channel roughness elements that not only promote sediment storage but encourage the hydraulic exchange of streamflow and subsurface flows. Vegetation and downed woody debris dissipate stream energy during floods and obstruct movement of sediment and organic matter (Sedell and Bestcha 1991). The combination creates very complex habitats for aquatic organisms. The canopy provides leaves and other organic materials that are part of the energy base for the stream ecosystem, and its shade limits algal production and moderates stream temperature. Trees that fall into the stream provide the principal structural features that shape the stream's morphology, linkages to the floodplain, habitat complexity, streambed materials, and other characteristics (Salo and Cundy 1987; Meehan 1991; Naiman 1992).

Protection for Riparian Dependent Plants and Animals—Second, some terrestrial and semi-aquatic plant and animal communities rely on the forest and shrubs adjacent to streams (Terrestrial Ecology, Chapter 5). Animals such as beavers, otters, dippers, and some amphibians are obligate stream and riparian vegetation dependent organisms. Other bird and mammal species and many bat species need the riparian management area at crucial life history periods or seasonally for feeding or breeding. Wildlife has a disproportionally high use of riparian areas and streamside forests compared with the overall landscape. RHCAs provide habitat needs such as water; cover; food; plant community structure, composition, and diversity; increased humidity; high edge-to-area ratios; and migration routes (Carlson 1991; O'Connell and others 1993). The Washington Department of Wildlife (1992) recommended wetland buffer widths for protection of wildlife species in the state. Roderick and Milner (1991) also prescribe wildlife protection buffer requirements for wetlands and riparian habitats in Washington. These widths vary from 30 to 183 meters depending on species and habitat usage (FEMAT 1993). The variable widths of riparian areas suggest a one-size-fits-all approach will not accommodate all organisms. Hence the community ecology functions of RHCAs will need to be determined both at the site and throughout a subbasin if the organism is wide ranging.

Importance of Small Streams—Third, small streams are more affected by hill slope activities than are larger streams because there are more smaller than larger streams within watersheds, smaller channels respond more quickly to changes in hydrologic and sediment regimes, and stream-

side vegetation is a more dominant factor in terms of woody debris inputs and leaf litter and shading. Small perennial and intermittent non-fish bearing streams are especially important in routing water, sediment, and nutrients to downstream fish habitats (Reid and Ziemer 1994). Intermittent streams account for more than one-half the total channel length in many watersheds in the Basin and therefore strongly influence the input of materials to the rest of the channel system.

Channelized flow from intermittent and small streams into fish bearing streams is a primary source of sediment in mountainous regions (Belt and others 1992). In steep, highly dissected areas, intermittent streams can move large amounts of sediment hundreds of meters, though buffer strips, and into fish bearing streams. In-channel sediment flows are limited primarily by the amount and frequency of flow and by the storage capacity of the channel. Flows in forested, intermittent streams are generally insufficient to move the average sized wood piece, allowing large wood to accumulate in small channels (Bisson and others 1987). These accumulations increase the channel storage capacity and reduce the likelihood of normal flows moving sediment downstream.

Live vegetation plays an important role in stabilizing granitic colluvium that accumulates in small headwater basins of the Idaho batholith. Typically, these draws or hollows show little evidence of surface flow and contain deep (several meters), unconsolidated granitic colluvium. Periodically these sites are rejuvenated by floods that flush some or most of the material until another period of relative stability results in accumulation of colluvium and filling (Gray and Megahan 1981; Megahan and others 1995).

Gray (1970, 1978) identified four mechanisms by which vegetation enhances soil stability including: 1) mechanical reinforcement by roots; 2) regulation of soil moisture content; 3) buttressing between trunks or stems of plants; and 4) surcharge from the weight of trees. Gray and Megahan (1981) evaluated these hydromechanical effects in the batholith and found that the first three are highly important in stabilizing slopes, hollows, and intermittent streams. Gray and Megahan (1981) recommended using buffer zones along the margins of streams and in critical areas such as hollows and intermittent streams.

The direct influence of riparian vegetation on stream and animal and plant community declines with increasing distance from the channel and with the height of the dominant tree species (FEMAT 1993). Ecological functions provided by riparian vegetation are achieved at different distances, depending on the type of function and the width of riparian vegetation needed for the function. The maximum height of dominant trees influences the potential distance over which riparian vegetation directly affects stream channels. For instance, tall trees potentially contribute shade, particulate organic matter, and large woody debris at greater distances from streams than do short trees. Areas capable of producing large tall trees thus possess wider functional riparian zones than areas in which trees do not grow as large. For this reason, FEMAT (1993), PACFISH (1995), and INFISH (1995) used the height of dominant late-successional tree species that would naturally grow in a particular riparian zone as the basis for reconnecting streamside buffers needed to safeguard ecological functions instead of suggesting a fixed "onesize-fits-all" linear distance. Use of a fixed distance from the streambank to the outer margin of the buffer strip would not allow for differences in potential tree growth between regions.

PACFISH (1995) prescribed 90 meter minimum RHCA widths for fish bearing streams to maintain stream function from sediment inputs from non-channelized sources. A review of the literature indicates that this should also be sufficient to provide for other riparian functions with a margin for error (Gregory and others 1987, Beschta and others 1987, Brazier and Brown 1973, Steinblums and others 1984, McDade and others 1990, Sedell and Beschta 1991, Belt and others 1992). These functions include litterfall and nutrient input and retention in streams (23 to 46 meters), shade to streams for maintenance of summer stream

temperatures (23 to 46 meters), woody debris delivery (30 to 46 meters), and stream bank stability (23 to 46 meters). RHCA widths for intermittent streams should protect small channels from large volumes of sediment and water that could be generated by land management activities and be channeled into fish bearing streams.

The effectiveness of riparian buffer strips in influencing sediment delivery from non-channelized flows is quite variable. Belt and others (1992), cited numerous studies conducted throughout the range of anadromous salmonids and reported that sediment travel-distances and filter strip efficiencies varied considerably from study to study. Belt and others (1992) concluded, based on studies conducted in Idaho (Haupt 1959a and 1959b, Ketcheson and Megahan 1990, Burroughs and King 1985 and 1989) and elsewhere (Trimble and Sartz 1957, Packer 1967, Swift 1986) that sediment rarely travels more than about 91 meters for non-channelized flow. Therefore, 91-meter filter strips are generally effective in controlling sediment that is not channelized. Trimble and Sartz 1957, recommended that where the highest possible water quality standard was required, this could be maintained with 100 meter buffer strips on 70 percent slopes. Recent work by Ketcheson and Megahan (1996) indicates that this may not be adequate on some lithologies and slopes.

Importance of Hill Slope Steepness—Fourth, the likelihood of disturbance resulting in discernible in-stream effects increases as adjacent slopes become steeper. Thus, greater preventive measures to avert or rehabilitate riparian function and structure on steeper slopes may be required to prevent or reduce in-stream effects. The designation of default RHCA widths can easily incorporate the major topographic driver of surface erosion and slope steepness.

Prior research on a variety of wildland and agricultural settings has demonstrated that surface erosion increases with increasing slope steepness, although the increase is not linear. The effect of slope has generally been modeled empirically, and has taken the shape of a power function where the exponent is less than 1, so that slope effects are large for gentle slopes, and decline as slopes get steeper (Foster 1982; Liebenow and others 1990; McCool and others 1987). Megahan and Ketcheson (1996) found that sediment travel distances from road cross drains in the Idaho batholith are proportional to slope gradient (in percent) raised to the 0.5 power. This study was conducted below roads on forested lands, and includes slope gradients ranging from 9 to 59 percent.

Megahan and Ketcheson (1996) and Ketcheson and Megahan (1996) present equations for estimating sediment travel distance below road fills and cross drains which incorporate sediment volume, obstructions, slope angle, and source area as significant explanatory variables. Slope is a significant predictor of distance, and it is not unreasonable to adjust an RHCA width to slope when lacking other intensive site variable information. At slopes greater than 70 percent, other screening tools that incorporate mass erosion risk are needed (Tang and Montgomery 1995). If risk varied solely as a function of slope, one could use the exceedence probability equation directly to tune a slope-directed RHCA model. However, at least three other site variables have been demonstrated to influence travel distance and therefore affect risk. Though it is erroneous to assume that the exceedence probability equations presented by Ketcheson and Megahan (1996) can be used to assign a general slope-driven risk to the RHCA width equation, at the subbasin scale a slope-driven default RHCA width is useful. It is also prudent to use for watershed analysis and planning at the subbasin and Forest project scales.

The research findings of Megahan and Ketcheson (1996) can be used to parameterize a slope-sensitive default RHCA width in the following manner: Distance can be made proportional to slope angle in percent raised to the 0.5 power to provide the proper shape. A constant can be derived from the exceedence probability function of Ketcheson and Megahan (1996) by taking the travel distance that is exceeded only one time in 20 (exceedence

p=0.05), a low probability but well-defined event from their data. The travel distance of this event for all their data combined is 480 feet. This distance can then be assigned to a slope of 70 percent, which results in the equation Distance = 58 X $(Slope)^{0.5}$ (fig. 4.26). Although this equation is adjusted to the 5 percent travel distance event, it is not strictly correct to assume that the relationship defines the 5 percent risk associated with operating on slopes of a given steepness.

Similarly, equations and curves that represent "10%" and "25%" risk can be derived by using the 10 percent and 25 percent probability of exceedence distance from Ketcheson and Megahan (1996; fig. 4.26). For the same reasons stated above, these equations do not directly represent 10 and 25 percent risk. They are less conservative than the 5 percent risk equation, but not necessarily by a factor of 2 and 5.

The strongest single variable affecting sediment travel distance from soil disturbing activities is the volume of material displaced, or delivered to a point on a slope from a culvert, drain, etc. Over 78 percent of the variance in sediment travel

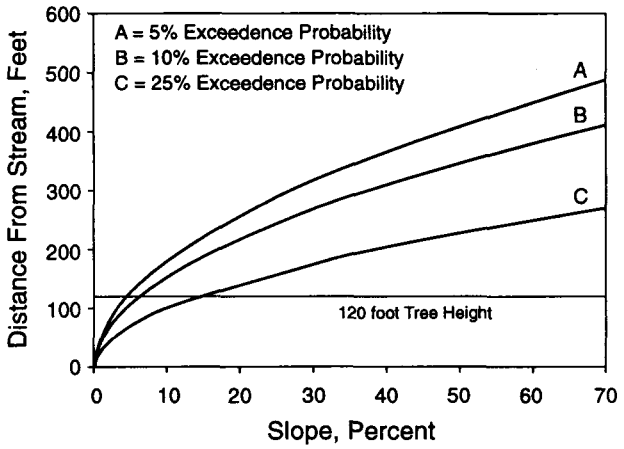


Figure 4.26—Examples of slope-sensitive adjustments to RHCA widths with associated probabilities of exceedence (0.05, 0.10, and 0.25), based on models described by Megahan and Ketcheson (1996) and Ketcheson and Megahan (1996). (A) Distance=58•$(Slope)^{0.5}$; (B) Distance=49•$(Slope)^{0.5}$; (C) Distance=32•$(Slope)^{0.5}$.

distance is explained by volume in the culvert model of Megahan and Ketcheson (1996). Given the strong influence of this relationship, the probability density function of sediment volumes from the data set used in developing their model can be used to define various levels of risk. This is a subtle difference from defining risk using the probability exceedence function (equation 4 of Ketcheson and Megahan 1996) as above, because risk is attributable to a single, measurable attribute — sediment volume. In contrast, the probability exceedence function for travel distance includes the combined effects of all driving variables. Defining risk by volume alone allows a direct application of the Megahan-Ketcheson model for tuning travel distance on slope.

This method assumes that travel distance is strongly influenced by slope in the culvert model. We tested this by regressing the residuals of a 3-variable model [Distance = f (volume, source area, obstacles) on slope]. This regression is significant at P=0.001 and has an r^2=0.33, indicating that there is ample variance to be explained by slope gradient after accounting for the other variables in the multiple model.

A slope-gradient sensitive default RHCA can be estimated directly by setting the two variables "obstacles" and "source area" equal to their median values, allowing slope gradient to vary from 0 to 70 percent, and assigning risk by taking various volumes based on the distribution of volumes sampled in the Megahan-Ketcheson data set. The following reconfiguration of the culvert model was used to generate the curves in fig. 4.27:

$$D=3.28 \cdot 10^{(0.393+0.554 \cdot \log_{10}Vol+0.5 \cdot \log_{10}Slope)}$$

The variable $\log_{10}$ Vol was set equal to 1.60, 1.57, and 1.41 corresponding to the 95, 90, and 75 percentile values of sediment volume sampled; median values of obstructions and source area were used and slope was allowed to vary from 0 to 70. This procedure results in a series of three curves that are similar, but somewhat more conservative than the curves based on the travel distance

exceedence curve of Ketcheson and Megahan (1996). Again, the utility of this second set of curves is that risk is defined from the single, strongly influential variable of volume, and the effect of slope is then predicted directly using the Megahan-Ketcheson model.

The width necessary to protect stream and riparian area structure and function can be determined from watershed and site-specific analysis. The dimensions of riparian protection areas, particularly if they are to be used as interim or default standards, should also include safety factors to allow for natural disturbances, uncertainties about the riparian ecosystem of interest, and changes in public values (National Research Council 1996). If an additional margin of error is allowed (not unlike bridge design accounting for unknown factors and longevity of structure), the probability of habitat improvement becomes greater and options for future management decisions are increased (FEMAT 1993).

In general, buffer widths prescribed in FEMAT (1993) and reexamined by Murphy (1995) and Spence and others (1995) are applicable to protecting ecological functions whether streams contain fish or not (National Research Council 1996). In contrast, all national forest plans, PACFISH, and INFISH maintain a higher level of riparian protection where fish are present or strongly affected than for non-fish bearing streams. The width of streamside management zones required by state land-use laws is much smaller than the width of natural vegetation needed to provide full ecological protection (FEMAT 1993; Murphy 1995; Spence and others 1995; National Research Council 1996). For example, the forest-practices regulations of California, Washington, Oregon, and Idaho require narrower buffers that leave only an estimated 23 to 58 percent of sources of potential large woody debris present in a mature conifer forest (Murphy 1995).

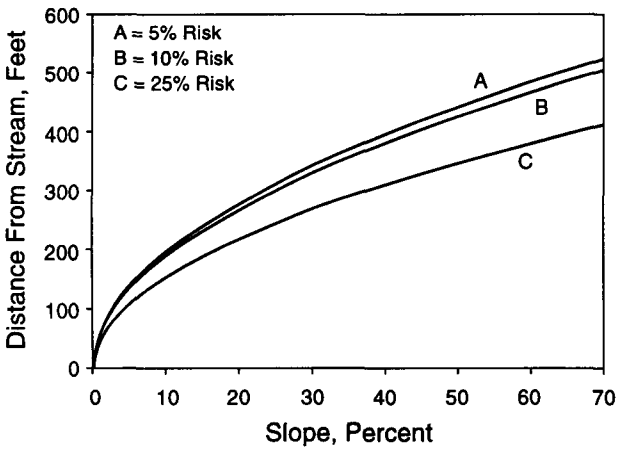


Figure 4.27—Examples of volume-driven risk associated with adjustments to RHCA widths, based on models developed and sediment volume sampled by Megahan and Ketcheson (1996) and Ketcheson and Megahan (1996).

Taken in aggregate, the standards for management of stream and riparian systems on forest lands are far more restrictive and ecologically more effective than requirements for riparian areas where agriculture and urban or industrial land uses are dominant. No state within the Basin has enacted an agricultural-practices act explicitly protecting riparian vegetation. Botkin and others (1995), the National Research Council (1996), and Spence and others (1995) all call for improved protection of riparian areas in agricultural lands if salmon and many native fishes are to survive in the long term. Currently, agricultural activities are limited by the water-quality requirements of the Clean Water Act, state water-quality standards, and voluntary compliances with best management practices (National Research Council 1996; Spence and others 1995). Even though state forest-practices regulations incompletely deal with maintenance of ecological function and structure, agricultural-practices regulations tend to emphasize meeting waterquality thresholds for drinking water and aquatic biota protection only, rather than addressing riparian protection. In urban and industrial areas, riparian area protection is generally left up to local ordinances (National Research Council 1996). Much of the historically most productive salmon habitat exists in lower river valleys and coastal lowlands where riparian zones are given the least protection (Sedell and other 1990).

Cumulative Watershed Effects—Without a larger-than-project-scale context, it is difficult for managers to assess the full spectrum of effects that management activities may have as well as how off-site activities and conditions may affect site conditions. Cumulative effects analyses are designed to provide this large context. Cumulative watershed effects (CWE) are those from more than one activity or disturbance event that have combined to affect a stream or riparian area more significantly than any of the single events alone. Most direct sources of cumulative effects are local in space and time. The analysis and management of cumulative watershed effects are intended in part to control watershed level sediment, hydrologic change, and biodiversity that project planning might miss (Reid 1993). Planning at the watershed or subwatershed levels can help forest managers reduce or prevent undesirable cumulative effects on fish habitat.

Evaluations of potential cumulative effects of a given project should consider watershed erosion potential; slope stability; disturbance from wildfires, timber harvest, roads, and other land uses; rate of recovery after disturbances; and overall watershed condition and stream condition. Assessments of cumulative effects account for land uses other than forestry. Grazing, mining, agriculture, hydroelectric and water development projects, recreation, and urbanization can all cause increments of cumulative effects on a watershed and its aquatic populations (Platts 1991; Nelson and others 1991; Clark and Gibbons 1991). Most important to cumulative effects is to provide a spatial and temporal context for assessing effects of a proposed project at different scales.

At the broad scale, the Biophysical Environment assessment (Chapter 2) developed three data layers which assess potential risk from roads, fire, and sensitivity of channels to the presence of vegetation (influence of vegetation on channel integrity in rangelands) for each subbasin (approximately 280,000 hectares each). The road hazard index is derived from coefficients of accelerated erosion from roads based on lithology, slope, and drainage density throughout the Basin. Risk of sedimentation from fire is derived from the potential erosivity of bare soil at the subwatershed level. These data plus stream recovery data driven primarily by channel gradient have been used to display relative risk of sedimentation to subbasins throughout the Basin (Quigley and others 1996). The utility of this basin-wide template is a spatially explicit strategic context from which one can consider watershed and aquatic risks.

At the mid-scale, within a watershed or subwatershed, several methods of cumulative effects assessments exist. Three methods are commonly used within the Basin: 1) equivalent clearcut area (ECA), 2) equivalent road area (ERA) used by Region 5 of the Forest Service (Pacific Southwest Region), and 3) the Region 1 and 4 (R1/R4) sediment model. These are the most useful models currently available for planning and evaluating the effects of management strategies.

Menning and others (in press), building on existing concepts and the work of McGurk and Fong (1995), propose a more spatially explicit model for assessing cumulative watershed effects and placing limits on watershed disturbances near streams. They propose a 45 meter-wide riparian area which would be conservatively managed for riparian and aquatic ecological processes and communities. They propose an adjacent zone of potential landscape disturbance or region of influence which is equal to 45 meters or adjusted for slope. The steeper the slope adjacent to the stream, the wider the zone. This second zone would protect the stream from sediments and provide habitat and microclimate if needed. The third zone, the uplands of the watershed, is assumed to have a small effect on streams and riparian areas. This system serves two main purposes: 1) it closely approximates the aquatic and riparian ecological regions described above and 2) it allows better consideration of the distance from a road or harvest area to the stream which they might affect. Their vegetation dynamics model is programed to limit activity in each zone up to respective levels of 5, 10, and 15 percent allowable ERA. Aquatic and riparian

systems are most influenced by activity close to the stream. Hence, the strictest limits on watershed disturbance are in the first zone. An intermediate allowable ERA percent is set for the potential landscape disturbance area and a more permissive ERA percent is established for the uplands. Applying this method in the highly dissected topography of the Eldorado and Plumas national forests resulted in about 46 percent of small watersheds being within the two riparian zones (13 percent in zone one, and 33 percent in zone two). This is a more logical approach to protection of ecological function than the "one-size-fits-all" default riparian zones. The objective is to reduce disturbance near streams and to assess and plan how ecological function can be maintained. Menning and others (in press) have provided an important improvement to making cumulative watershed effects spatially explicit with their approach to riparian buffers. In their scheme, streams with adjacent steep slopes have greater protection from management, streams get a full compliment of energy inputs and large wood, in-stream aquatic biodiversity is minimally effected, and riparian habitat for transitory and obligate species is maintained.

Each of the three CWE models requires more information on streams, adjacent slopes, and soils than is currently available. They do not predict effects with precision, and have a tenuous link between upland area disturbance and in-stream effects. Each model can be modified to express near stream disturbances distinct from upslope disturbances and set lower thresholds near streams than on the upslope (McGurk and Fong 1995; Menning and others, in press). Compared with watershed level CWE treatment, this would provide a more conservative approach to maintaining ecological function of RHCAs within a watershed by partitioning disturbance which could accommodate the four basic principles listed in the beginning of this section. Use of watershed analysis, use of modified cumulative effects models, and adoption of quantifiable objectives for riparian forest stand structure and cover would allow land managers to limit disturbance close to stream channels while identifying acceptable or rehabilitative management activities in the uplands away from the stream. The absolute width of the riparian management area is less important in many ways than specifying site specific and watershed riparian goals and objectives in a way that gives clear direction as to expected ecological outcomes. The principles and tools described above attempt to provide a means to attaining clear goals, and will provide the most accountable system for restoring riparian areas, limiting disturbance, and achieving proper functioning condition.

Another strategy to protect streams from the effects of management activities and cumulative watershed effects, Riparian Management Objectives (RMOs), is currently being proposed in the Basin. While the intended goals are water quality protection and in-stream habitat and bank protection, these strategies are primarily performance or end-use oriented and not prescriptive, giving little direction or flexibility to meet these goals. Though explicit thresholds or standards are established by RMOs and must be met, how they must be met is not specified. The use of RMOs as standards and thresholds has four primary problems. Such standards usually become inflexible and are unable to accommodate the range of spatial variability within a watershed through time as well as for the rare event. Second, because it is difficult to anticipate and accommodate the temporal nature of biophysical processes operating in the watershed, a specified means of attaining standards (such as managing toward mature forest structure and cover in RHCAs and setting cumulative watershed effects thresholds lower near streams than in the uplands) is needed. Third, RMOs tend to be simplistic and often disconnected from watershed processes and adjacent forests. The complex interaction between watershed and in-channel processes are not well represented by a few measurable RMOs for sediment and large wood. Finally, RMOs often distinguish between fish-bearing and non-fishbearing streams, with more relaxed standards for the latter. Since non-fishbearing streams are generally more numerically abundant and in steeper and more erodible terrain, this can result in much of the stream network being without adequate protection.

Discussion

The acknowledgment of landscape issues in recent conservation strategies and the implementation of watershed and ecosystem analysis represent an important advance from the use of simple habitat standards (Montgomery 1995). The existence of even the most productive habitats and populations are likely to be dynamic and uncertain through time. Our ability to effectively predict and manage disturbance effects is still unproven; we cannot simply control or predict the natural disturbances that will undoubtedly challenge these systems in the future (Frissell and Bayles 1996).

Long term persistence of aquatic biological diversity will depend on more than the current distribution of productive habitats for many systems. It will likely depend on restoring watershed processes that create and maintain habitats across broad networks that will support the species, genetic, and phenotypic diversity necessary to buffer populations and communities in variable and changing environments. Therefore, while attempts to preserve existing conditions are focused in some watersheds, it is important that others be actively managed with the intent of rehabilitating more complete systems. As Bisson and others (1996) suggest, bold steps and experimentation will be necessary to make progress.

The opportunity for conservation of currently important watersheds will be dictated by the current distribution of those watersheds and the conflict with future management goals. The opportunity for rehabilitation will depend on the amount of investment in effective practices and convergence with other goals. The current management emphasis on restoring structure, composition, and the processes relevant to the condition of terrestrial ecosystems through active management has been strongly articulated in the Landscape Dynamics chapter (Chapter 3) and in the public debate regarding issues of forest health. The discussion must be broadened to integrate active rehabilitation of aquatic systems and watershed processes as well.

The assessments of aquatic, watershed, and terrestrial communities demonstrate that each has departed dramatically from historical conditions. It is striking, however, that the changes in forest communities parallel those in aquatic and watershed systems, often in the same areas and for similar reasons. Dramatic changes in these systems, for example, are associated with the homogenization and fragmentation of habitat types, selective and overly optimistic harvest regimes, artificial culture and stocking practices, and the introduction of non-native species. Road densities appear to be one of the best predictors of departure from historic conditions and indicators of current integrity for those landscapes (Landscape Dynamics, Chapter 3).

Conventional timber harvest activities and road building can threaten watershed processes and the conditions of aquatic habitats. But changing fire regimes have become a major issue in forest management that has galvanized new efforts to actively restore/manipulate forest structure and composition. In some cases this could be viewed as a threat to the persistence of aquatic systems. Restoration of structure, composition, and function of forest ecosystems more consistent with natural disturbance regimes, however, might also benefit aquatic ecosystems. We suggest that efforts to restore forests could represent an opportunity to reestablish a mosaic and more natural disturbance regime in aquatic systems without risking those that are currently productive. Three elements to this approach include: 1) an opportunity to conserve key remnant habitats and populations; 2) an opportunity to rehabilitate degraded watersheds to a more productive condition; and 3) an opportunity to restore a structure and composition in forests that reduces the risks of simultaneous events among productive or critical habitats.

Conservation

The focus on conservation of critical elements is clear from this and preceding work. The habitats supporting the most productive, diverse or otherwise critical populations provide the best opportunities for shortterm persistence. They also provide the best opportunities for rehabilitation of more complete systems in the future. An emphasis on conservation in those areas does not necessarily mean forest management activities cease. It does imply that any management must clearly minimize or eliminate risks that might compromise the ability of populations to maintain or improve their status over time.

Watershed Rehabilitation

Many of the subbasins in the Basin appear to support a patchwork of productive and degraded watersheds. The best remaining aquatic habitats are often found in higher elevation systems associated with cold forest types that also are in relatively good condition. Subwatersheds at mid and lower elevations also support important elements for aquatic systems and native species, but they are more strongly influenced by habitat loss, degradation, and watershed disturbance associated with timber harvest, grazing, and more extensive roading. Active watershed rehabilitation, particularly the obliteration of excessive road networks and use of new grazing strategies, will be an important step to conserving and expanding the network of habitats. The mid-elevation landscapes often show the greatest departure in forest conditions and potentially the greatest needs for active restoration of vegetation structure and composition (Landscape Dynamics, Chapter 3). We suspect that in many cases the need for active restoration of forest and aquatic systems will coincide. Existing road networks could represent a key to progress in both. Existing road systems provide ready access and the opportunity for active management and generally exist where recomposition of forests is most urgent. By focusing projects in individual and heavily roaded watersheds rather than dispersing them across a basin (Sensu, Franklin 1992; Reeves and others 1995) forest management needs might be accomplished quickly. This would also allow longer periods for recovery in watershed processes and eliminate the need for continued road maintenance. Existing road densities often exceed those necessary for modern, logging systems. The obliteration of unnecessary or particularly damaging roads could accompany many projects to actively recompose forests.

Active watershed restoration has not been an emphasis of past land management. There is a great deal to learn, and work will necessarily be experimental with uncertain results. Because a mosaic of watershed conditions often exists in the basins where active management might play a role, minimizing risks in subwatersheds supporting critical habitats by prioritizing new work in areas of less concern would be possible.

Forest Rehabilitation

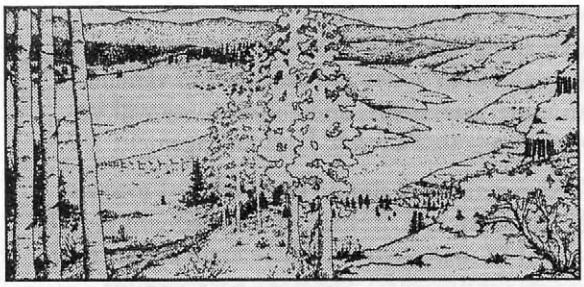
Changing fire regimes have been associated with the homogenization of forest habitat types (Landscape Dynamics, Chapter 3). A major conclusion of the landscape analysis is that future wild fires are likely to burn with increased severity and over larger areas than in the past. Though wildfires were important historically to healthy aquatic ecosystems, depressed and strongly isolated populations could be vulnerable to the effects of intense or very large fires. In addition, the potential for increasing synchrony in fire related disturbance among streams and populations is of concern. Even though fires have likely played an important role in the succession and long term complexity of stream habitats, extreme fires could essentially reset the successional stage of many systems at one time. The temporal and spatial diversity of habitat conditions created and maintained through the mosaic of landscape patterns and historical disturbance regimes could be simplified or lost. Threats from such fires will be most important in aquatic systems that are already highly degraded and fragmented.

We understand little about the historical disturbance regimes structuring aquatic ecosystems. We do not believe that the natural disturbance critical to the maintenance of productive habitats can easily be restored or replaced through active management. The risks of active management may well outweigh the risks associated with large and uncharacteristic fires. There is also uncertainty about whether restoration of ecosystem structure, composition, and process can even be effective (Baker 1994; Stanley 1995). Aquatic and terrestrial systems have been strongly altered from historical conditions and in many cases natural recovery seems highly unlikely. Changing fires regimes have clearly become a dominant issue in forest management and substantial resources will be focused on the problem. Those resources could be focused in work that creates the greatest potential benefit and least possible risk to diversity and condition of aquatic ecosystems. We suggest that the logical priorities for active management lie in the watersheds and areas surrounding the population strongholds, critical habitats, and riparian zones most important in the aquatic system. Often the forest lands most in need of active forest restoration will be those that are most heavily roaded and encompass the most degraded watersheds. The opportunity and need to attempt restoration of forests without risking critical habitats may be more common than not.

Even within watersheds where forest restoration proceeds, efforts could focus to minimize disruption to aquatic processes. Active management within RHCAs is often proposed as a way to reduce fire severity by recreating a more historical-like mosaic of stands that offer natural firebreaks and less concentrated food sources for pests. The trade-off between fire risk and the risks associated with management activities is a watershed and site specific issue. Ecologically, it makes sense for treatment to begin in upland zones and work down to riparian zones, where activities occurring closer to the stream have a greater probability for adverse effects on the stream. We believe this is a prudent approach. Productivity and fuel loading may be highest in riparian zones but these zones are generally more moist and historically had longer fire return intervals (Agee 1994). Thus, in an ecological sense, fire management concerns are generally not a primary emphasis in riparian zones. Given the critical nature of the riparian management area to fish and aquatic habitat, a prudent course of treatment with benefits for both RHCAs and the entire landscape might be to treat the fire-prone portions of the landscape outside riparian areas to protect historical refuges in RHCAs.

By focusing work outside the most productive or critical aquatic habitats, we minimize the risk associated with direct disturbance but still gain experience and the potential for reestablishing a more characteristic vegetation mosaic and a broader distribution of productive watersheds. We can begin the process of experimentation and adaptive management that may ultimately lead to management more consistent with the natural processes that structure aquatic ecosystems.

INFORMATION AND RESEARCH NEEDS



To maintain a coordinated, adaptive approach to management of federal forests and rangelands in the Basin, a comprehensive inventory, research, and monitoring program is needed to assess success over time and to modify management strategies as new information becomes available. To be effective, the program must fully integrate research and management areas and must be consistently applied on Federal lands. Recently, scientists and managers identified six freshwater priorities based on scientific significance, sociopolitical relevance, and needs of decision makers (Naiman and others 1995):

- **Ecological restoration and rehabilitation** - Restoration and rehabilitation are a high priority because water quality standards under the Federal Clean Water Act cannot be met in one-third of the nation's freshwater ecosystems.
- **Maintaining biodiversity** - The goal of maintaining biodiversity focuses on preserving individual species as well as the diversity of ecological processes and the integrity of ecological systems. This includes understanding relations between species and ecological processes as well as the consequences of exotic invasions.
- **Modified hydrological flow patterns** - The hydrological regime in virtually every freshwater body in the Basin has been modified to some extent by dams, diversions, and withdrawals.
- **Ecosystem goods and services** - An improved understanding of environmental factors responsible for natural resources and their values, including the costs associated with their loss, is necessary for responsible management.
- **Predictive management** - If we are to predict the consequences of cumulative and synergistic effects of management activities, we need more information on disturbance regimes and their physical and biological legacies.
- **Solving future problems** - We must ensure that basic science and education can provide the framework for meeting future water-resource challenges.

The following section briefly describes additional information and research needed to support long-term management for productive, healthy ecosystems with a high probability of ensuring the viability of species and ecosystem processes.

Riparian Management

Riparian management areas have important roles in maintaining biological diversity and productivity (such as fish, birds, bats and frogs) and regulating energy and nutrient flow between waterbodies and uplands. These areas have important values in landscape aesthetics. The basic concerns of river and lake management related to water quality and water-based recreation can be

improved through a better understanding of riparian dynamics. Evaluation of the roles of riparian buffer zones and corridors of variable structure, size, shape, and connectivity will improve integrated aquatic-land management.

Field experiments should be developed to assess the potential role of riparian management areas in watershed management. These experiments may answer fundamental questions necessary for knowledgeable watershed management. They may provide information on the spatial dimensions (that is, width, length, depth, space and continuity) necessary to achieve single and multiple ecological and/or social objectives.

Understanding the Rare Event

The structure and function of stream and river riparian areas are often related to the frequency of disturbance by extreme hydrological events. Natural systems adjust to the whole range of natural process variations. The dependence of natural systems on extreme events relates to variability in geomorphic and hydrologic processes, stream habitat structure, and to the roles of succession and biological interactions. The significance of rare events (such as droughts, floods, fires, etc.) in sustaining riparian and aquatic systems may vary with climate region and from naturally stable to highly variable systems. Rare events are important for sustaining some riparian and flood plain systems. Therefore, management and restoration options for these areas must include the variability of riparian structure and function. This is particularly important given the Basin-wide efforts to regulate and dewater rivers and improve water-level control rules on lakes and reservoirs.

Evaluating the role of hydrologic and geomorphic disturbance from effects of extreme events on the biological structure and function of streams, lakes and riparian management areas is important. Three types of studies can contribute to this evaluation: 1) field surveys to assess the impact of historical events such as fires and large floods. 2) intensive, opportunistic surveys during and following such rare events (for example, the landslide of North Fork Boise River). 3) use of human impacts as analogues to assess the resilience of riparian and aquatic ecosystems to changes in the magnitude and frequency of extreme events (such as, below regulating dams and reservoirs).

Stream Habitat Inventory

Stream habitat inventories provide the foundation for land management, watershed analysis, activity planning, monitoring, and watershed restoration. Maintenance of stream habitats and watersheds that are currently in good condition is critical to reduce degradation of aquatic systems. Physical and biological conditions and processes of aquatic systems vary greatly in area and scale across federal forest and range lands in the Basin. Programs to manage these ecosystems are best based on site-specific information.

Currently, 20,000 kilometers of streams have been inventoried using a standard protocol. This represents less than 5 percent of the estimated 444,000 kilometers of stream in the assessment area. Although a complete inventory of all stream and riparian habitats would be ideal, a comprehensive coverage across physiographies and stream types, at minimum, is needed for accurate extrapolation of information. Inventory methodologies must be standardized to facilitate broad-scale analysis.

Limited stream habitat inventory data describes conditions in ERUs. The Snake Headwaters, Upper Snake, Owyhee Uplands, and eastern sections of the Central Idaho Mountains ERUs have essentially no data on condition of stream habitat. The Northern Great Basin, most of the Columbia Plateau, the southern and eastern sections of the Northern Glaciated Mountains, the Upper Clark Fork, and the southern sections of the Lower Clark Fork have very limited stream-inventory information. Overall, stream habitat data are more available in forested regions, less available in rangelands, and practically nonexistent in valley-bottom and agricultural areas.

Aquatic habitat inventory and monitoring data need to be incorporated and integrated with other resource information and linked to a Geographical Information System (GIS). Information submitted for this assessment came in many formats and levels of quality, which made it difficult to compile and interpret. A pressing need exists for both spatially referenced information and a consistent approach to collecting, accessing, and sorting these data.

Information collected at any scale needs to have both the data structure unique to the point, line, or polygon and a spatial reference. Positional data provides for further spatial and temporal analysis as well as a framework to combine and integrate other spatially located data sets. Considerable time was spent spatially referencing data from more than 6,300 stream reaches from multiple agencies. Little information had locational components.

Specific information includes:

- Exact locations of the start and end of each stream need to be recorded using Global Positioning System Units.
- The EPA reach number at both the 1:100,000 and 1:24,000 scales for each stream reach is needed.
- River miles for each stream reach need to be accurately calculated from the USGS 1:100,000 and 1:24,000 scale.
- Unnamed streams and tributary locations, as well as stream channel gradients, need to be explicitly described using 1:100,000 and 1:24,000 USGS map layers and river miles.
- Clear interagency spatial information data collection protocols need to be developed.
- The ICBEMP Master Habitat Database needs to be maintained, periodically revised, and widely distributed.
- An interagency infrastructure to provide a data repository and vehicle to transfer multiscale spatial analyses and associated technical expertise to field units needs to be developed and implemented.

Aquatic Species

Fishes

Complete species inventories are necessary to evaluate the structure and composition of aquatic communities in the Basin fully. Because of the inherent complexity of watershed and ecological processes and their interaction and linkages with stream productivity and riparian condition, the probability of understanding these processes and interactions improves through long-term research. The evaluation of the seven key salmonids and 39 additional sensitive fish species in the study area revealed some common research needs: a basic understanding of life history and habitat requirements; species viability and taxonomic and genetic characteristics; population status and distribution; predator/prey relationships and competition from non-native introductions; and effects on survival from changes in habitat condition and water quality and quantity.

Regularly scheduled population and habitat monitoring is needed for many sensitive species. This is especially critical for many rare species with restricted distribution which are particularly vulnerable to disturbance events including the introduction of exotic species, parasites, and diseases. For several species, particularly the redband-inland rainbow complex, basic genetic information is needed to determine which populations represent native genomes, which have been modified, and which have been replaced with genes of introduced fishes. However, to meet the needs of river basin and watershed management, future research must concentrate on integrated community studies to understand the diversity and complexity of habitat needs and life-history requirements of fish, and species interactions, which will compliment the species-by-species studies. Monitoring to detect changes or trends in the structure, composition, and diversity of aquatic communities across whole systems such as the subbasins defined in this assessment should be considered as important as monitoring to detect trends in individual populations. Because large-scale and community rather

than population specific monitoring imply wholly different sampling schemes, substantial effort will be needed to develop efficient and effective sampling approaches.

Predictive models were invaluable for our assessment of fish distributions and the identification of management issues and opportunities. Databases and models for similar evaluations relevant to planning and management at the scale of subbasins and watersheds are virtually nonexistent. Because of the lack of complete inventories, such models could be critical in the identification and prioritization of conservation and restoration opportunities and issues. Further development and refinement of such models will require the collaboration of research and management programs to develop and access the necessary data sets. Integration with other landscape-based assessments will be critical to provide generalized models with the potential for broad application.

There is a relatively extensive body of work regarding the distribution, dynamics, and interrelationships of fish and physical habitats at the scale of individual habitat units and stream reaches. We know far less, however, about the large-scale relationships and processes that influence the structure, composition, dynamics, and persistence of populations and communities. Effective conservation and restoration of aquatic biodiversity will require a better understanding of the spatial and temporal distribution of habitats necessary to sustain functioning systems. Large-scale spatially influenced population dynamics have been a focus of interest among conservation biologists and managers dealing with fishes. These new concepts are well based in theory and appear to have particular relevance for management of aquatic systems and especially stream fishes. The empirical basis for application in management, notably information regarding extinction dynamics, dispersal and recolonization processes, the nature and relevance of disturbance, and the mechanisms structuring populations, however, are poorly developed. If large scale patterns and processes influence the dynamics and persistence of populations as we suspect, such information will be important in guiding more efficient and effective conservation and restoration efforts.

Aquatic Invertebrates

The basic biotic components of most aquatic habitats, including algae, microinvertebrates, and macroinvertebrates, are poorly known in the Basin. Data on the composition and relative abundance of various macroinvertebrate species are widely used to indicate overall productivity, biotic integrity and health of stream systems. Studies are needed which identify aquatic species composition and track their abundance and diversity.

General patterns across the breath of the assessment area were surprisingly interpretable for stream macroinvertebrate assemblages characterized from an array of information sources compiled by Li and others (1995) in a study conducted for this assessment. Using four to five general invertebrate metrics, assemblages were classified into five general groups: riverine; low diversity from hydrologically flashy systems; low diversity from high desert or disturbed systems; moderate diversity from good stream habitat conditions; and high diversity from cool water habitats.

Differences within ERUs can be detected by macroinvertebrate metrics. The Blue Mountains ERU was the most taxa rich, with high numbers of mayflies, stoneflies, and caddisflies and low dominance by the most abundant taxa. The Columbia Plateau exhibited the lowest taxa richness, and high dominance by the most abundant taxa. These values were influenced by Lower Snake River samples that were very low in several metrics. Other streams within the Columbia Plateau ecoregion have characteristics more similar to the High Desert ecoregion of the Great Basin in southern Oregon and Idaho. These distinctions within the Columbia Plateau demonstrated the importance of examining within-region variability. The information available for the Northern

Rockies indicated that streams from the Bitteroot Mountains were distinctly more diverse than streams from upper Salmon River tributaries.

Using invertebrate metrics such as taxa richness, abundance and proportion of Ephemeroptera, Plecoptera and Trichoptera, and correlations with specific landuses were vague. For instance, lack of correlation between assemblage characteristics and road densities was due in part to data collected at very different scales. Whereas road density data was collected for the entire Basin and summarized at a relatively broad scale, invertebrate samples are site-specific to a point or reach in a stream. Though invertebrates may be very sensitive to disturbances resulting from roads, such as sedimentation and increased solar radiation, these assemblages may reflect riparian or streambank conditions relatively immediate to the stream. If roads are dense but somewhat distant from the stream, there may not be stream disturbances that result in changes within invertebrate communities. On the other hand, composite information for invertebrates, representing long stream extents, may better represent assemblages comparable to road densities at the same scale. The metrics used for this analysis were those most readily calculated from available information, representing very general assemblage characteristics. Perhaps more finely-tuned metrics in concert with finer scale resolution road data would be more appropriate for detecting the effects of road density.

Short-term Research and Data Needs (1-3 years)

- Relevant geomorphic and hydrologic data needs to be matched to the invertebrate sample sites throughout the Basin.
- In the Blue Mountains a joint National Science Foundation and Environmental Protection Agency Watershed Ecosystems study is underway in the John Day and Grande Ronde rivers. A systematic effort to sample wilderness areas, seeps, springs, and other unusual habitats with detailed description of taxa could be accomplished in conjunction with this ongoing study.

Long-term Research (1-15 years)

- Research is needed to establish more direct links between biological responses to landscape conditions. Gradients of influence such as changing riparian canopy cover and composition, sedimentation, road density, and grazing system could be established within and between watersheds with corresponding invertebrate sampling along these gradients.
- Tests for causal mechanisms controlling invertebrate assemblages can be experimentally designed at sites where human activities are least and where active restoration activities are planned.

Lake and Stream Productivity in Relation to Lithologic Variables

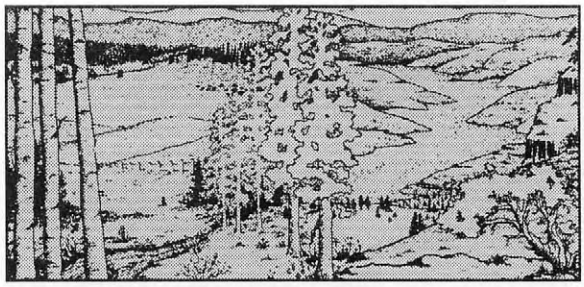
Research into lithologic variables, including geochemistry, sediment yield and texture, morphologic character, erosion rates, and their controls on species distributions and habitat suitability are needed. That three lithologic variables, simplified from the original 41 bedrock lithologic types of Johnson and Raines (1995), which were themselves simplified from over 800 lithologic units, emerged as significant components in the analysis of habitat suitability and populations suggests that linkages between aquatic and riparian conditions, stream productivity, and bedrock geology may be stronger than previously believed. Linkages between bedrock geochemical nutrient distributions (Raines and others 1995) and aquatic/riparian conditions and populations appear to be a particularly fruitful area for research. Such investigations would be appropriate at regional to watershed extents.

Monitoring

With the future likelihood of reduced Federal land-management budgets and staffs, monitoring of individual projects and inventory of all streams will not be feasible. Long-term systematic inventory and monitoring of reference watersheds, however, are likely feasible, and are necessary to assess whether standards, guidelines and objectives are met and to provide reference points for effectiveness and validation monitoring. Long-term data sets from reference watersheds will provide an essential basis for adaptive management and a gauge by which to assess trends in stream and riparian condition. Establishment of reference watersheds that contain lands administered by both the Forest Service and BLM would facilitate long-term coordination between the agencies.

Because of the variability among watersheds, study designs to facilitate broad application of reference watershed information must focus on appropriate pairing and aggregation of data based on such variables as basin groups and size, parent geology, geomorphology, discharge, vegetation types, and stream types. Monitoring results need to be documented, analyzed, reported, and stored by a method that is easily retrievable by the agencies responsible for land management in any given river basin and/or watershed.

Monitoring of water quality, riparian vegetation trends, and channel characteristics can be remotely assessed. These remote sensing techniques have the potential to provide less costly and more extensive assessment of riparian management areas. There is an urgent need to compare capabilities of field and remotely-sensed imagery at several resolutions for monitoring riparian and instream processes.



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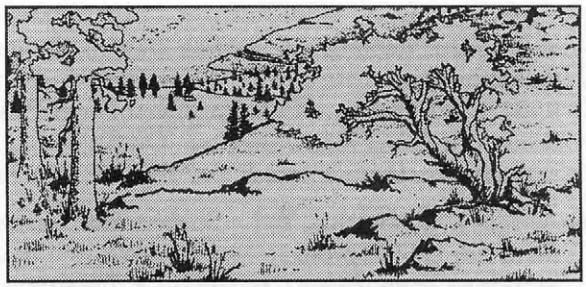
Appendices 4C and 4D include lists of individuals who provided information that was critical to the preparation of the section entitled "Distribution and Status of Fishes." Gwynne Chandler and Deborah Myers assisted with creating, correcting, merging, and managing many of the databases in the section and they created most of the figures and tables. John Gebhards, Julie Gott, John Guzevich, Lori Leatherbury, Polly Merritt, Mike Radko, and Mary Stafford supported database development and maintainence.

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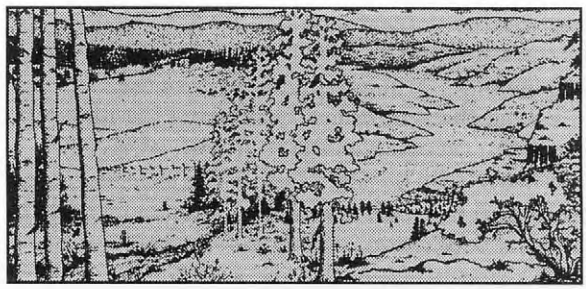
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GLOSSARY

adfluvial - fishes that spawn in tributary streams but spend a significant portions of their life in a lake.

alevin - a newly-hatched salmon or trout prior to absorption of the yolk sac.

allopatric - species, taxa, or life-history forms occurring in separate or disjunct geographic areas.

allospecies - semispecies; The component species of a superspecies.

ammocoetes - larval stage of lampreys, usually lasting four to seven years.

anadromous - fishes which spawn in fresh water but spend a significant portion of their life in the ocean.

escapement - the number of adults which survive to reach the spawning grounds.

eutrophic - rich in dissolved nutrients, photosynthetically productive, and often deficient in oxygen during warm periods.

life history - the significant features of the life cycle through which a fish passes - may include timing and age of maturation, reproduction, migration, patterns of migration, etc.

parr - juvenile anadromous salmonids which normally reside for a year or more in fresh water and are not capable of tolerating saline water; may refer to steelhead trout, coho, sockeye, or chinook salmon.

phenotype - the physical expression resulting from the combined influences of genotype and environment; different phenotypes may be represented by different life-history expressions of patterns.

pool - portion of a stream with reduced current velocity, often with deeper water than surrounding areas and with a smooth surface.

population - organisms of the same species that occur in a particular place at a given time; a population may contain several discrete breeding groups or stocks.

redd - the spawning nest of salmonids; usually a scooped depression in clean gravel in which eggs are deposited and buried.

resident - spends entire life in a single stream.

riparian area - area with distinctive soils and vegetation between a stream or other body of water and the adjacent upland; includes wetlands and those portions of floodplains and valley bottoms that support riparian vegetation.

salmonid - fishes of the family Salmonidae; includes salmon, trout, char, white fishes, and grayling.

stronghold - defined by the ICBEMP Science Integration Team as directly associated with strong populations. Strong populations have the following characteristics: 1) all major life-history forms (for example: resident, fluvial, adfluvial) that historically occurred within the watershed are present; 2) numbers are stable or increasing and the local population is likely to be at half or more of its historical size or density; and 3) the population or metapopulation within the watershed, or within a larger region of which the watershed is a part, probably contains at least 5,000 individuals or 500 adults.

sucker - fishes of the family Catostomidae.

Symbiont - A species of plant or animal that lives closely associated (sometimes necessarily so) with another species.

sympatric - distinct species, taxa, or life-history forms occupying the same or overlapping geographic areas without interbreeding.

taxa - refers to more than one species, subspecies, or other taxonomic units (taxon - singular).

tributary - stream or river flowing into a lake or larger stream or river.

zooplankton - small (often microscopic) aquatic animals suspended or weakly swimming in water.

APPENDIX 4A

Lake Systems of the Upper Columbia River Basin

The Aquatic/Riparian Staff of the Interior Columbia Basin Ecosystem Management Project contracted Gary Larson and William Liss of Oregon State University and E&S Environmental Chemistry in Corvallis, Oregon to (1) characterize lakes within the assessment area and (2) evaluate the potential effects of land-use activities of lake ecosystems across the assessment area. Data was compiled from multiple sources throughout the Basin into a single database (Pacific Northwest Lakes DLG) that was spatially identified at the 1:100,000 scale (map 4A.1). A total of 9,186 was identified. Because wetlands and/or dry lakes were sometimes counted as lakes, this data may overestimate the number of lakes, particularly in some arid areas such as the Northern Great Basin.

Characterization of Lakes Within the ICBEMP Assessment Area

Lakes in the study area were initially grouped by modified Bailey Ecoregions (to section level) which roughly correspond to ICBEMP Ecological Reporting Unit boundaries. General comparisons for this report were based on conversions from Bailey Ecoregions to ERUs. The greatest number of lakes occurs in the Northern Rockies (Northern Glaciated Mountains and Lower Clark Fork; N=2,339), and Middle Rockies provinces (Upper Clark Fork, Blue Mountains, and Central Idaho Mountains; N=2,171). The Southern Rockies (Snake Headwaters ERU; N=814) and Cascades provinces (Northern and Southern Cascades; N=811) have the fewest lakes. The greatest number of lakes are small (1-5 hectares) and are located at high elevations (>1,600 meters).

Total alkalinity, total phosphorous, and conductivity were used for determining trophic status on productivity. Higher phosphorous and alkalinity conductivity combinations generally related to higher levels of productivity in assessment area lakes.

Chemical Classification by ERUs

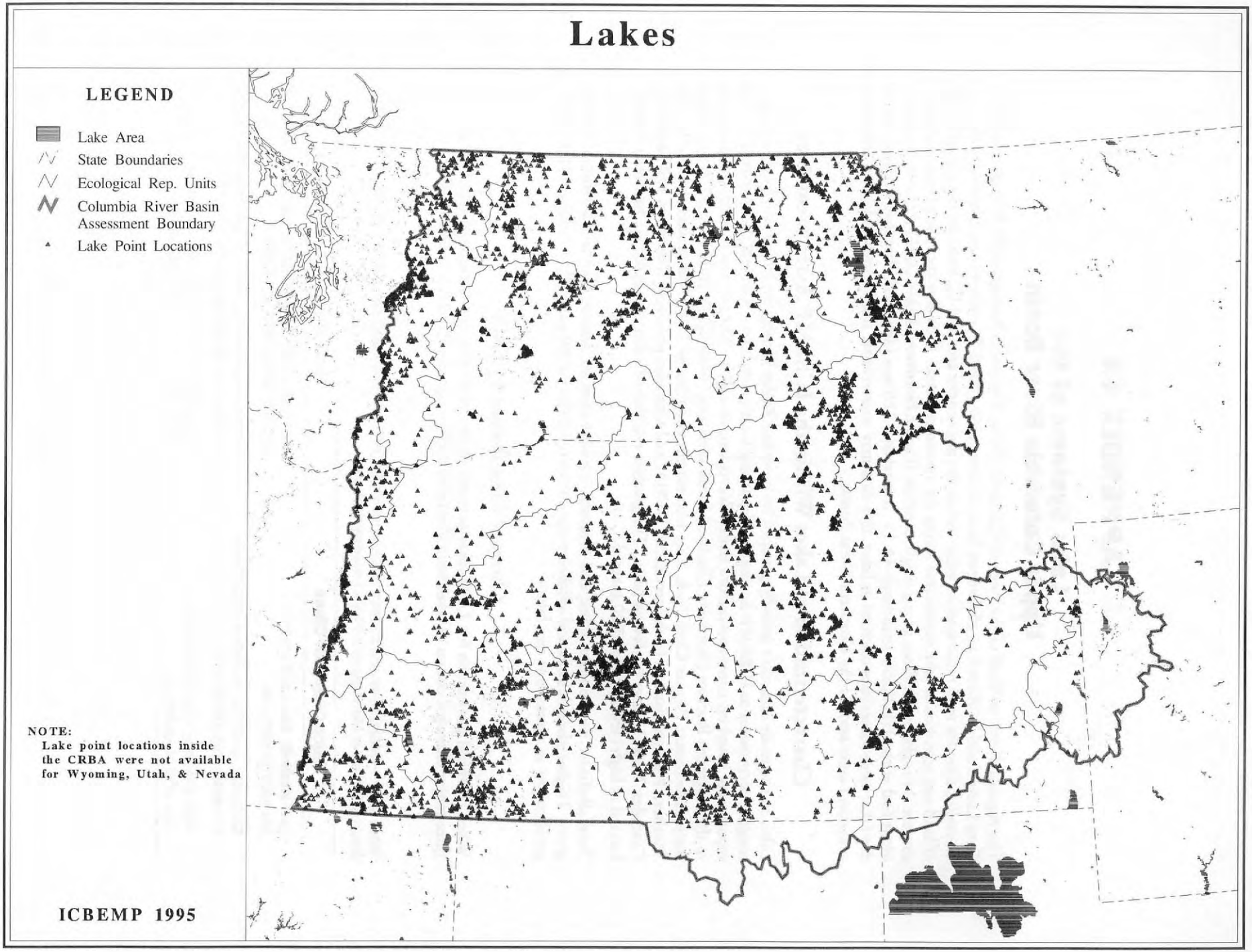
When chemical parameters for 1,543 lakes sampled in the study area were compared among ecoregions, three major chemical classes of lakes were identified and summarized by ERU (table 4A.1).

Table 4A.1— Major chemical classes of lakes identified from 1543 sampled lakes within the Interior Columbia Basin Ecosystem Management Project assessment area.

Major Chemical Class	Ecological Reporting Unit
Low alkalinity, low conductivity, low total phosphorus	Northern and Southern Cascades, Upper Clark Fork, Central Idaho, Blue Mountains
Moderate alkalinity, moderate conductivity, moderate total phosphorus	Snake Headwaters, Northern Glaciated Mountains (Okanagan Highlands), Lower Clark Fork
High alkalinity, high conductivity, high total phosphorus	Columbia Plateau, Northern Great Basin, Upper Snake, Owyhee Uplands

Map 4A.1—Lakes.

Lakes



A major caveat in this analysis is that a "found" sample was used to make inferences on the entire population of lakes; therefore, it was not possible to assign levels of statistical confidence to differences in lake attributes. Different sampling protocols and analytical methods for the data sets used in this evaluation also confounded direct comparison. Furthermore, there was no consistency in the number of observations among parameters.

Lakes that were most sensitive to atmospheric pollution sources (such as low alkalinity lakes) were located in the Central Idaho, upper Clark Fork, Blue Mountains, and Northern and Southern Cascades. Lakes most sensitive to land-use disturbance (for example, lakes in more accessible terrain that currently have low levels of total phosphorus) are those in the eastern part of the Northern Glaciated Mountains and Lower Clark Fork ERUs. Other sections with low total phosphorus include the Northern and Southern Cascades, Upper Clark Fork, Central Idaho, and Blue Mountains. These areas would be sensitive to nutrient additions from any source.

Some areas, including the Columbia Plateau, Northern Great Basin, and Upper Klamath have very high total phosphorus values. Although these areas contain volcanically-influenced soils, a significant anthropogenic signal may be superimposed on these lakes. Likely nutrient sources would include grazing and irrigated agriculture. The Columbia Plateau and Northern Great Basin are also noteworthy because of the strong saline influence (sodic soils).

Lake Classifications by Kuchler Potential Natural Vegetation Type

There appeared to be a strong relationship between lake water chemistry and Kuchler vegetation types (table 4A.2). Productive land for forests or agriculture has productive lakes nested on it. A general relationship between elevation and lake chemistry was also noted. Higher elevation lakes generally were low alkalinity/conductivity/total phosphorus; however this relationship does not hold when comparisons are expanded to western lakes overall (Eilers and others 1987).

Total phosphorus, alkalinity, and conductivity were logarithmically transformed and statistically grouped using a disjoint Euclidean distance cluster analysis (SAS 1989). Ten clusters were identified and the maximum number of iterations from recomputing cluster seeds was ten. If a lake had a missing value for a variable, the missing value was estimated by the cluster seed value. This allowed all observations to be classified without complete data. Table 4A.3 presents the mean statistics for each cluster for selected chemical and physical parameters.

The major cluster groups (dilute, moderate, hard water, and saline) were mapped. The dilute group is located at high elevations (~2000 m) in the Cascades, the Bitterroots, and Grand Tetons (map 4A.2). The bedrock types in these areas are granites, andesites, and other rocks resistant to weathering. These lakes tend to be smaller and have lower ionic concentrations. The maximum conductivity in the dilute group is 55 µS.

The moderate group has average alkalinity of 420 µeq/L, and total phosphorus can range from near zero to 194 µg/L with average concentrations near 20 µg/L. Lakes in the moderate group are geographically more diverse than the dilute system (map 4A.3) and are located in lower elevations in the Cascades, Idaho batholith, and Wyoming. The average elevation is approximately 1700 meters, and average lake size is larger than the dilute lake group. These lakes are also generally located over granites and andesites, but because of their lower elevation, they probably have longer flow paths through deeper soils.

The hard water group has higher alkalinity (~3000 µeq/L) and higher average total phosphorus (~200 µg/L). These lakes are moderate-to-large in size and are at lower elevations (~560 m). The hard water lakes are generally located over sedimentary bedrock and/or alluvial surficial deposits. Some of these lakes are in areas of basalt overlain by loess (map 4A.4).

Table 4A.2— Attributes of lakes classified by Kuchler Potential Vegetation. Data are arrayed on a lake productivity basis, lowest to highest.

Kuchler Vegetation Type	N	pH	Alkalinity (ueq/L)	Conductivity (uS)	Total Phosphorus (ug/L)	Trophic State Index	Elevation (m)	Depth (m)	Area (ha)
Western Spruce/Fir	114-318	6.96	83	13	4	24.7	2128	8.0	4.0
Alpine Meadows	61-05	7.20	86	18	6	30.1	1702	10.0	4.8
Cedar/Hemlock/Pine	9-24	6.76	530	58	8	34.1	IS	IS	IS
Fir/Hemlock	57-78	7.10	135	18	8	35.8	1608	9.0	9.2
Grand fir/Douglas-fir	21-92	6.85	82	12	8	44.5	2161	6.5	3.0
Douglas-fir	127-252	7.09	910	99	29	48.6	841	10.4	11.3
Ponderosa/Shrub	29-42	7.61	342	41	25	50.6	IS	IS	IS
Western Ponderosa	30-139	7.12	297	26	34	54.8	2194	8.5	3.7
Sagebrush/Steppe	187-218	8.40	3850	438	95	69.8	361	5.4	20.6
Fescue/Wheat grass	87-97	7.37	5016	565	119	72.3	642	6.2	18.2
Wheat grass/Bluegrass	14-27	6.86	2280	258	191	79.7	523	5.2	13.4

IS = Insufficient Sample

The saline group consists of lakes with high conductivity and alkalinity. The minimum alkalinity is 8000 μeq/L and the maximum alkalinity is 373,788 μeq/L (conductivity of 42,000 μS). The lakes are located in the central Washington and south central Oregon deserts (map 4A.5). The average elevation is 540 meters. The bedrock composition in these areas is typically basalt with sodic soils.

Effects of Land-use Activities on Lake Ecosystems

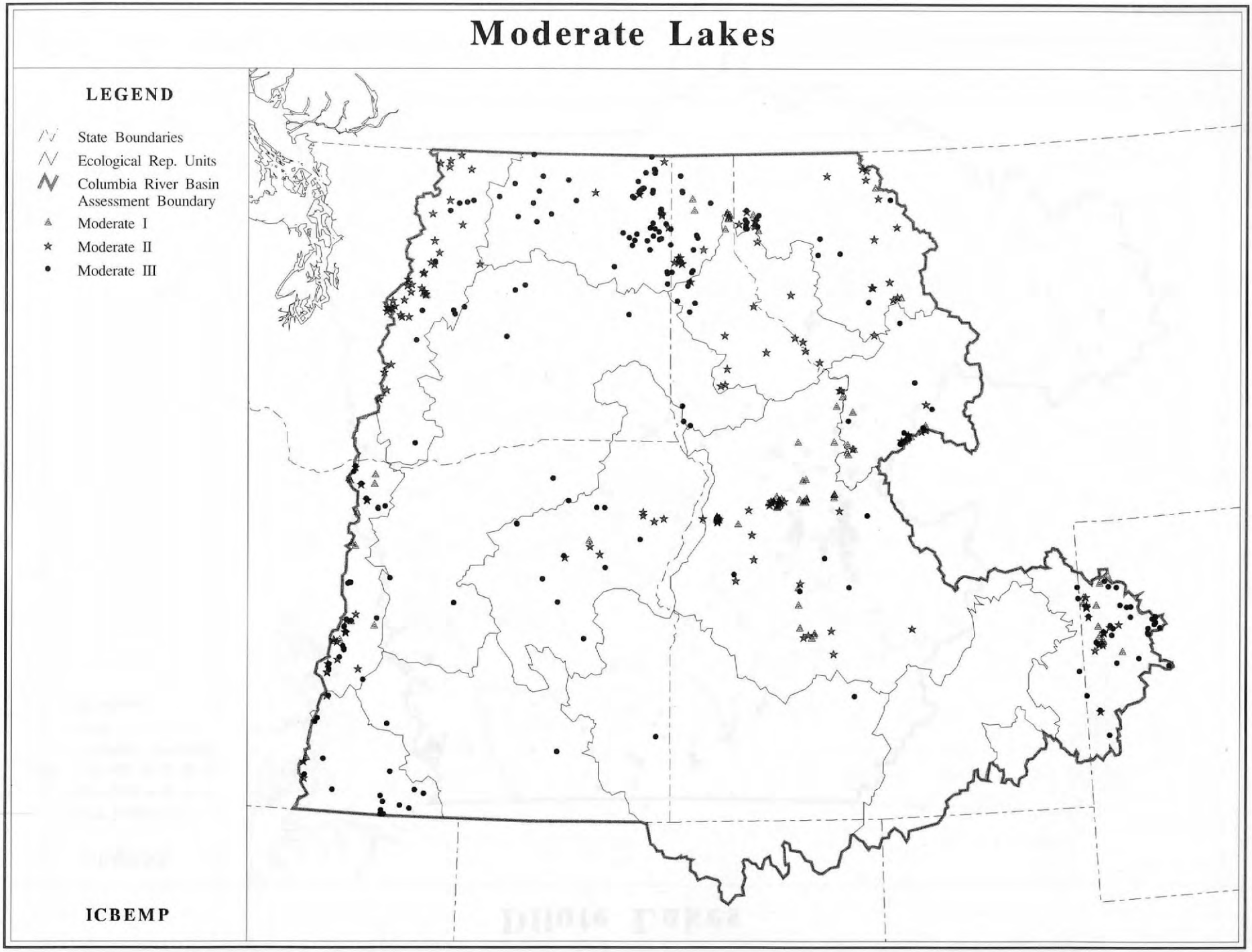
Evaluating the potential effects of land-use activities on lake ecosystems is difficult at a broad scale, and determinations for ERU sections rely on generalizations that may not be applicable in specific lake basins. The relative rankings of land-use effects on lakes in the study area were based largely on land use and cultural ecology described for each of the sections by McNab and Avers (1994).

Information on the importance of timber production in the study area was supplemented by vegetation types described by Küchler (1964). The impacts from timber production will vary greatly within the sections depending on land ownership, special land use categories such as wilderness area, national parks or refuges, and vegetation zone. For example, the greatest timber production will generally occur within the montane zone and to a lesser degree the sub-alpine zone. Much of the research suggests that the damage to surface waters occurs largely because of erosion associated with logging roads. There is a low risk from timber harvest to the vast majority of lakes within forested areas because most lakes enjoy special management status and subsequent protection. A few researchers feel that timber harvest accelerates nutrient input into lakes in amounts that accelerate production in oligatrophic lakes, but this conclusion is controversial among the research community.

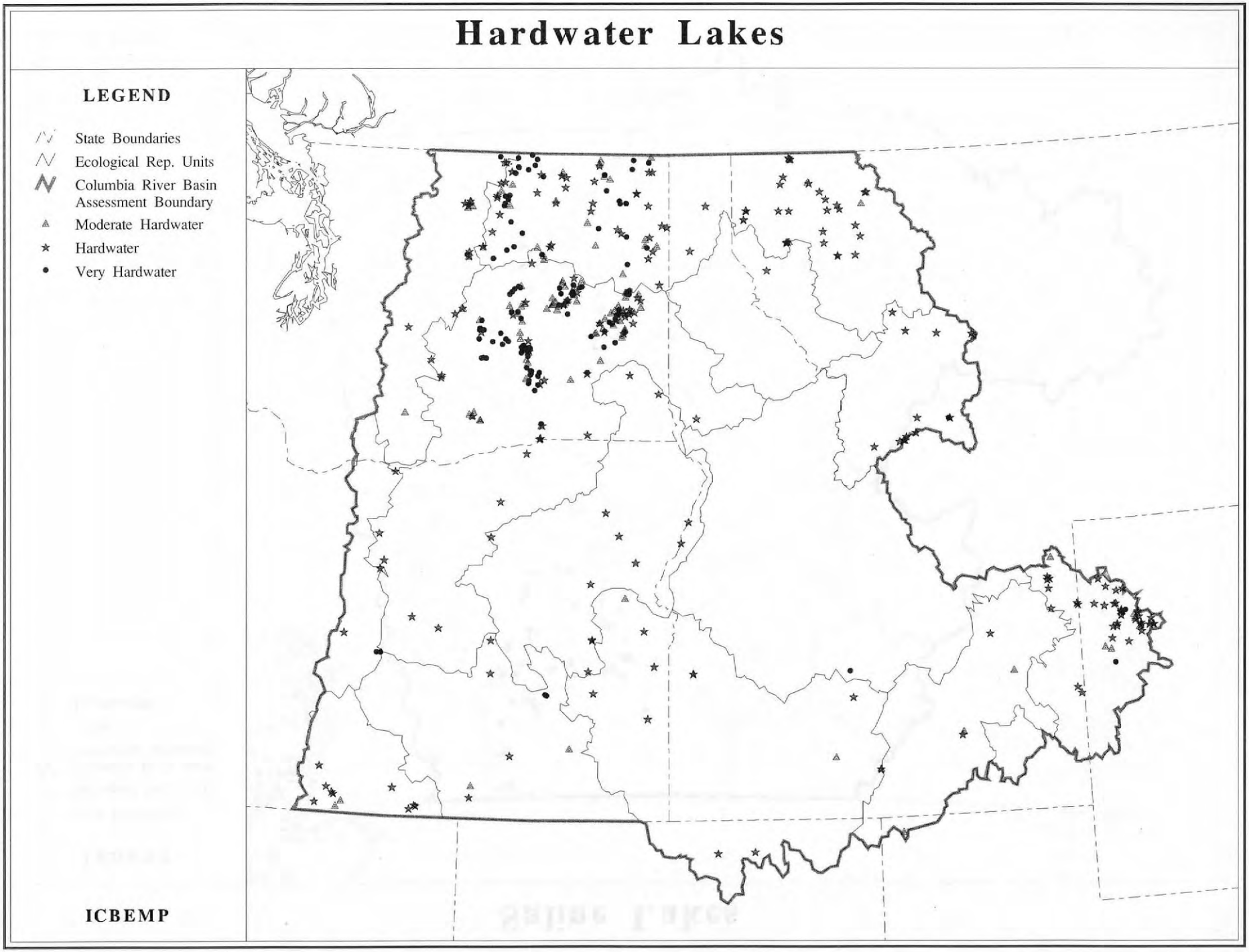
Map 4A.2—Dilute lakes.

Map 4A.3—Moderate lakes.

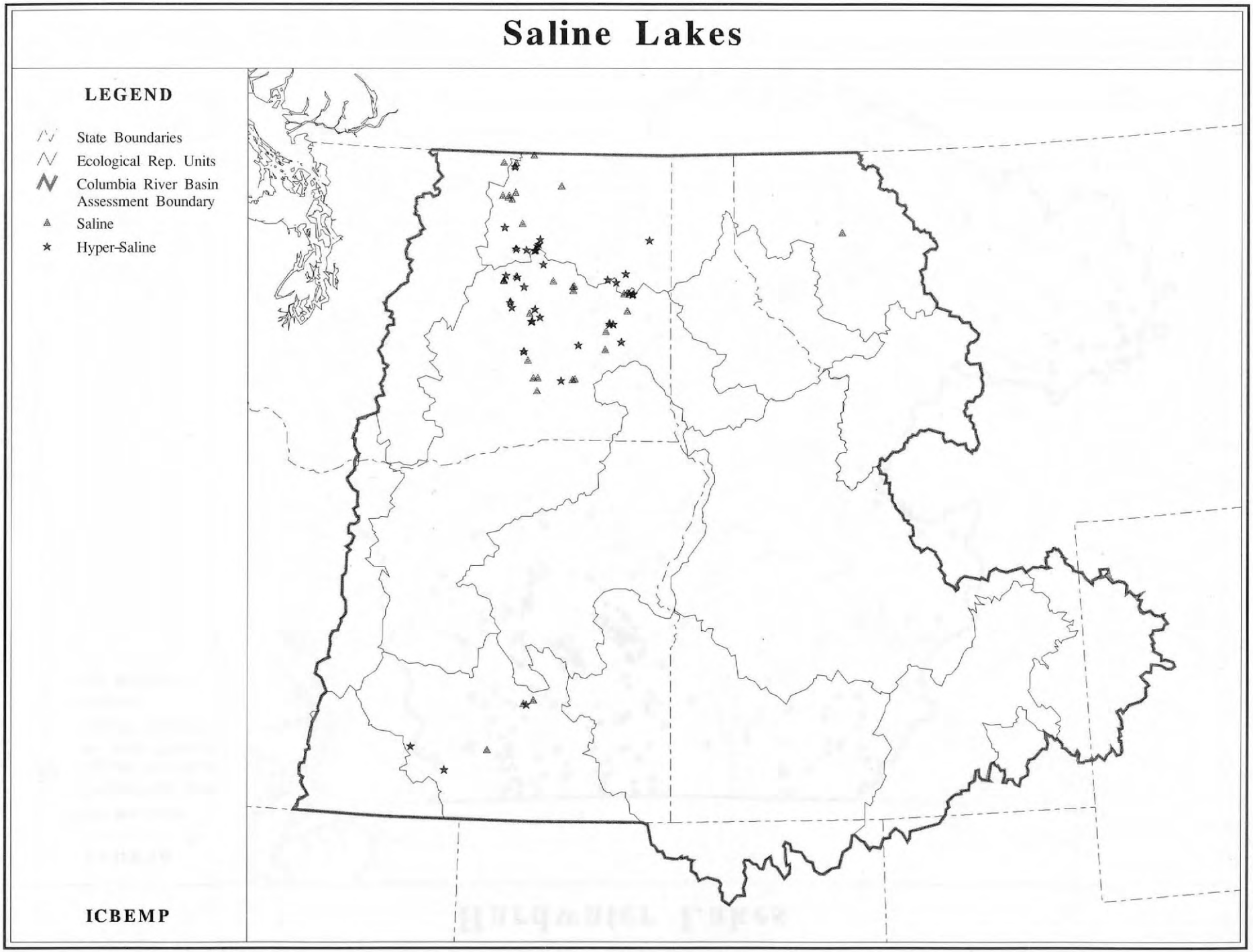
Moderate Lakes



Hardwater Lakes



Map 4A.4—Hardwater lakes.



Map 4A.5—Saline lakes.

Table 4A.3—Chemistry of lake clusters, arranged from near distilled water to salt water. See maps 4A.2-4A.5 for assessment area distribution within each of the four clusters.

	Alkalinity	Conductivity	TP	Area	Elevation	Land Use Sensitivity
Dilute						
Ultra Dilute	35	7	3	30	1993	Atmospheric deposition (smoke, acid rain)
Dilute	67	12	12	15	1997	
Moderate						
Moderate I	132	17	0	10	2230	Development, Recreation(boats), Water consumption
Moderate II	350	38	4	228	1790	
Moderate III	634	70	34	207	1210	
Hardwater						
Mod-Hardwater	4516	499	469	64	507	Grazing, Mining, Development, Water consumption
Hardwater	1818	196	127	133	708	
Very Hardwater	5423	604	52	164	492	
Saline						
Saline	18247	2010	173	53	570	Irrigation, Agriculture, Grazing
Hyper Saline	57848	6526	2700	39	577	

Grazing impacts are expected to be greatest in the areas historically used as grasslands in the low elevation areas. Slight to moderate effects of grazing will occur in the higher elevation forested areas. However, because of the greater slopes in the forested areas, some localized effects of grazing may be severe.

Timber and grazing impacts are generally the most widespread impacts to the landscape. Many mining impacts remain from long-abandoned mines throughout the West. In some cases mining impacts may be restricted to relatively benign borrow pits for gravel or crushed rock. In other cases, processed ores generate considerable leachate which contaminate surface waters far from their source. Valuable ores remain scattered throughout the study area and future mining endeavors continue to look risky for lakes downstream from such activities.

Recreation pressures are increasing, causing damage to some resources, particularly beaches and littoral areas. Recreation activities include backpacking, horsepacking, use of motorized vehicles, and the road and trail development associated with greater demand to use the resources. National parks and scenic forested areas are areas where recreational impacts can be expected to increase at the fastest rate.

Development refers to urbanization/suburbanization of formerly rural areas. In some cases, the development is closely related to recreation, particularly with respect to construction of seasonal dwellings on lakeshores. Many soils in the moderate to higher elevation areas in the study area have very limited capabilities to sustain development pressures.

Lake biological communities have been seriously modified throughout the study area, and the most common modification is introduction of non-indigenous fishes. The consequences of deliberate and inadvertent introductions of fishes and invertebrates vary from changes in historic population structure and distribution to extirpation of indigenous invertebrates, amphibians, and fish (for example, bull trout and westslope cutthroat trout). In some cases, native species have been intentionally eradicated to enhance other recreational fishing for desirable "sport" species. Boating associated with angling and other recreational activities has led to the introduction of numerous exotic plants such as Eurasian watermilfoil, *Myriophyllum spicatum.*

Water transfers for potable water supply or for irrigation continue to impact lakes throughout the study area. Even where precipitation is adequate, diversions (even in wilderness areas) to more arid areas in the valleys have negative effects on the lakes and stream resources. Dozens of moderate sized lakes throughout the assessment area have their shoreline heavily influenced through regulation of their outlet streams or rivers. Regulation of the lake level for consumptive and irrigation purposes has major effects on near shore aquatic and wetland communities and spawning success of near shore spawning fishes. Additionally, interbasin water transfers promote the continued spread of non-indigenous plants and animals while often inhibiting natural migration routes of native species.

Currently, effects of atmospheric pollutants appear to be negligible for lakes in the study area. There is no evidence of anthropogenic acidification, but greater use of gas fields and coal in the region could be a long-term concern. Pesticides and various chlorinated hydrocarbons have been measured in the sediments of wilderness lakes in the region, suggesting that these compounds have been transported atmospherically. Though data do not yet exist, a potential risk to very dilute and dilute lakes could be nutrient augmentation from extensive prescribed burning (161,900 hectares/year) and wildfires in general. Spencer and Hauer (1991) found that phosphorus and nitrogen concentrations in streams increased from 5- to 60-fold over background levels within the first two days of fire, likely from leaching of ash and diffusion of smoke gases into surface waters.

The mid-elevation lakes throughout the basin have and will continue to show the greatest impacts from a growing regional population seeking to live or recreate near lakes. Lakes like Flathead, Priest, Hayden, Payette, Lake of the Woods, Odell and many others share common elements of the same theme from the past or likely trend for the future. A short story of changes to Flathead Lake, Montana will provide a glimpse of what growing lakeside development and recreational use might mean combined with the threat of wildfires and extensive prescribed burning.

Flathead Lake is one of the largest and most pristine natural lakes in the western United States and is valued for the clarity and purity of its water (Spencer and others 1991; Stanford and others 1994, 1995). Even though nearly 70 percent of the lake's watershed occurs in Glacier National Park and surrounding wilderness areas, human activities continue to threaten the quality of the lake's waters.

Cultural Eutrophication of Flathead Lake

Both point and nonpoint sources of pollution have affected water quality in Flathead Lake. The increase in primary production of algae from 1977 to 1989, a possible indicator of deteriorating water quality, was associated with high levels of phosphorous and nitrogen loading from sewage treatment plants located on tributaries to the lake (Stanford and others 1994, 1995). Water clarity, as measured by secchi depth, was negatively related to nutrient loading (Stanford and others 1995).

A program to reduce phosphorous input to the lake was instituted by the Montana Water Quality Department. The program included technological improvements in sewage treatment plants to remove phosphorous from effluents and a ban on the sale of phosphorous-containing detergents. This program has resulted in a decline in the contribution of sewage treatment plants from near 20 percent to less than 5 percent of the total phosphorous load delivered to Flathead Lake. The decline in nutrients has been accompanied by a decline in primary productivity (Stanford and others 1994, 1995).

Although nutrient inputs from sewage treatment plants have been reduced, investigators have documented high concentrations of phosphorous and nitrogen stored in the sediments of a tributary stream of Flathead Lake receiving effluent from a sewage treatment facility. They suggest that these nutrients can be released under anoxic condition and so may partially offset reductions in nutrient discharge achieved by technological improvements in the treatment plants (Stanford and others 1994).

Although input of nutrients from sources along the lake shoreline such as domestic sewage drain fields probably do not contribute extensively to the total nutrient load of the lake (Stanford and others 1994), localized shoreline sources can increase algal production along the lake margin, creating a "ring around the lake" (Stanford and others 1994, 1995).

There is concern about increased nutrient loading from nonpoint sources. In part this increase may be related to population expansion which is occurring in the Flathead watershed at a rate of 2 percent per year. Input from bulk precipitation is also a significant source of nutrients, accounting for 10-38 percent of the total phosphorous load over the time period of record (Stanford and others 1995). Smoke and dust particles in the atmosphere are thought to be responsible for the high levels of phosphorous in precipitation (Stanford and others 1995).

Exotic Species Introductions to Flathead Lake

At least seventeen species of fish and invertebrates have been introduced into Flathead Lake (Spencer and others 1991). The appearance of the oppossum shrimp, *Mysis relicta*, apparently triggered major shifts in the food web of the Flathead Lake ecosystem. In addition to *Mysis*, a complex of introduced species including kokanee salmon (*Oncorhynchus nerka*), lake trout (*Salvelinus namaycush*), and lake whitefish (*Coregonus clupeaformis*) may have been involved in the food web changes. *Mysis* prey upon zooplankton. Following the appearance of the shrimp in Flathead Lake, cladoceran zooplankton and a diaptomid copepod decreased in abundance (Beattie and Clancey 1991; Spencer and others 1991). Kokanee salmon, a valuable sport fish, also declined dramatically as *Mysis* abundance peaked. Kokanee feed extensively on zooplankton, especially cladocerans (Beattie and Clancy 1991; Reiman and Bowler 1980). *Mysis* are thought to have contributed to the decline in salmon through reduction in the salmon's food resources. Since *Mysis* and kokanee are able to coexist in some lakes (Beattie and Clancy 1991), the decline in kokanee in Flathead Lake may have been related not only to interspecific competition with *Mysis* but also to the presence of kokanee predators such as lake trout (Bowles and others 1991; Spencer and others 1991) and other planktivorous competitors such as juvenile lake whitefish (Beattie and Clancy 1991). The collapse of the kokanee population in Flathead Lake following *Mysis* introduction reduced the number of migrating bald eagles and other wildlife that congregated to feed on kokanee during their spawning migration (Spencer and others 1991).

APPENDIX 4B

A Description of the 61 Vegetative Classes Used In the Cluster Analysis.

Vegetative Class	Potential Vegetation Type	Structural Stage	Cover Type	Total Area (hectares)
1	Agricultural	Closed Herbland	Cropland / Hay / Pasture	7529100
2	Agricultural	Agricultural	Cropland / Hay / Pasture	4307200
3	*Alpine*	*Open Low Shrub*	*Alpine Tundra*	372400
4	Cold Forest	Stand Initiation Forest	Whitebark Pine / Alpine Larch Engelmann Spruce/Subalpine Fir Whitebark Pine Interior Douglas-fir Aspen Lodgepole Pine	1908200
5	Cold Forest	Stem Exclusion Open Canopy Forest Stem Exclusion Closed Canopy Forest	Whitebark Pine / Alpine Larch Whitebark Pine Aspen	304500
6	Cold Forest	Stem Exclusion Closed Canopy Forest	Engelmann Spruce/Subalpine Fir Interior Douglas-fir Lodgepole Pine	3253900
8	Cold Forest	Understory Reintiation Forest	Engelmann Spruce/Subalpine Fir Interior Douglas-fir Lodgepole Pine	760800
10	Cold Forest	Young Multi-strata Forest	Engelmann Spruce/Subalpine Fir Interior Douglas-fir Lodgepole Pine	1033300
13	Cold Forest	Old Multi-strata Forest	Engelmann Spruce/Subalpine Fir Lodgepole Pine	468700
14	Cold Forest	Old Single-strata Forest	Whitebark Pine	906100
17	Cold Forest	Closed Mid Shrub	Shrub or Herb/Tree Regeneration	926400
19	Cool Shrub	Stand Initiation Woodland	Juniper / Sagebrush	982500
21	Cool Shrub	Understory Reintiation Woodland	Juniper / Sagebrush	494900
23	Cool Shrub	Open Herbland Closed Herbland Open Low Shrub Closed Mid Shrub	Exotic Forbs / Annual Grass Fescue-Bunchgrass *Agropyron* Bunchgrass Fescue-Bunchgrass Chokecherry/Serviceberry/Rose Mountain Big Sagebrush	4187800
25	Dry Forest	Stand Initiation Forest	Grand Fir/White Fir Interior Douglas-fir Lodgepole Pine Interior Ponderosa Pine Sierra Nevada Mixed Conifer Pacific Ponderosa Pine	556000
26	Dry Forest	Stem Exclusion Open Canopy Forest	Interior Ponderosa Pine	1767200

Vegetative Class	Potential Vegetation Type	Structural Stage	Cover Type	Total Area (hectares)
27	Dry Forest	Stem Exclusion Closed Canopy Forest	Grand Fir/White Fir	1641200
			Interior Douglas-fir	
			Lodgepole Pine	
			Interior Ponderosa Pine	
			Pacific Ponderosa Pine	
28	Dry Forest	Understory Reintiation Forest	Grand Fir/White Fir	628100
			Interior Douglas-fir	
			Lodgepole Pine	
			Interior Ponderosa Pine	
			Pacific Ponderosa Pine	
29	Dry Forest	Young Multi-strata Forest	Grand Fir/White Fir	4028800
			Interior Douglas-fir	
			Lodgepole Pine	
			Interior Ponderosa Pine	
			Sierra Nevada Mixed Conifer	
			Pacific Ponderosa Pine	
30	Dry Forest	Old Multi-strata Forest	Grand Fir/White Fir	4114200
			Interior Douglas-fir	
			Interior Ponderosa Pine	
			Sierra Nevada Mixed Conifer	
			Pacific Ponderosa Pine	
		Old Single-strata Forest	Interior Douglas-fir	
			Interior Ponderosa Pine	
			Sierra Nevada Mixed Conifer	
			Pacific Ponderosa Pine	
32	Dry Forest	Open Herbland	Fescue-Bunchgrass	1798000
		Closed Herbland	Shrub or Herb/Tree Regeneration	
			Exotic Forbs / Annual Grass	
			Fescue-Bunchgrass	
		Open Low Shrub	Shrub or Herb/Tree Regeneration	
		Open Mid Shrub	Mountain Big Sagebrush	
		Closed Mid Shrub	Shrub or Herb/Tree Regeneration	
			Mountain Big Sagebrush	
34	Dry Grass	Stem Exclusion Woodland	Mixed Conifer Woodlands	291600
		Old Multi-strata Woodland	Mixed Conifer Woodlands	
35	Dry Grass	Open Herbland	*Agropyron* Bunchgrass	3713500
			Native Forb	
			Exotic Forbs / Annual Grass	
			Agropyron Bunchgrass	
			Exotic Forbs / Annual Grass	
			Fescue-Bunchgrass	
37	Dry Shrub	Open Herbland	*Agropyron* Bunchgrass	20937900
			Exotic Forbs / Annual Grass	
		Closed Herbland	Big Sagebrush	
			Agropyron Bunchgrass	
			Exotic Forbs / Annual Grass	

Vegetative Class	Potential Vegetation Type	Structural Stage	Cover Type	Total Area (hectares)
38	Moist Forest	Stand Initiation Forest	Pacific Silver Fir/Mountain Hemlock Grand Fir/White Fir Mountain Hemlock Engelmann Spruce/Subalpine Fir Interior Douglas-fir Western Larch Western White Pine Lodgepole Pine Western Redcedar/Western Hemlock Interior Ponderosa Pine	14118300
39	Moist Forest	Stem Exclusion Closed Canopy Forest	Pacific Silver Fir/Mt. Hemlock Grand Fir/White Fir Mt. Hemlock Western Redcedar/Western Hemlock	1766900
40	Moist Forest	Stem Exclusion Closed Canopy Forest	Engelmann Spruce/Subalpine Fir Interior Douglas-fir Western Larch Western White Pine Lodgepole Pine Interior Ponderosa Pine	3100500
41	Moist Forest	Understory Reintiation Forest	Pacific Silver Fir/Mountain Hemlock Grand Fir/White Fir Mt. Hemlock Engelmann Spruce/Subalpine Fir Interior Douglas-fir Western Larch Western White Pine Lodgepole Pine Western Redcedar/Western Hemlock Interior Ponderosa Pine	4595300
42	Moist Forest	Young Multi-strata Forest	Pacific Silver Fir/Mountain Hemlock Grand Fir/White Fir Red Fir Mountain Hemlock Engelmann Spruce/Subalpine Fir Interior Douglas-fir Western Larch Western White Pine Lodgepole Pine Western Redcedar/Western Hemlock Interior Ponderosa Pine	6178000
43	Moist Forest	Old Multi-strata Forest	Pacific Silver Fir/Mountain Hemlock Mt. Hemlock Engelmann Spruce/Subalpine Fir Lodgepole Pine Western Redcedar/Western Hemlock	1617700
		Old Single-strata Forest	Mt. Hemlock	

Vegetative Class	Potential Vegetation Type	Structural Stage	Cover Type	Total Area (hectares)
44	Moist Forest	Old Multi-strata Forest	Grand Fir/White Fir	14119800
			Red Fir	
			Interior Douglas-fir	
			Western Larch	
			Western White Pine	
			Interior Ponderosa Pine	
		Old Single-strata Forest	Grand Fir/White Fir	
			Interior Douglas-fir	
			Western Larch	
			Western White Pine	
			Interior Ponderosa Pine	
45	Moist Forest	Open Low Shrub	Shrub or Herb/Tree Regeneration	5349600
		Closed Mid Shrub	Shrub or Herb/Tree Regeneration	
		Open Tall Shrub	Shrub or Herb/Tree Regeneration	
	Riparian Shrub	Open Herbland	Herbaceous Wetlands	
			Exotic Forbs / Annual Grass	
45	Moist Forest	Closed Herbland	Herbaceous Wetlands	
		Closed Low Shrub	Shrub Wetlands	
		Open Low Shrub	Shrub Wetlands	
		Open Mid Shrub	Salt Desert Shrublands	
		Closed Tall Shrub	Shrub Wetlands	
46	Rock	Rock	Rock	228000
47	Urban	Urban	Urban	114300
48	Water	Water	Water	754800
50	Woodland	Stem Exclusion Open Canopy Forest	Limber Pine	2403800
		Stem Exclusion Closed Canopy Forest	Aspen	
		Understory Reintiation Forest	Aspen, Limber Pine	
53	Woodland	Young Multi-strata Forest	Aspen	855100
58	Woodland	Understory Reintiation Woodland	Juniper Woodlands	113400
61	Woodland	Closed Herbland	Exotic Forbs / Annual Grass	4321700
			Fescue-Bunchgrass	
		Closed Low Shrub	Mountain Mahogany	
			Mountain Big Sagebrush	
		Closed Mid Shrub	Shrub or Herb/Tree Regeneration	
			Shrub Wetlands	

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APPENDIX 4C

Fish Status and Distribution Databases

The information conveyed in the section entitled "Distribution and Status of Fishes" on fish assemblages and key salmonids is available in a series of four electronic databases. The discussion below and accompanying tables supplement the information given in that section regarding derivation of the fisheries data and provide a guide to the databases. The sources for data contained therein were available from preexisting databases and from professional biologists throughout the Basin. Databases were compiled for subbasins, watersheds, and subwatersheds in the following manner.

Current-Status Database

Preexisting Data—The following databases were available at the initiation of this effort: the River Information Systems (RIS) databases for Washington (WARIS), Oregon (ORIS), Montana (MRIS) and Idaho (IRIS); the Oregon State University fish collection data base; the Coordinated Information System (CIS) database for anadromous fish maintained by the Pacific States Marine Fisheries Commission, and the Wilderness Society distributions of anadromous salmonids. The RIS and CIS databases were attributed to stream segments based on the EPA river-reach codes. The Wilderness Society database was represented by GIS coverages that were used only in development of the historical ranges. We worked with the State agencies to update RIS information for the key salmonids in Idaho and Montana; biologists in both states reviewed and updated existing information regarding known presence or absence of key species.

Data acquisition was closed in June 1995 to begin proofing and analysis. Data that were not incorporated because of delayed availability include: the Washington Department of Fisheries and Wildlife Streams and Lakes Fish Database; Oregon Department of Fish and Wildlife database for the distribution of bull trout; Oregon Department of Fish and Wildlife database for habitat and fish inventory sampling; University of Washington collection records; Oregon State University collection records; and the Plum Creek Timber Company bull trout inventories. This information is not included in the current database, but can be incorporated in future versions. Relevant portions of these data were used in a validation exercise.

Biologists' Classifications—Biologists (more than 140 participated, table 4C.1) from throughout the Basin were asked to classify the distribution and status of each of the key salmonids within subwatersheds. Possible classifications included strong or depressed in spawning and rearing areas, present but status unknown, migration corridor, absent, or unknown. Proofing of the status calls was initiated where a second opinion was possible; changes in the original classifications generally were confirmed with the biologists that made the original classifications. Corridor habitats were added in the proofing process where the oversight was obvious (for example, missing segments for anadromous or non-anadromous species that are known to move completely through entire rivers or river segments).

Merging—We merged the status classification calls with preexisting data to produce as comprehensive a database as possible. In most cases, the RIS and CIS databases were limited to presence/absence information. In some cases (MRIS all species, IRIS for bull and cutthroat trout), additional information was available for classification of status and/or life history stage. Rules for interpretation of data from IRIS and MRIS are summarized in table 4C.2. All RIS data were attributed to the corresponding subwatershed. A "present" call implies presence in any stream reach within the unit; status reflects the

predominant status among all reaches. The biologists' judgements were merged with the RIS data sets using the rules in table 4C.3. In cases where species classifications differed between presence and absence, the final classification was "unknown" unless we could clearly resolve the inconsistency with recent data. Where differences were in status, the most recent information was used. The final database includes summaries of the number of key salmonids classified as strong, strong or depressed, present, and unknown, all within the potential historical range. Table 4C.4 documents the format for the current status database, CRBFISH6. In addition to the status calls, the database also includes predicted status based on the landscape data and classification trees developed by the aquatics team (see "Distribution and Status of Fishes, this chapter), and historical-range information.

Limitations of the Database—The framework of the assessment required that the species status information be summarized by subwatersheds rather than stream reaches. With limited time for development, it was necessary to classify subwatersheds directly, rather than first classifying all stream reaches and then attributing subwatersheds. This limits further analysis. Because many subwatersheds contain a combination of small, first- and second-order streams within a section of a larger river or stream, the type or quality of habitat available to a species or life stage may vary widely. In these cases, distinguishing migration corridors from spawning and rearing areas may have been confusing. This is a particular problem for westslope cutthroat trout that often use small tributaries in direct association with mainstem areas.

Extrapolating status from information limited to only a few sites was often necessary. In watersheds that vary widely in habitat type or condition, such classification may not be representative of the watershed. It was not always possible to access all or the most recent information sources, and information sources varied in quality. It is difficult to judge the status of a population if historical or basin-wide data are limited. For species like bull trout, there is often little information available to judge whether current densities are high or low. Sampling methods vary in their efficiencies making comparisons across broad scales difficult. Rare species may be missed by limited sampling, and sampling protocols rarely address that error in existing inventories (see Rieman and McIntyre 1995 for one example). As a result, classifications of a species' presence are likely to be more robust than those of absence, classification of strong and depressed may be equivocal and perhaps inconsistent from one region to another.

Despite the limitations, we believe these data provide an accurate representation of current distributions at the broad scale. We were conservative in the development of the database by cross checking sources and by encouraging biologists to rely on empirical information when making classifications. We accepted classifications of absent from RIS databases only where sampling was documented. A number of subwatersheds were classified as unknown because of conflicting information from RIS databases and biologists' designations: 23 for Yellowstone cutthroat trout, 163 for westslope cutthroat trout, 160 for redband trout, 92 for summer steelhead, 16 for ocean-type chinook salmon, 106 for stream-type chinook salmon, and 323 for bull trout. While the status calls retain an element of subjectivity and inconsistency, the professional biologists who classified watersheds generally hold the best understanding of current distributions and relative status for these species. There is simply no other way to provide a current and comprehensive assessment of fish distribution than to rely on the existing but often unpublished information that can be summarized by these people. Although some classifications may be equivocal, we anticipate no consistent bias. The overall patterns should reflect important characteristics of the species distributions and the current state of our collective knowledge. The database can be useful for interpreting broad patterns in distribution and general relationships with landscape characteristics. These data should not be used to draw detailed conclusions about extinctions where historical ranges are uncertain (for example, bull trout, redband trout, cutthroat trout), and should not be used for project-level management decisions without local review and validation.

Other Databases

Derivation of the species-assemblage database (CRBFISH5) is described in the text. It includes information on 127 species and 15 species groups at the watershed level (table 4C.5). Presence/absence for the key salmonid species at the watershed level was derived by summing over subwatersheds using the current-status database. In a similar fashion, a presence/absence database at the subbasin level (CRBFISH4, table 4C.6) was constructed by summing over watersheds within each subbasin. The subbasin-level database contains information on additional species that were not reported at smaller scales.

The measures of community integrity described in the text are available in a separate database. Values are expressed at the watershed level.

Table 4C.1— List of participants in classification of watersheds for the key salmonid status and assemblage databases, historical ranges, genetic integrity, and validation information.

Rich Torquemada	Bitterroot National Forest	Bruce Zoellick	Bureau of Land Management
Karen Kuzis	Boise Cascade Corporation	Neal Anderson	Challis National Forest
Tim Burton	Boise National Forest	Leon Jadlowski	Challis National Forest
Don Corley	Boise National Forest	Ken Meyer	Challis National Forest
John Augsburger	Bureau of Land Management	Pat Murphy	Clearwater National Forest
Dana Danzer	Bureau of Land Management	Tom Shuhda	Colville National Forest
Jim Eisner	Bureau of Land Management	John Kelly	CTWSIR
Scott Feldhausen	Bureau of Land Management	S. Gerdes	Deerlodge National Forest
Lisa Healy	Bureau of Land Management	Brian Sanborn	Deerlodge National Forest
Robert House	Bureau of Land Management	Tom Merritt	Deschutes National Forest
Craig Johnson	Bureau of Land Management	Mike Riehle	Deschutes National Forest
Craig Johnson	Bureau of Land Management	Tom Walker	Deschutes National Forest
Lou Jurs	Bureau of Land Management	Steve Robertson	Dixie National Forest
Joe Kelly	Bureau of Land Management	Don Hair	Flathead National Forest
Pat Koelsch	Bureau of Land Management	Pat VanEimeren	Flathead National Forest
Mark Lacy	Bureau of Land Management	Darryl Gowan	Fremont National Forest
Paul McClain	Bureau of Land Management	Darrell Martin	Fremont National Forest
Alan Munhall	Bureau of Land Management	C. Speas	Fremont National Forest
Pat Olmstead	Bureau of Land Management	Bruce May	Gallatin National Forest
Brent Ralston	Bureau of Land Management	Mike Faler	Gifford-Pinchot National Forest
Gina Sato	Bureau of Land Management	Len Walch	Helena National Forest
G. Sheeter	Bureau of Land Management	Kathy Ramsey	Humboldt National Forest
Cynthia Tate	Bureau of Land Management	Dale Allen	Idaho Department of Fish and Game
Todd Thompson	Bureau of Land Management		
Cindy Weston	Bureau of Land Management	Don Anderson	Idaho Department of Fish and Game
Jack Williams	Bureau of Land Management		
David Young	Bureau of Land Management	Bart Butterfield	Idaho Department of Fish and Game

Table 4C.1 (continued).

Tim Cochnauer	Idaho Department of Fish and Game
Chip Corsi	Idaho Department of Fish and Game
Steve Elle	Idaho Department of Fish and Game
Mark Gamblin	Idaho Department of Fish and Game
Stacy Gebhards	Idaho Department of Fish and Game
Judy Hall-Griswold	Idaho Department of Fish and Game
Jerome Hansen	Idaho Department of Fish and Game
Terry Holubetz	Idaho Department of Fish and Game
Ned Horner	Idaho Department of Fish and Game
Dwight Kilgore	Idaho Department of Fish and Game
Mark Larkin	Idaho Department of Fish and Game
Mark Leider	Idaho Department of Fish and Game
Jim Mende	Idaho Department of Fish and Game
Fred Partridge	Idaho Department of Fish and Game
Richard Scully	Idaho Department of Fish and Game
Kathy Worthen	Idaho Department of Fish and Game
Steve Yundt	Idaho Department of Fish and Game
Gwynne Chandler	Intermountain Research Station
John Gebhards	Intermountain Research Station
Lori Leatherbury	Intermountain Research Station
Danny Lee	Intermountain Research Station
Jack McIntyre	Intermountain Research Station
Deborah Myers	Intermountain Research Station
Kerry Overton	Intermountain Research Station
Mike Radko	Intermountain Research Station
Bruce Rieman	Intermountain Research Station
Russ Thurow	Intermountain Research Station
Doug Perkinson	Kootenai National Forest
Ken Furrow	Lolo National Forest
Richard Kramer	Lolo National Forest
Brian Riggers	Lolo National Forest
Rich Gritz	Malheur National Forest
John Morris	Malheur National Forest
Bill Stover	Malheur National Forest
Joel Waldo	Malheur National Forest
Janet Decker-Hess	Montana Dept. of Fish, Wildlife and Parks
Sue Ireland	Montana State University
Brad Shepard	Montana State University
Joe Moreau	Mt. Hood National Forest
Wayne Paradis	Nez Perce National Forest
Mary Ann High	Nez Perce National Forest
Kathy Moynan	Nez Perce National Forest
Scott Russell	Nez Perce National Forest
Dean Grover	Ochoco National Forest
Jim Spotts	Okanogan National Forest
Wayne Bowers	Oregon Department of Fish and Wildlife
Rich Carmichael	Oregon Department of Fish and Wildlife
Steve Preble	Oregon Department of Fish and Wildlife
Mike Gray	Oregon Department of Fish and Wildlife
Steve Marx	Oregon Department of Fish and Wildlife
Ray Perkins	Oregon Dept. of Fish and Wildlife
Amy Stuart	Oregon Dept. of Fish and Wildlife
Steve Thiesfeld	Oregon Dept. of Fish and Wildlife
Tim Unterwegner	Oregon Dept. of Fish and Wildlife
Jeff Zakel	Oregon Dept. of Fish and Wildlife
Bob Gresswell	Pacific Northwest Research Station
Dave Cross	Panhandle National Forest
John Chatel	Panhandle National Forest
Rob Daves	Panhandle National Forest
Kathy Heffner	Panhandle National Forest

Table 4C.1 (continued).

Ed Lider	Panhandle National Forest
Mike Owen	Panhandle National Forest
Dave Burns	Payette National Forest
Kate Forster	Salmon National Forest
Bruce Smith	Salmon National Forest
Mark Moulton	Sawtooth National Recreation Area
Gary Dean	Targhee National Forest
Ted Kellogg	Targhee National Forest
Phil Howell	Umatilla National Forest
Mike Northrop	Umatilla National Forest
Dan Mahony	U.S. Fish and Wildlife Service
Billy Connor	U.S. Fish and Wildlife Service
Reg Reisenbichler	U.S. Fish and Wildlife Service
John Anderson	Wallowa-Whitman National Forest
Ralph Browning	Wallowa-Whitman National Forest
Joe Platz	Wallowa-Whitman National Forest
Gretchen Sausen	Wallowa-Whitman National Forest
Wade Sims	Wallowa-Whitman National Forest
Greg Willmore	Wallowa-Whitman National Forest
Paul Cowley	Wasatch-Cache National Forest
Larry Brown	Washington Dept. of Wildlife and Fish
Joe Foster	Washington Dept. of Wildlife and Fish
Pete Hahn	Washington Dept. of Wildlife and Fish
Pat Hulett	Washington Dept. of Wildlife and Fish
Larry Lavoy	Washington Dept. of Wildlife and Fish
Bob Peck	Washington Dept. of Wildlife and Fish
Mark Shuck	Washington Dept. of Wildlife and Fish
John Weinheimer	Washington Dept. of Wildlife and Fish
John Whalen	Washington Dept. of Wildlife and Fish
Philip Archibald	Wenatchee National Forest
Judy Delavergne	Wenatchee National Forest
Jackie Haskins	Wenatchee National Forest
Scott Hoefer	Wenatchee National Forest
Karen Lindhurst	Wenatchee National Forest
Tina Mayo	Wenatchee National Forest
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Dan Rife	Wenatchee National Forest
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Rob Gipson	Wyoming Game and Fish
Ralph Huddelson	Wyoming Game and Fish
John Kiefling	Wyoming Game and Fish
David Lind	Yakima Indian Nation
Jim Matthews	Yakima Indian Nation
Mark Teske	Yakima Indian Nation
Bruce Watson	Yakima Indian Nation

Table 4C.2—Rules for classification of status in 6th code watersheds from the IRIS and MRIS databases.

Database	Status Call	Rules(s) used
MRIS	Present	Species was considered present if the species or a hybrid was present in the subwatershed
	Present - Migration corridor	If present and *fishuse* was designated as (A) Spawning elsewhere; (C) Migration corridor; or (F) Feeding run.
	Present - Depressed	If present and *fishabund* was not equal to (A) Abundant or (Y) Present - no further information and fishuse was not equal to (A) Spawning elsewhere; (C) Migration corridor; (F) Feeding run; or (Z) Use undetermined.
	Present - Strong	Only if non-hybrid species were present and *fishabund* was designated as (A) Abundant fishuse was not equal to (A) Spawning elsewhere; (C) Migration corridor; (F) Feeding run; or (Z) Use undetermined.
	Present - Unknown	If present and *fishabund* was designated as (Y) Present - no further information.
	Known Absent	If not present and *fishrat* was greater than or equal to 5 which represents some form of sampling has been done and the subwatershed was within the species historic range.
	Unknown	All other subwatersheds not included above and within the species historic range.
IRIS	Present	Species was considered present if it was noted as (P) Present but abundance unknown in the database.
	Present - Migration corridor	Not possible to determine for any key salmonid from this database.
	Present - Depressed	Only possible with westslope cutthroat trout which was designated as *abund* equal to (D) Depressed or (R) Remnant in the WESTCUTT database.
	Present - Strong	Again, only westslope cutthroat trout is possible where *abund* was designated as (S) Strong.
	Present - Unknown	Same as present
	Known Absent	If the species was not present and *document* was designated as (P) which denotes some form of sampling has been done.
	Unknown	All other subwatershed's not included above that are within the species historic range.

Table 4C.3— Decision matrix for merging classification of 6th code watersheds from the RIS and status classification databases. The only case where these rules were not followed was where steelhead and native rainbow/redband trout coexist. In this case the status call for steelhead was kept and native rainbow/redband trout were coded as present unknown.

RIS Calls	Status Calls					
	Present Unknown	**Present Corridor**	**Present Strong**	**Present Depressed**	**Known Absent**	**Unknown**
Present	Present	Present	Present	Present		Present
Unknown	Unknown	Corridor	Strong	Depressed	Unknown	Unknown
Present	Present	Present	Present	Present		Present
Corridor	Corridor	Corridor	Strong	Depressed	Unknown	Corridor
Present	Present	Present	Present	Present		Present
Strong	Unknown	Corridor	Strong	Depressed	Unknown	Strong
Present	Present	Present	Present	Present		Present
Depressed	Unknown	Corridor	Strong	Depressed	Unknown	Depressed
Known					Known	Known
Absent	Unknown	Unknown	Unknown	Unknown	Absent	Absent
	Present	Present	Present	Present	Known	
Unknown	Unknown	Corridor	Strong	Depressed	Absent	Unknown

Table 4C.4— Format of the database describing status of key salmonids in subwatersheds.

Variable	Field type/size[1]	Range of values	Definition
HUC4	N/8	16040201 - 18080001	subbasin identifier
HUC5	N/10	1604020102 - 1808000101	watershed identifier
HUC6	N/12	160402010201 - 180200011204	subwatershed identifier
ERU	N/2	1 - 13[2]	Ecological reporting unit
YCT_STAT	N/1	1 - 7[3]	Yellowstone cutthroat trout status
WCT_STAT	N/1	1 - 7[3]	Westslope cutthroat trout status
RBT_STAT	N/1	1 - 7[3]	Native rainbow/redband trout status
STH_STAT	N/1	1 - 7[3]	Summer steelhead status
OTC_STAT	N/1	1 - 7[3]	Ocean-type chinook salmon status
STC_STAT	N/1	1 - 7[3]	Stream-type chinook salmon status
BTR_STAT	N/1	1 - 7[3]	Bull trout status
YCT_HIST	N/1	0, 1[4]	Historical range for Yellowstone cutthroat trout
WCT_HIST	N/1	0, 1[4]	Historical range for westslope cutthroat trout
RBT_HIST	N/1	0, 1[4]	Historical range for native rainbow/redband trout
STH_HIST	N/1	0, 1[4]	Historical range for summer steelhead
OTC_HIST	N/1	0, 1[4]	Historical range for ocean-type chinook salmon
STC_HIST	N/1	0, 1[4]	Historical range for stream-type chinook salmon
BTR_HIST	N/1	0, 1[4]	Historical range for bull trout
BTR_POT	N/1	0, 1[4]	Potential range for bull trout
STH_WILD	N/1	0, 1[5]	Wild indigenous steelhead
OTC_WILD	N/1	0, 1[5]	Wild indigenous ocean-type chinook salmon
STC_WILD	N/1	0, 1[5]	Wild indigneous stream-type chinook salmon
BTR_PRB	N/8	0-1	Probability of bull trout presence from model
BTR_PRD	A/2	PA, PD, PS[6]	Predicted status of bull trout from model
BTR_PV1	N/2	0-1	Known and predicted probability of bull trout presence
BTR_PV2	A/2	A, D, S, PA, PD, PS[7]	Known and predicted bull trout status

Table 4C.4 (continued).

Variable	Field type/size[1]	Range of values	Definition
OTC_PRB	N/8	0-1	Probability of ocean-type chinook salmon presence from model
OTC_PRD	A/2	PA, PD, PS, PM[6]	Predicted status of ocean-type chinook salmon from model
OTC_PV1	N/2	0-1	Known and predicted probability of ocean-type chinook salmon presence
OTC_PV2	A/2	A, D, S, M, PA, PD, PS, M[7]	Known and predicted ocean-type chinook salmon status
RBT_PRB	N/8	0-1	Probability of native rainbow/redband trout presence from model
RBT_PRD	A/2	PA, PD, PS[6]	Predicted status of native rainbow/redband trout from model
RBT_PV1	N/8	0-1	Known and predicted probability of native rainbow/redband trout presence
RBT_PV2	A/4	A, D, S, PA, PD, PS[7]	Known and predicted native rainbow/redband trout status
STC_PRB	N/8	0-1	Probability of stream-type chinook salmon presence from model
STC_PRD	A/3	PA, PD, PS, PM[6]	Predicted status of stream-type chinook salmon from model
STC_PV1	N/8	0-1	Known and predicted probability of stream-type chinook salmon presence
STC_PV2	A/2	A, D, S, M, PA, PD, PS, M[7]	Known and predicted stream-type chinook salmon status
STH_PRB	N/8	0-1	Probability of summer steelhead presence from model
STH_PRD	A/2	PA, PD, PS, PM[6]	Predicted status of summer steelhead from model
STH_PV1	N/8	0-1	Known and predicted probability of summer steelhead presence
STH_PV2	A/2	A, D, S, M, PA, PD, PS, M[7]	Known and predicted summer steelhead status
WCT_PRB	N/8	0-1	Probability of westslope cutthroat trout presence from model
WCT_PRD	A/2	PA, PD, PS[6]	Predicted status of westslope cutthroat trout from model
WCT_PV1	N/8	0-1	Known and predicted probability of westslope cutthroat trout presence
WCT_PV2	A/2	A, D, S, PA, PD, PS[7]	Known and predicted westslope cutthroat trout status
YCT_PRB	N/8	0-1	Probability of Yellowstone cutthroat trout presence from model
YCT_PRD	A/2	PA, PD, PS[6]	Predicted status of Yellowstone cutthroat trout from model
YCT_PV1	N/8	0-1	Known and predicted probability of Yellowstone cutthroat trout presence
YCT_PV2	A/2	A, D, S, PA, PD, PS[7]	Known and predicted Yellowstone cutthroat trout status
HISTORIC	N/1	0-7	Number of key salmonids historically present
PRESENT	N/1	0-7	Number of key salmonids present within their historical range
STRONG	N/1	0-7	Number of key salmonids with strong status
STR_DEP	N/1	0-7	Number of key salmonids with strong or depressed status
STR_PRD	N/1	0-7	Number of key salmonids with strong status (known and predicted)
TOT_REM	N/1	0-6	Number of key salmonids remaining from historical within subwatershed (known and predicted)
TOT_PRD	N/1	0-6	Total number of key salmonids now present (known and predicted)

[1] - Field type/size values: N=Numeric; A=Alphanumeric

[2] - ERU range of values: 1=Northern Cascades; 2=Southern Cascades; 3=Upper Klamath; 4=Northern Great Basin; 5=Columbia Plateau; 6=Blue Mountains; 7=Northern Glaciated Mountains; 8=Lower Clark Fork; 9=Upper Clark Fork; 10=Owyhee Uplands; 11=Upper Snake; 12=Snake Headwaters; 13=Central Idaho Mountains.

[3] - Species' status range of values: 1=strong; 2=depressed; 3=known absent; 4=present but status unknown; 5=migration corridor; 6=no classification; and 7=introduced.

[4] - 0=Outside historical range, 1=within historical range.

[5] - 0=Presumed hatchery influence, 1=No known hatchery influence.

[6] - Species' predicted status range of values: PA=Predicted absent; PD=Predicted depressed; PS=Predicted strong; and PM (for anadromous species)=Predicted migratory corridor.

[7] - Species_PV2 range of values: A=Absent; D=Depressed; S=Strong; M (for anadromous species)=Migratory corridor; PA=Predicted absent; PD=Predicted depressed; PS=Predicted strong; and PM (for anadromous species)=Predicted migratory corridor.

Table 4C.5— Format of the database describing species' presence within watersheds.

Variable	Field type/size[1]	Range of values	Definition
HUC4	N/8	16040201 - 18080001	subbasin identifier
HUC5	N/10	1604020102 - 1808000101	watershed identifier
ERU	N/2	1 - 13 [2]	Ecological reporting unit
CLASS	A/1	A-P, Z	Species assemblage designation (Z indicates no information)
GRP1	N/1	0, 1[3]	Suckers
GRP2	N/1	0, 1[3]	Dace
GRP3	N/1	0, 1[3]	Sculpins
GRP4	N/1	0, 1[3]	Shiners
GRP5	N/1	0, 1[3]	Chubs
GRP6	N/1	0, 1[3]	Crappie
GRP7	N/1	0, 1[3]	bullheads
GRP8	N/1	0, 1[3]	Lampreys
GRP9	N/1	0, 1[3]	Cutthroat
GRP10	N/1	0, 1[3]	Trout
GRP11	N/1	0, 1[3]	Whitefish
GRP12	N/1	0, 1[3]	Steelhead
GRP13	N/1	0, 1[3]	Rainbow
GRP14	N/1	0, 1[3]	Chinook
GRP15	N/1	0, 1[3]	Sunfish
HD_1	N/1	0, 1[4]	Historical range for white sturgeon
HD_8	N/1	0, 1[4]	Historical range for Goose Lake sucker
HD_11	N/1	0, 1[4]	Historical range for Klamath largescale sucker
HD_13	N/1	0, 1[4]	Historical range for Warner sucker
HD_15	N/1	0, 1[4]	Historical range for shortnose sucker
HD_16	N/1	0, 1[4]	Historical range for Lost River sucker
HD_20	N/1	0, 1[4]	Historical range for Malheur sculpin
HD_21	N/1	0, 1[4]	Historical range for piute sculpin
HD_22	N/1	0, 1[4]	Historical range for slimy sculpin
HD_23	N/1	0, 1[4]	Historical range for shorthead sculpin
HD_24	N/1	0, 1[4]	Historical range for Shoshone sculpin
HD_27	N/1	0, 1[4]	Historical range for Wood River sculpin
HD_28	N/1	0, 1[4]	Historical range for margined sculpin
HD_29	N/1	0, 1[4]	Historical range for reticulate sculpin
HD_30	N/1	0, 1[4]	Historical range for pit sculpin
HD_32	N/1	0, 1[4]	Historical range for torrent sculpin
HD_33	N/1	0, 1[4]	Historical range for slender sculpin
HD_37	N/1	0, 1[4]	Historical range for Alvord chub
HD_40	N/1	0, 1[4]	Historical range for Sheldon tui chub
HD_41	N/1	0, 1[4]	Historical range for Oregon Lakes tui chub
HD_42	N/1	0, 1[4]	Historical range for Catlow tui chub
HD_43	N/1	0, 1[4]	Historical range for Hutton tui chub
HD_44	N/1	0, 1[4]	Historical range for Summer Basin tui chub
HD_48	N/1	0, 1[4]	Historical range for Goose Lake tui chub
HD_50	N/1	0, 1[4]	Historical range for leatherside chub
HD_51	N/1	0, 1[4]	Historical range for pit roach
HD_59	N/1	0, 1[4]	Historical range for foskett speckeled dace

Table 4C.5 (continued).

Variable	Field type/size[1]	Range of values	Definition
HD_64	N/1	0, 1[4]	Historical range for burbot
HD_66	N/1	0, 1[4]	Historical range for sand roller
HD_67	N/1	0, 1[4]	Historical range for River lamprey
HD_68	N/1	0, 1[4]	Historical range for Pit Klamath brook lamprey
HD_71	N/1	0, 1[4]	Historical range for Klamath River lamprey
HD_72	N/1	0, 1[4]	Historical range for Pacific lamprey
HD_73	N/1	0, 1[4]	Historical range for Goose Lake lamprey
HD_74	N/1	0, 1[4]	Historical range for Yellowstone cutthroat trout
HD_75	N/1	0, 1[4]	Historical range for Coastal cutthroat trout
HD_76	N/1	0, 1[4]	Historical range for Lahontan cutthroat trout
HD_77	N/1	0, 1[4]	Historical range for westslope cutthroat trout
HD_79	N/1	0, 1[4]	Historical range for chum salmon
HD_80	N/1	0, 1[4]	Historical range for coho salmon
HD_81	N/1	0, 1[4]	Historical range for native rainbow/redband trout
HD_82	N/1	0, 1[4]	Historical range for summer steelhead
HD_86	N/1	0, 1[4]	Historical range for sockeye (kokanee) salmon
HD_87	N/1	0, 1[4]	Historical range for ocean-type chinook salmon
HD_88	N/1	0, 1[4]	Historical range for stream-type chinook salmon
HD_89	N/1	0, 1[4]	Historical range for pygmy whitefish
HD_91	N/1	0, 1[4]	Historical range for bull trout
SPC_1	N/1	0, 13	White sturgeon
SPC_2	N/1	0, 13	Utah sucker
SPC_3	N/1	0, 13	Longnose sucker
SPC_4	N/1	0, 1[3]	Bridgelip sucker
SPC_5	N/1	0, 1[3]	Bluehead sucker
SPC_6	N/1	0, 1[3]	Largescale sucker
SPC_7	N/1	0, 1[3]	Sacramento sucker
SPC_8	N/1	0, 1[3]	Goose Lake sucker
SPC_9	N/1	0, 1[3]	Mountain sucker
SPC_10	N/1	0, 1[3]	Klamath smallscale sucker
SPC_11	N/1	0, 1[3]	Klamath largescale sucker
SPC_12	N/1	0, 1[3]	Tahoe sucker
SPC_13	N/1	0, 1[3]	Warner sucker
SPC_14	N/1	0, 1[3]	Sucker, generic
SPC_15	N/1	0, 1[3]	Shortnose sucker
SPC_16	N/1	0, 1[3]	Lost River sucker
SPC_17	N/1	0, 1[3]	Coastrange sucker
SPC_18	N/1	0, 1[3]	Prickly sculpin
SPC_19	N/1	0, 1[3]	Mottled sculpin
SPC_20	N/1	0, 1[3]	Malheur sculpin
SPC_21	N/1	0, 1[3]	Piute sculpin
SPC_22	N/1	0, 1[3]	Slimy sculpin
SPC_23	N/1	0, 1[3]	Shorthead sculpin
SPC_24	N/1	0, 1[3]	Shoshone sculpin
SPC_25	N/1	0, 1[3]	Riffle sculpin
SPC_26	N/1	0, 1[3]	Marbled sculpin
SPC_27	N/1	0, 1[3]	Wood River sculpin
SPC_28	N/1	0, 1[3]	Margined sculpin

Table 4C.5 (continued).

Variable	Field type/size[1]	Range of values	Definition
SPC_29	N/1	0, 1[3]	Reticulate sculpin
SPC_30	N/1	0, 1[3]	Pit sculpin
SPC_31	N/1	0, 1[3]	Klamath Lake sculpin
SPC_32	N/1	0, 1[3]	Torrent sculpin
SPC_33	N/1	0, 1[3]	Slender sculpin
SPC_34	N/1	0, 1[3]	Sculpin, generic
SPC_35	N/1	0, 1[3]	Pacific staghorn sculpin
SPC_36	N/1	0, 1[3]	Chiselmouth
SPC_37	N/1	0, 1[3]	Alvord chub
SPC_38	N/1	0, 1[3]	Utah chub
SPC_39	N/1	0, 1[3]	Tui chub
SPC_40	N/1	0, 1[3]	Sheldon tui chub
SPC_41	N/1	0, 1[3]	Oregon Lakes tui chub
SPC_42	N/1	0, 1[3]	Catlow tui chub
SPC_43	N/1	0, 1[3]	Hutton tui chub
SPC_44	N/1	0, 1[3]	Summer Basin tui chub
SPC_45	N/1	0, 1[3]	Warner Basin tui chub
SPC_46	N/1	0, 1[3]	XL Spring tui chub
SPC_47	N/1	0, 1[3]	Goose Lake tui chub
SPC_48	N/1	0, 1[3]	Borax Lake chub
SPC_49	N/1	0, 1[3]	Blue chub
SPC_50	N/1	0, 1[3]	Leatherside chub
SPC_51	N/1	0, 1[3]	Pit roach
SPC_52	N/1	0, 1[3]	Peamouth
SPC_53	N/1	0, 1[3]	Northern squawfish
SPC_54	N/1	0, 1[3]	Umpqua squawfish
SPC_55	N/1	0, 1[3]	Longnose dace
SPC_56	N/1	0, 1[3]	Leopard dace
SPC_57	N/1	0, 1[3]	Speckeled dace
SPC_58	N/1	0, 1[3]	Klamath speckled dace
SPC_59	N/1	0, 1[3]	Foskett speckled dace
SPC_60	N/1	0, 1[3]	Dace, generic
SPC_61	N/1	0, 1[3]	Redside shiner
SPC_62	N/1	0, 1[3]	Lahontan redside shiner
SPC_63	N/1	0, 1[3]	Shiner perch
SPC_64	N/1	0, 1[3]	Burbot
SPC_65	N/1	0, 1[3]	Three spine stickelback
SPC_66	N/1	0, 1[3]	Sand roller
SPC_67	N/1	0, 1[3]	River lamprey
SPC_68	N/1	0, 1[3]	Pit Klamath brook lamprey
SPC_69	N/1	0, 1[3]	Miller Lake Lamprey
SPC_70	N/1	0, 1[3]	Western brook lamprey
SPC_71	N/1	0, 1[3]	Klamath river lamprey
SPC_72	N/1	0, 1[3]	Pacific lamprey
SPC_73	N/1	0, 1[3]	Goose Lake lamprey
SPC_74	N/1	0, 1[3]	Yellowstone cutthroat trout
SPC_75	N/1	0, 1[3]	Coastal cutthroat trout
SPC_76	N/1	0, 1[3]	Lahontan cutthroat trout

Table 4C.5 (continued).

Variable	Field type/size[1]	Range of values	Definition
SPC_77	N/1	0, 1[3]	Westslope cutthroat trout
SPC_78	N/1	0, 1[3]	Cutthroat trout, generic
SPC_79	N/1	0, 1[3]	Chum salmon
SPC_80	N/1	0, 1[3]	Coho salmon
SPC_81	N/1	0, 1[3]	Interior redband trout
SPC_82	N/1	0, 1[3]	Summer steelhead
SPC_83	N/1	0, 1[3]	Winter steelhead
SPC_84	N/1	0, 1[3]	Catlow Valley redband trout
SPC_85	N/1	0, 1[3]	Warner Valley redband trout
SPC_86	N/1	0, 1[3]	Sockeye (kokanee) salmon
SPC_87	N/1	0, 1[3]	Ocean-type chinook salmon
SPC_88	N/1	0, 1[3]	stream-type chinook salmon
SPC_89	N/1	0, 1[3]	Pygmy whitefish
SPC_90	N/1	0, 1[3]	Mountain whitefish
SPC_91	N/1	0, 1[3]	Bull trout
SPC_92	N/1	0, 1[3]	White sucker
SPC_93	N/1	0, 1[3]	Green sunfish
SPC_94	N/1	0, 1[3]	Pumpkinseed
SPC_95	N/1	0, 1[3]	Warmouth
SPC_96	N/1	0, 1[3]	Bluegill
SPC_97	N/1	0, 1[3]	Smallmouth bass
SPC_98	N/1	0, 1[3]	Largemouth bass
SPC_99	N/1	0, 1[3]	White crappie
SPC_100	N/1	0, 1[3]	Black crappie
SPC_101	N/1	0, 1[3]	American shad
SPC_102	N/1	0, 1[3]	Goldfish
SPC_103	N/1	0, 1[3]	Finescale dace
SPC_104	N/1	0, 1[3]	Carp
SPC_105	N/1	0, 1[3]	Spottail shiner
SPC_106	N/1	0, 1[3]	Fathead minnow
SPC_107	N/1	0, 1[3]	Tench
SPC_108	N/1	0, 1[3]	Northern pike
SPC_109	N/1	0, 1[3]	Black bullhead
SPC_110	N/1	0, 1[3]	Yellow bullhead
SPC_111	N/1	0, 1[3]	Brown bullhead
SPC_112	N/1	0, 1[3]	Channel catfish
SPC_113	N/1	0, 1[3]	Tadpole madtom
SPC_114	N/1	0, 1[3]	Flathead catfish
SPC_115	N/1	0, 1[3]	Yellow perch
SPC_116	N/1	0, 1[3]	Walleye
SPC_117	N/1	0, 1[3]	Variable platyfish
SPC_118	N/1	0, 1[3]	Lake whitefish
SPC_119	N/1	0, 1[3]	Golden trout
SPC_120	N/1	0, 1[3]	Rainbow trout
SPC_121	N/1	0, 1[3]	Kamloops trout
SPC_122	N/1	0, 1[3]	Atlantic salmon
SPC_123	N/1	0, 1[3]	Brown trout

Table 4C.5 (continued).

Variable	Field type/size[1]	Range of values	Definition
SPC_124	N/1	0, 1[3]	Sunapee char
SPC_125	N/1	0, 1[3]	Brook trout
SPC_126	N/1	0, 1[3]	Lake trout
SPC_127	N/1	0, 1[3]	Arctic grayling
TOT_SPC	N/2	-1, 0-465	Total number of species present
TOT_GRP	N/2	-1, 0-145	Total number of groups present
TOT_NAT	N/2	-1, 0-295	Total number of native species present
TOT_EXOT	N/2	-1, 0-195	Total number of exotic species present
PCT_NAT	N/8	0-1	Fraction of total comprised of native species
PCT_EXOT	N/8	0-1	Fraction of total comprised of exotic species
FEDLIST	N/2	0-3	Number of Federally listed species
SENLIST	N/2	0-10	Number of designated sensitive species

[1] - Field type/size values: N=Numeric; A=Alphanumeric

[2] - ERU range of values: 1=Northern Cascades; 2=Southern Cascades; 3=Upper Klamath; 4=Northern Great Basin; 5=Columbia Plateau; 6=Blue Mountains; 7=Northern Glaciated Mountains; 8=Lower Clark Fork; 9=Upper Clark Fork; 10=Owyhee Uplands; 11=Upper Snake; 12=Snake Headwaters; 13=Central Idaho Mountains.

[3] - 0=Not reported as present, 1=reported as present.

[4] - 0=Outside historical range, 1=within historical range.

[5] - A value of -1 indicates insufficient information for estimation.

Table 4C.6— Format of the database describing species' presence within subbasins.

Variable	Field type/size[1]	Range of values	Definition
ERU	N/2	1 - 1[32]	Ecological reporting unit
HUC4	N/8	16040201 - 18080001	subbasin identifier
HD_1	N/1	0, 1[3]	Historical range for white sturgeon
HD_8	N/1	0, 1[3]	Historical range for Goose Lake sucker
HD_11	N/1	0, 1[3]	Historical range for Klamath largescale sucker
HD_13	N/1	0, 1[3]	Historical range for Warner sucker
HD_15	N/1	0, 1[3]	Historical range for shortnose sucker
HD_16	N/1	0, 1[3]	Historical range for Lost River sucker
HD_20	N/1	0, 1[3]	Historical range for Malheur sculpin
HD_21	N/1	0, 1[3]	Historical range for piute sculpin
HD_22	N/1	0, 1[3]	Historical range for slimy sculpin
HD_23	N/1	0, 1[3]	Historical range for shorthead sculpin
HD_24	N/1	0, 1[3]	Historical range for Shoshone sculpin
HD_27	N/1	0, 1[3]	Historical range for Wood River sculpin
HD_28	N/1	0, 1[3]	Historical range for margined sculpin
HD_29	N/1	0, 1[3]	Historical range for reticulate sculpin
HD_30	N/1	0, 1[3]	Historical range for pit sculpin
HD_32	N/1	0, 1[3]	Historical range for torrent sculpin
HD_33	N/1	0, 1[3]	Historical range for slender sculpin
HD_37	N/1	0, 1[3]	Historical range for Alvord chub
HD_40	N/1	0, 1[3]	Historical range for Sheldon tui chub
HD_41	N/1	0, 1[3]	Historical range for Oregon Lakes tui chub
HD_42	N/1	0, 1[3]	Historical range for Catlow tui chub
HD_43	N/1	0, 1[3]	Historical range for Hutton tui chub
HD_44	N/1	0, 1[3]	Historical range for Summer Basin tui chub
HD_48	N/1	0, 1[3]	Historical range for Goose Lake tui chub
HD_50	N/1	0, 1[3]	Historical range for leatherside chub
HD_51	N/1	0, 1[3]	Historical range for pit roach
HD_59	N/1	0, 1[3]	Historical range for foskett speckeled dace
HD_64	N/1	0, 1[3]	Historical range for burbot
HD_66	N/1	0, 1[3]	Historical range for sand roller
HD_67	N/1	0, 1[3]	Historical range for River lamprey
HD_68	N/1	0, 1[3]	Historical range for Pit Klamath brook lamprey
HD_71	N/1	0, 1[3]	Historical range for Klamath River lamprey
HD_72	N/1	0, 1[3]	Historical range for Pacific lamprey
HD_73	N/1	0, 1[3]	Historical range for Goose Lake lamprey
HD_74	N/1	0, 1[3]	Historical range for Yellowstone cutthroat trout

Table 4C.6 (continued).

Variable	Field type/size[1]	Range of values	Definition
HD_75	N/1	0, 1[3]	Historical range for Coastal cutthroat trout
HD_76	N/1	0, 1[3]	Historical range for Lahontan cutthroat trout
HD_77	N/1	0, 1[3]	Historical range for westslope cutthroat trout
HD_79	N/1	0, 1[3]	Historical range for chum salmon
HD_80	N/1	0, 1[3]	Historical range for coho salmon
HD_81	N/1	0, 1[3]	Historical range for native rainbow/redband trout
HD_82	N/1	0, 1[3]	Historical range for summer steelhead
HD_86	N/1	0, 1[3]	Historical range for sockeye (kokanee) salmon
HD_87	N/1	0, 1[3]	Historical range for ocean-type chinook salmon
HD_88	N/1	0, 1[3]	Historical range for stream-type chinook salmon
HD_89	N/1	0, 1[3]	Historical range for pygmy whitefish
HD_91	N/1	0, 1[3]	Historical range for bull trout
SPC_1	N/1	0, 1[4]	White sturgeon
SPC_2	N/1	0, 1[4]	Utah sucker
SPC_3	N/1	0, 1[4]	Longnose sucker
SPC_4	N/1	0, 1[4]	Bridgelip sucker
SPC_5	N/1	0, 1[4]	Bluehead sucker
SPC_6	N/1	0, 1[4]	Largescale sucker
SPC_7	N/1	0, 1[4]	Sacramento sucker
SPC_8	N/1	0, 1[4]	Goose Lake sucker
SPC_9	N/1	0, 1[4]	Mountain sucker
SPC_10	N/1	0, 1[4]	Klamath smallscale sucker
SPC_11	N/1	0, 1[4]	Klamath largescale sucker
SPC_12	N/1	0, 1[4]	Tahoe sucker
SPC_13	N/1	0, 1[4]	Warner sucker
SPC_14	N/1	0, 1[4]	Sucker, generic
SPC_15	N/1	0, 1[4]	Shortnose sucker
SPC_16	N/1	0, 1[4]	Lost River sucker
SPC_17	N/1	0, 1[4]	Coastrange sucker
SPC_18	N/1	0, 1[4]	Prickly sculpin
SPC_19	N/1	0, 1[4]	Mottled sculpin
SPC_20	N/1	0, 1[4]	Malheur sculpin
SPC_21	N/1	0, 1[4]	Piute sculpin
SPC_22	N/1	0, 1[4]	Slimy sculpin
SPC_23	N/1	0, 1[4]	Shorthead sculpin
SPC_24	N/1	0, 1[4]	Shoshone sculpin
SPC_25	N/1	0, 1[4]	Riffle sculpin
SPC_26	N/1	0, 1[4]	Marbled sculpin
SPC_27	N/1	0, 1[4]	Wood River sculpin

Table 4C.6 (continued).

Variable	Field type/size[1]	Range of values	Definition
SPC_28	N/1	0, 1[4]	Margined sculpin
SPC_29	N/1	0, 1[4]	Reticulate sculpin
SPC_30	N/1	0, 1[4]	Pit sculpin
SPC_31	N/1	0, 1[4]	Klamath Lake sculpin
SPC_32	N/1	0, 1[4]	Torrent sculpin
SPC_33	N/1	0, 1[4]	Slender sculpin
SPC_34	N/1	0, 1[4]	Sculpin, generic
SPC_35	N/1	0, 1[4]	Pacific staghorn sculpin
SPC_36	N/1	0, 1[4]	Chiselmouth
SPC_37	N/1	0, 1[4]	Alvord chub
SPC_38	N/1	0, 1[4]	Utah chub
SPC_39	N/1	0, 1[4]	Tui chub
SPC_40	N/1	0, 1[4]	Sheldon tui chub
SPC_41	N/1	0, 1[4]	Oregon Lakes tui chub
SPC_42	N/1	0, 1[4]	Catlow tui chub
SPC_43	N/1	0, 1[4]	Hutton tui chub
SPC_44	N/1	0, 1[4]	Summer Basin tui chub
SPC_45	N/1	0, 1[4]	Warner Basin tui chub
SPC_46	N/1	0, 1[4]	XL Spring tui chub
SPC_47	N/1	0, 1[4]	Goose Lake tui chub
SPC_48	N/1	0, 1[4]	Borax Lake chub
SPC_49	N/1	0, 1[4]	Blue chub
SPC_50	N/1	0, 1[4]	Leatherside chub
SPC_51	N/1	0, 1[4]	Pit roach
SPC_52	N/1	0, 1[4]	Peamouth
SPC_53	N/1	0, 1[4]	Northern squawfish
SPC_54	N/1	0, 1[4]	Umpqua squawfish
SPC_55	N/1	0, 1[4]	Longnose dace
SPC_56	N/1	0, 1[4]	Leopard dace
SPC_57	N/1	0, 1[4]	Speckeled dace
SPC_58	N/1	0, 1[4]	Klamath speckled dace
SPC_59	N/1	0, 1[4]	Foskett speckled dace
SPC_60	N/1	0, 1[4]	Dace, generic
SPC_61	N/1	0, 1[4]	Redside shiner
SPC_62	N/1	0, 1[4]	Lahontan redside shiner
SPC_63	N/1	0, 1[4]	Shiner perch
SPC_64	N/1	0, 1[4]	Burbot
SPC_65	N/1	0, 1[4]	Three spine stickelback
SPC_66	N/1	0, 1[4]	Sand roller

Table 4C.6 (continued).

Variable	Field type/size[1]	Range of values	Definition
SPC_67	N/1	0, 1[4]	River lamprey
SPC_68	N/1	0, 1[4]	Pit Klamath brook lamprey
SPC_69	N/1	0, 1[4]	Miller Lake Lamprey
SPC_70	N/1	0, 1[4]	Western brook lamprey
SPC_71	N/1	0, 1[4]	Klamath river lamprey
SPC_72	N/1	0, 1[4]	Pacific lamprey
SPC_73	N/1	0, 1[4]	Goose Lake lamprey
SPC_74	N/1	0, 1[4]	Yellowstone cutthroat trout
SPC_75	N/1	0, 1[4]	Coastal cutthroat trout
SPC_76	N/1	0, 1[4]	Lahontan cutthroat trout
SPC_77	N/1	0, 1[4]	Westslope cutthroat trout
SPC_78	N/1	0, 1[4]	Cutthroat trout, generic
SPC_79	N/1	0, 1[4]	Chum salmon
SPC_80	N/1	0, 1[4]	Coho salmon
SPC_81	N/1	0, 1[4]	Interior redband trout
SPC_82	N/1	0, 1[4]	Summer steelhead
SPC_83	N/1	0, 1[4]	Winter steelhead
SPC_84	N/1	0, 1[4]	Catlow Valley redband trout
SPC_85	N/1	0, 1[4]	Warner Valley redband trout
SPC_86	N/1	0, 1[4]	Sockeye (kokanee) salmon
SPC_87	N/1	0, 1[4]	Ocean-type chinook salmon
SPC_88	N/1	0, 1[4]	stream-type chinook salmon
SPC_89	N/1	0, 1[4]	Pygmy whitefish
SPC_90	N/1	0, 1[4]	Mountain whitefish
SPC_91	N/1	0, 1[4]	Bull trout
SPC_92	N/1	0, 1[4]	White sucker
SPC_93	N/1	0, 1[4]	Green sunfish
SPC_94	N/1	0, 1[4]	Pumpkinseed
SPC_95	N/1	0, 1[4]	Warmouth
SPC_96	N/1	0, 1[4]	Bluegill
SPC_97	N/1	0, 1[4]	Smallmouth bass
SPC_98	N/1	0, 1[4]	Largemouth bass
SPC_99	N/1	0, 1[4]	White crappie
SPC_100	N/1	0, 1[4]	Black crappie
SPC_101	N/1	0, 1[4]	American shad
SPC_102	N/1	0, 1[4]	Goldfish
SPC_103	N/1	0, 1[4]	Finescale dace
SPC_104	N/1	0, 1[4]	Carp
SPC_105	N/1	0, 1[4]	Spottail shiner

Table 4C.6 (continued).

Variable	Field type/size[1]	Range of values	Definition
SPC_106	N/1	0, 1[4]	Fathead minnow
SPC_107	N/1	0, 1[4]	Tench
SPC_108	N/1	0, 1[4]	Northern pike
SPC_109	N/1	0, 1[4]	Black bullhead
SPC_110	N/1	0, 1[4]	Yellow bullhead
SPC_111	N/1	0, 1[4]	Brown bullhead
SPC_112	N/1	0, 1[4]	Channel catfish
SPC_113	N/1	0, 1[4]	Tadpole madtom
SPC_114	N/1	0, 1[4]	Flathead catfish
SPC_115	N/1	0, 1[4]	Yellow perch
SPC_116	N/1	0, 1[4]	Walleye
SPC_117	N/1	0, 1[4]	Variable platyfish
SPC_118	N/1	0, 1[4]	Lake whitefish
SPC_119	N/1	0, 1[4]	Golden trout
SPC_120	N/1	0, 1[4]	Rainbow trout
SPC_121	N/1	0, 1[4]	Kamloops trout
SPC_122	N/1	0, 1[4]	Atlantic salmon
SPC_123	N/1	0, 1[4]	Brown trout
SPC_124	N/1	0, 1[4]	Sunapee char
SPC_125	N/1	0, 1[4]	Brook trout
SPC_126	N/1	0, 1[4]	Lake trout
SPC_127	N/1	0, 1[4]	Arctic grayling
SPC_128	N/1	0, 1[4]	Shortnose sucker
SPC_129	N/1	0, 1[4]	Rock Bass
SPC_130	N/1	0, 1[4]	Sacramento perch
SPC_131	N/1	0, 1[4]	Redear sunfish
SPC_132	N/1	0, 1[4]	Tambaqui
SPC_133	N/1	0, 1[4]	Convict cichlid
SPC_134	N/1	0, 1[4]	Tilapia
SPC_135	N/1	0, 1[4]	Oriental weatherfish
SPC_136	N/1	0, 1[4]	Loach
SPC_137	N/1	0, 1[4]	Grass carp
SPC_138	N/1	0, 1[4]	Tiger barb
SPC_139	N/1	0, 1[4]	Grass pickerel
SPC_140	N/1	0, 1[4]	Gar
SPC_141	N/1	0, 1[4]	Striped bass
SPC_142	N/1	0, 1[4]	Rainbow smelt
SPC_143	N/1	0, 1[4]	Saddleback gunnel
SPC_144	N/1	0, 1[4]	Mosquitofish

Table 4C.6 (continued).

Variable	Field type/size[1]	Range of values	Definition
SPC_145	N/1	0, 1[4]	Green swordtail
SPC_146	N/1	0, 1[4]	Shortfin molly
SPC_147	N/1	0, 1[4]	Guppy
SPC_148	N/1	0, 1[4]	Artic char
TOT_EXOT	N/2	-1, 0-23[5]	Number of exotic species present
TOT_NAT	N/2	-1, 0-37[5]	Number of native species present
TOT_SPC	N/2	-1, 0-58[5]	Total number of species present
PCT_EXOT	N/8	0-1	Percent of species present made up of exotics
PCT_NAT	N/8	0-1	Percent of species present made up os native species
SENLIST	N/2	0-11	Number of sensitive species present
FEDLIST	N/2	0-3	Number of federally listed species present

[1] - Field type/size values: N=Numeric; A=Alphanumeric

[2] - ERU range of values: 1=Northern Cascades; 2=Southern Cascades; 3=Upper Klamath; 4=Northern Great Basin; 5=Columbia Plateau; 6=Blue Mountains; 7=Northern Glaciated Mountains; 8=Lower Clark Fork; 9=Upper Clark Fork; 10=Owyhee Uplands; 11=Upper Snake; 12=Snake Headwaters; 13=Central Idaho Mountains.

[3] - 0=Outside historical range, 1=within historical range.

[4] - 0=Not reported as present, 1=reported as present.

[5] - A value of -1 indicates insufficient information to judge.

Table 4C.7— Format of the database of aquatic integrity measures for watersheds.

Variable	Field type/size[1]	Range of values	Definition
ERU	N/2	1 - 13 [2]	Ecological reporting unit
HUC5	N/10	1604020102 - 1808000101	watershed identifier
CLASS	A/1	A-P, Z	Species assemblage designation (Z indicates no information)
FEDLIST	N/2	0-3	Number of Federally listed species
SENLIST	N/2	0-10	Number of designated sensitive species
WILD_AND	N/1	0-2	Number of genetically pure anadromous populations
ENDEMIC	N/1	0-5	Number of narrow-endemic species present
STRIDX	N/8	0-1	Relative index of strong populations of key salmonids
INT_EVN	N/8	0-1	Realtive index of the ratio of native species diversity to total species diversity, multiplied by native species eveness
RICH4	N/2	0-1	Relative index of species richness within parent subbasin
INTEG5	N/8	0-1	Composite index of fish community integrity = average of STRIDX, INT_EVN, and RICH4

[1] - Field type/size values: N=Numeric; A=Alphanumeric

[2] - ERU range of values: 1=Northern Cascades; 2=Southern Cascades; 3=Upper Klamath; 4=Northern Great Basin; 5=Columbia Plateau; 6=Blue Mountains; 7=Northern Glaciated Mountains; 8=Lower Clark Fork; 9=Upper Clark Fork; 10=Owyhee Uplands; 11=Upper Snake; 12=Snake Headwaters; 13=Central Idaho Mountains.

Table 4C.8— Format of the database of vegetation and management clusters for 6th-code watersheds.

Variable	Field type/size[1]	Range of values	Definition
ERU	N/2	1 - 13 [2]	Ecological reporting unit
HUC6	N/12	160102020101 - 180200011402	6th code watershed number
MNGCLUS	A/2	BR, FG, FH, FM, FW, NP, PA, PF, PR, TL[3]	Management cluster designation
VEGCLUS	A/1	A - L[4]	Vegetation cluster designation

[1] - Field type/size values: N=Numeric; A=Alphanumeric

[2] - ERU range of values: 1=Northern Cascades; 2=Southern Cascades; 3=Upper Klamath; 4=Northern Great Basin; 5=Columbia Plateau; 6=Blue Mountains; 7=Northern Glaciated Mountains; 8=Lower Clark Fork; 9=Upper Clark Fork; 10=Owyhee Uplands; 11=Upper Snake; 12=Snake Headwaters; 13=Central Idaho Mountains.

[3] - Designations reflect principal ownership and use: BR=BLM rangelands, FG=USFS grazing lands, FH=USFS high-impact, FM=USFS moderate impact, FW=USFS low impact and wilderness, NP=National Parks, PA=Private agriculture, PF=Private forests, TL=Tribal lands.

[4] - Clusters based on vegetative composition: A=Agriculture, B=Moist forest — understory reinitiation, C=Grasslands, D=Desert shrublands, E=Transitional areas, F=Young, dry forests, G=Aspen stands, H=Young, spruce-fir-lodgepole stands, I=Older, spruce-fir-lodgepole stands, J=Older, dry forests, K=Mountain shrublands, L=Moist forest — stem exclusion.

APPENDIX 4D

Historical Ranges Defined for the Key Salmonids Within the Basin

Key Salmonids

Our estimates of the historical ranges of the key salmonids were based on known historical distributions in published literature, available historical accounts, and speculative distributions as summarized in the Idaho, Montana, Oregon, and Washington River Information System databases (see appendix 4C), expanded to include any natural (non-introduced) occurrences in the status survey that were not included in the historical distributions.

Bull Trout

This range was based on the known historical or speculative distributions for bull trout from the individual state accounts as summarized in the 1994-95 updates for the Oregon bull trout distribution database, IRIS, and MRIS, and the Washington status review (Mongillo 1992), but expanded to include any occurrences in the status survey that were not included in the historical distributions. The historical accounts from WARIS have not been updated because the Washington stream and lakes database was not available at the time of this analysis. Where bull trout are known to have occurred within a subbasin we generally included the entire subbasin as part of the historical range if access was likely. Occasional reports from agency sampling and anecdotal accounts suggest that bull trout still occur in the mainstem Columbia and Snake rivers; we therefore included other mainstems below known historical or current occurrences as part of the historical range assuming that fish moved through these areas. There are no available records to indicate occurrence of bull trout in the Sanpoil or Colville river subbasins, but both are close to known distributions. There is no historical barrier known for the Sanpoil river but there is an impassable falls near the mouth of the Colville River that might have excluded bull trout.[1] Because both basins have streams that should have been suitable for bull trout based on models of occurrence with elevation and latitude, they are included in the historical range, but recognized as speculative. The occurrence of bull trout within the more isolated Upper Snake River/Rock Creek and Salmon Falls Creek subbasins are also apparently based on anecdotal information[2] and should also be considered speculative.

Yellowstone Cutthroat Trout

Data sources include summaries provided by Bruce May[3] and Behnke (1992). Two disjunct populations were known to exist outside the core in the headwaters of the Snake and Missouri rivers: 1) Crab Creek in Washington, and 2) Waha Lake in Idaho near Lewiston in the Clearwater drainage (Behnke 1992). The species is believed extinct in both of these areas. Above Shoshone Falls the Yellowstone cutthroat trout was known in all waters directly connected to the Snake River except those between Jackson Lake and Palisades Reservoir, where the closely allied fine-spotted Snake River cutthroat trout was thought to be native (Behnke 1992). We recognized both forms as Yellowstone cutthroat trout because the Snake River

[1]Personal communication. 1995. T. Shuhda, Colville National Forest, Colville, WA.

[2]Personal communication. 1995. B. Horton, Idaho Department of Fish and Game, Boise, ID.

[3]Personal communication. 1995. Bruce May, Gallatin National Forest, Bozeman, MT. Personal communication of unpublished data.

form has not received formal taxonomic recognition. It is unclear which form (Yellowstone or finespotted) was native to Jackson Lake. Populations of both occur in the Gros Ventre River drainage.[4] The range of Yellowstone cutthroat trout represents most of the Snake River Basin above Shoshone Falls, but excludes the Sinks drainages and the Wood River basin. The history of the Sinks drainages is unclear; Hubbs and Miller (1948) believed cutthroat trout were native but it is not clear whether they were the westslope or Yellowstone subspecies. Thurow and others (1988) reported Yellowstone cutthroat trout in the Sinks drainages, but it is unknown if they were the result of introductions. We relied on Behnke (1992) to place the Sinks drainages outside the Snake zoogeographic basin and so did not include them in the Yellowstone cutthroat trout historical range. Yellowstone cutthroat trout have been widely introduced to high lakes and other areas. Observations outside this defined range are considered introduced.

Westslope Cutthroat Trout

The historical range of westslope cutthroat trout is based largely on current distribution and accounts from Behnke (1992) and Mullan and others (1992). Gilbert and Evermann (1894) reported "cut-throat" in the Little Spokane River, and we assume those to have been westslope cutthroat trout and have included them here. The status of cutthroat trout in the Lost rivers and in other sink drainages in Idaho are uncertain. There is no known documentation of occurrence but Behnke (1992) speculates westslope cutthroat trout may have been in some of those drainages because of the apparent headwater capture of other species such as bull trout. The historical distribution of westslope cutthroat trout in the Snake River drainage between the Salmon River and Shoshone Falls is unclear. Although Gilbert and Evermann (1894) reported cutthroat trout in the Wood River, Idaho, Behnke (1992) examined three museum specimens and reported all as redband trout. Jordan and Evermann (1902) mention cutthroat trout in the same paragraphs in which they refer to "fine trout fishing" in Payette and Redfish lakes. It is not clear whether they meant that cutthroat were found in both lakes, but other accounts make it clear that cutthroat trout did occur in the river basin of the latter. Because redband trout often exhibit a cutthroat-like red/orange slash under the jaw, and were termed "cutthroat" in other popular accounts, it is possible the reference in the Payette River was actually for redband trout. Westslope cutthroat trout have persisted well throughout much of the known portions of the historical range but have not been confirmed from any samples above the mouth of the Salmon River that cannot be attributed to recent introduction. For these reasons we did not include any of the Snake River drainage above the mouth of the Salmon River as part of the historical range for this fish. We conclude that any cutthroat trout in the Payette drainage are the results of high lake introductions, or introductions to Deadwood Reservoir (IDFG records, Nampa, Idaho). The historical distribution of westslope cutthroat trout along the Eastern slope of the Cascades is problematic. Behnke (1992) suggests that populations were native to the Wenatchee, Methow, and Entiat river drainages. Other evidence indicates historical occurrence in Ahtanum Creek, a tributary to the lower Yakima River, and the Chelan River basin (Behnke 1992). Mullan and others (1992) indicate that stocking of westslope cutthroat trout in mountain lakes led to the establishment of the species throughout many of the mid-Columbia River tributary systems. Given the very broad occurrence currently we assume that the native range included all of the previously mentioned drainages but recognize the uncertainty in how complete that distribution may have been.

Redband Trout

We identified two forms of redband trout within the Basin, allopatric and sympatric. We considered allopatric redband trout those fish outside the historical range of steelhead. We assumed the allopatric form was genetically and evolutionarily distinct from other redband trout because of isolation from steel-

[4]Personal communication. 1995. B. Gresswell, U.S. Fish and Wildlife Service, Corvallis, OR.

head. We considered sympatric redband trout to be the non-anadromous form historically derived from or associated with steelhead. Historically redband trout were widely distributed (Behnke 1992) occupying most accessible waters from the southern desert basins to the high mountain coniferous forests (Cope 1879; Cope 1889; Jordan 1892; Gilbert and Evermann 1894; Jordan and Evermann 1896; Snyder 1908; Jordan and others 1930; Behnke 1992). Because of the broad distribution and occurrence over the widest range of conditions evident for any of the salmonids, we assumed that redband trout occurred historically in all of the drainages contiguous with the current distribution. They are believed to be native in the Kootenai River basin below Kootenai Falls.[5,6] A barrier falls below Klamath Lake separated interior redband trout from coastal rainbow trout (Behnke 1992). The only major portions of the Basin not believed to support redband trout are the Snake River upstream from Shoshone Falls, tributaries to the Spokane River above Spokane Falls, Eastern Rocky Mountain basins in Montana, and portions of the northern Great Basin in Oregon. We relied on knowledge of established barriers to anadromy to define the range for the allopatric form (see the discussion of steelhead). The distribution of small populations of allopatric redband trout isolated from, but within the general range of steelhead (for example, above natural barriers in 2nd and 3rd order streams) was poorly documented and not considered here. The historical sympatric redband trout range is assumed to include everything within the range of steelhead. There is no clear distinction between steelhead and non-anadromous redband trout throughout the range of steelhead. Because redband trout that have been isolated from steelhead by geologic processes (natural barriers) may be evoluntionarily distinct while those overlapping in distribution may be different life histories of the same populations, we have identified two historical ranges (isolated from and overlapping with the historical range of steelhead). Redband trout also had access to most of the rest of the Basin with the exception of the Upper Snake zoogeographic basin. All redband trout found within the Upper Snake basin are assumed to be introduced coastal rainbow trout.

Steelhead

Data sources for Idaho included Evermann (1896), Chapman (1940), Parkhurst (1950), Gebhards (1959), Fulton (1970), NWPPC (1986), IDFG (1992), and F. Partridge[7]. Summer steelhead were found in all accessible reaches of the Snake River and tributaries in Idaho downstream from Shoshone Falls. Steelhead were also found in the Bruneau and Owyhee rivers, and Salmon Falls Creek drainages in Nevada. Cold water temperatures at high elevations may have restricted the upper limit of steelhead (Mullan and others 1992) but this limit is not well defined. Natural barriers limited the distribution in certain areas within the historical range but most inaccessible areas are at the subwatershed scale or smaller. We were conservative in the development of historical ranges for areas with little formal documentation.

Data for Washington were compiled primarily by K. MacDonald, Wenatchee National Forest, Wenatchee, Washington and T. Shuhda, Colville National Forest, Colville, Washington. Data sources included Sholz and others (1985), Ashe and Sholz (1992), Chance (1986), Fulton (1970), and Mullan (1986). Some information was based on interviews with tribal elders who fished streams in the upper Columbia River above what is now Grand Coulee Dam, including conversations with Chuck Jones, Jerry Marcot, and Joe Peone of the Colville Confederated Tribes, and Bill Touhey and Dean Osterman of the Kalispel Tribes. Other interviewees included A. Sholz, Eastern Washington Biology Department, Cheney, Washington; J. Nisbet, historian and author; and, D. Mattson, archeologist, Colville National Forest. Data for Oregon were compiled primarily by P. Howell,

[5]Personal communication. 1996. L. Nelson, Idaho Fish and Game, Coeur d'Alene, ID. Personal communication of unpublished data.

[6]Personal communication. 1995. D. Perkinson, Kootenai National Forest, Libby, MT. Personal communication of unpublished data.

[7]Personal communication. 1995. F. Partridge, Idaho Department of Fish and Game.

Umatilla National Forest, Ukiah, Oregon. Information sources for Oregon included Fulton (1968, 1970); Howell and others (1985); Bakke and Felstner (1990); and personal communications with various biologists recorded by P. Howell, Umatilla National Forest.

Stream-Type Chinook Salmon

Data sources for Idaho included Evermann (1896), Chapman (1940), Schoning (1947), Miller and Miller (1948), Parkhurst (1950), Gebhards (1959), Fulton (1968), and IDFG (1992). Thompson (1951) reported that prior to overfishing and environmental alterations, the runs of chinook salmon in the Columbia River formed a continuum from early spring to late fall. Similar to summer steelhead, stream-type chinook salmon were found in all accessible reaches of the Snake River and tributaries in Idaho downstream from Shoshone Falls. Stream-type chinook salmon were also found in the Bruneau and Owyhee rivers, and Salmon Falls Creek drainages in Nevada. Cold water temperatures at high elevations and the presence of suitable spawning reaches may have restricted the upper limit of salmon but this limit is not well defined. Natural barriers limited the distribution in certain areas within the historical range but most inaccessible areas are at the subwatershed level or smaller.

Data for Washington were compiled primarily by K. MacDonald, Wenatchee National Forest, Wenatchee, Washington and T. Shuhda, Colville National Forest, Colville, Washington. Data sources were similar to those cited for steelhead. Data for Oregon were compiled primarily by P. Howell, Umatilla National Forest, Ukiah, Oregon. Information sources for Oregon were similar to those cited for steelhead in addition to Thompson and Haas (1960). Howell also stated that stream-type chinook were widely distributed but probably had more limited distribution and were farther downstream in watersheds compared to the distribution of steelhead.

Ocean-Type Chinook Salmon

Data sources for Idaho included Evermann (1896), Chapman (1940), Schoning (1947), Parkhurst (1950), Gebhards (1959), Fulton (1968), Irving and others (1981), IDFG (1992), and J. Chandler[8] and B. Connor.[9] Ocean-type (fall) chinook salmon spawning areas in Idaho appear to have been confined to the mainstem Snake River. Information suggests that suitable spawning areas for fall chinook salmon are restricted to mainstem reaches where at least 960 temperature units accumulate from November 15 (spawning) to a late April-early May emergence. In the Snake River near Marshing, formerly an important fall chinook salmon spawning area, reconstruction of historical temperature data suggests fry emerged primarily in April. Fry that emerge after mid-May may not be large enough to smolt in late may-early June and begin their downstream migration as age zero fish, a characteristic of fall chinook salmon. Because of these potential temperature constraints, it is likely that fall-spawning chinook salmon observed in higher elevation basins including the Clearwater and South Fork Salmon rivers were actually late spawning stream-type (summer) chinook salmon.

Data for Washington were compiled primarily by K. MacDonald, Wenatchee National Forest, Wenatchee, Washington and T. Shuhda, Colville National Forest, Colville, Washington. Data sources were similar to those cited for steelhead. Data for Oregon were compiled primarily by P. Howell, Umatilla National Forest, Ukiah, Oregon. Information sources for Oregon were similar to those cited for steelhead in addition to Thompson and Haas (1960) and USFWS-NMFS (1981).

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[8]Personal communication. 1995. J. Chandler, Idaho Power Company, Boise, ID.

[9]Personal communication. 1995. B. Connor, U.S. Fish and Wildlife Service, Orofino, ID.

APPENDIX 4E

Classification Tree Results for Six Key Salmonids

1.A. Bull Trout Status

A. Summary

Variables actually used in tree construction:

mtemp	roaddn	hucorder	vegclus	solar	alsi3
ero	con3	elev	slope	bank	eru
baseero	pprecip	con1	streams	alsi1	mngclus
slope2x	con2	vmf			

Number of terminal nodes: 57 Residual mean deviance: 0.8296 = 2207 / 2660

Misclassification error rate: 0.184 = 500 / 2717

B. Tree structure

Node) Split criterion	Sample Size	Deviance	Mode	Relative Frequencies Absent	Depressed	Strong
1) root	2717	4103.000	A	(0.70810	0.229700	0.062200)
2) mtemp<5.08	1474	2726.000	A	(0.55830	0.339900	0.101800)
4) roaddn<2.5	539	1131.000	A	(0.47500	0.304300	0.220800)
8) hucorder<35.5	500	1070.000	A	(0.43400	0.328000	0.238000)
16) vegclus:C,D,E,J,K	147	262.400	A	(0.62590	0.258500	0.115600)
32) solar<351.796	118	228.900	A	(0.55080	0.305100	0.144100)
64) alsi3<21.3151	109	199.100	A	(0.57800	0.321100	0.100900)
128) ero<0.2975	9	6.279	D	(0.11110	0.888900	0.000000)*
129) ero>0.2975	100	178.500	A	(0.62000	0.270000	0.110000)*
65) alsi3>21.3151	9	15.280	S	(0.22220	0.111100	0.666700)*
33) solar>351.796	29	14.560	A	(0.93100	0.068970	0.000000)*
17) vegclus:A,B,F,H,I,L	353	772.400	D	(0.35410	0.356900	0.289000)
34) solar<242.778	47	65.130	A	(0.51060	0.489400	0.000000)*
35) solar>242.778	306	672.300	D	(0.33010	0.336600	0.333300)
70) roaddn<0.5	123	249.700	S	(0.39840	0.154500	0.447200)
140) con3<0.03295	61	127.500	A	(0.49180	0.245900	0.262300)
280) elev<6413.5	19	7.835	A	(0.94740	0.000000	0.052630)*
281) elev>6413.5	42	91.840	D	(0.28570	0.357100	0.357100)
562) slope<30.322	13	16.050	A	(0.69230	0.307700	0.000000)*
563) slope>30.322	29	54.720	S	(0.10340	0.379300	0.517200)
1126) bank<54.7459	16	26.600	D	(0.12500	0.687500	0.187500)*
1127) bank>54.7459	13	7.051	S	(0.07692	0.000000	0.923100)*
141) con3>0.03295	62	103.000	S	(0.30650	0.064520	0.629000)
282) elev<8355	54	78.820	S	(0.22220	0.055560	0.722200)
564) slope<40.107	48	49.130	S	(0.20830	0.000000	0.791700)*
565) slope>40.107	6	12.140	D	(0.33330	0.500000	0.166700)*
283) elev>8355	8	6.028	A	(0.87500	0.125000	0.000000)*
71) roaddn>0.5	183	389.500	D	(0.28420	0.459000	0.256800)
142) elev<6000.5	38	73.840	A	(0.52630	0.131600	0.342100)
284) eru:2,6,8,9	6	0.000	S	(0.00000	0.000000	1.000000)*
285) eru:1,7,13	32	58.640	A	(0.62500	0.156200	0.218800)*
143) elev>6000.5	145	291.300	D	(0.22070	0.544800	0.234500)
286) mtemp<2.646	120	227.700	D	(0.15830	0.591700	0.250000)
572) baseero<23.807	32	38.020	D	(0.00000	0.718800	0.281200)*

573) baseero>23.807	88	176.600	D	(0.21590	0.545500	0.238600)
1146) solar<326.372	41	55.520	D	(0.12200	0.780500	0.097560)*
1147) solar>326.372	47	103.000	S	(0.29790	0.340400	0.361700)*
287) mtemp>2.646	25	49.890	A	(0.52000	0.320000	0.160000)
574) bank<43.4606	7	9.561	S	(0.00000	0.428600	0.571400)*
575) bank>43.4606	18	21.270	A	(0.72220	0.277800	0.000000)*
9) hucorder>35.5	39	0.000	A	(1.00000	0.000000	0.000000)*
5) roaddn>2.5	935	1466.000	A	(0.60640	0.360400	0.033160)
10) pprecip<644.06	252	312.900	A	(0.77780	0.190500	0.031750)
20) con1<50.5696	211	207.300	A	(0.84830	0.128000	0.023700)
40) slope<19.0185	122	23.180	A	(0.98360	0.008197	0.008197)*
41) slope>19.0185	89	137.300	A	(0.66290	0.292100	0.044940)
82) eru:1,7,10	18	0.000	A	(1.00000	0.000000	0.000000)*
83) eru:6,8,9,13	71	120.300	A	(0.57750	0.366200	0.056340)*
21) con1>50.5696	41	73.720	D	(0.41460	0.512200	0.073170)*
11) pprecip>644.06	683	1106.000	A	(0.54320	0.423100	0.033670)
22) eru:3,6,9	130	186.500	D	(0.21540	0.730800	0.053850)
44) elev<6149.5	88	132.400	D	(0.30680	0.659100	0.034090)
88) pprecip<1060.71	71	103.900	D	(0.38030	0.605600	0.014080)
176) hucorder<0.5	40	54.550	A	(0.57500	0.425000	0.000000)*
177) hucorder>0.5	31	32.400	D	(0.12900	0.838700	0.032260)*
89) pprecip>1060.71	17	12.320	D	(0.00000	0.882400	0.117600)*
45) elev>6149.5	42	35.670	D	(0.02381	0.881000	0.095240)*
23) eru:1,2,5,7,8,13	553	847.500	A	(0.62030	0.350800	0.028930)
46) pprecip<875.085	169	154.900	A	(0.82840	0.171600	0.000000)
92) elev<7132	162	132.400	A	(0.85800	0.142000	0.000000)
184) hucorder<1.5	98	39.500	A	(0.94900	0.051020	0.000000)*
185) hucorder>1.5	64	76.050	A	(0.71880	0.281200	0.000000)
370) eru:8	9	6.279	D	(0.11110	0.888900	0.000000)*
371) eru:1,7,13	55	52.160	A	(0.81820	0.181800	0.000000)*
93) elev>7132	7	5.742	D	(0.14290	0.857100	0.000000)*
47) pprecip>875.085	384	639.200	A	(0.52860	0.429700	0.041670)
94) streams<19.4	99	123.400	A	(0.75760	0.222200	0.020200)
188) alsi1<60.3367	59	91.340	A	(0.62710	0.339000	0.033900)
376) mngclus:FH,FW	16	0.000	A	(1.00000	0.000000	0.000000)*
377) mngclus:FG,FM,PF,TL	43	72.990	A	(0.48840	0.465100	0.046510)*
189) alsi1>60.3367	40	15.880	A	(0.95000	0.050000	0.000000)*
95) streams>19.4	285	486.500	D	(0.44910	0.501800	0.049120)
190) hucorder<27.5	271	463.200	D	(0.42070	0.527700	0.051660)
380) baseero<45.6534	164	286.700	A	(0.52440	0.414600	0.060980)
760) bank<61.0671	60	121.400	A	(0.43330	0.416700	0.150000)
1520) slope2x<53.4915	43	86.930	D	(0.25580	0.534900	0.209300)*
1521) slope2x>53.4915	17	12.320	A	(0.88240	0.117600	0.000000)*
761) bank>61.0671	104	151.200	A	(0.57690	0.413500	0.009615)
1522) con2<44.4019	13	0.000	A	(1.00000	0.000000	0.000000)*
1523) con2>44.4019	91	135.600	A	(0.51650	0.472500	0.010990)*
381) baseero>45.6534	107	154.700	D	(0.26170	0.700900	0.037380)
762) slope2x<26.035	23	34.040	D	(0.08696	0.739100	0.173900)*
763) slope2x>26.035	84	103.900	D	(0.30950	0.690500	0.000000)*
191) hucorder>27.5	14	0.000	A	(1.00000	0.000000	0.000000)*
3) mtemp>5.08	1243	995.000	A	(0.88580	0.098950	0.015290)
6) baseero<47.0346	1121	704.600	A	(0.91700	0.074040	0.008921)
12) vmf<0.272017	880	657.300	A	(0.89430	0.094320	0.011360)
24) eru:2,3,6,9	210	269.200	A	(0.77620	0.181000	0.042860)
48) elev<5393	198	235.200	A	(0.80810	0.146500	0.045450)
96) eru:2	46	55.010	A	(0.80430	0.043480	0.152200)
192) slope<11.805	28	0.000	A	(1.00000	0.000000	0.000000)*
193) slope>11.805	18	34.490	A	(0.50000	0.111100	0.388900)*
97) eru:3,6,9	152	162.700	A	(0.80920	0.177600	0.013160)
194) pprecip<909.063	147	144.600	A	(0.83670	0.149700	0.013610)
388) bank<74.3221	62	89.200	A	(0.69350	0.274200	0.032260)
776) baseero<24.0754	36	49.460	A	(0.55560	0.444400	0.000000)*

777) baseero>24.0754	26	22.420	A	(0.88460	0.038460	0.076920)*
389) bank>74.3221	85	38.030	A	(0.94120	0.058820	0.000000)*
195) pprecip>909.063	5	0.000	D	(0.00000	1.000000	0.000000)*
49) elev>5393	12	13.500	D	(0.25000	0.750000	0.000000)*
25) eru:1,5,7,8,10,13	670	344.800	A	(0.93130	0.067160	0.001493)
50) slope<11.575	186	12.450	A	(0.99460	0.005376	0.000000)*
51) slope>11.575	484	309.100	A	(0.90700	0.090910	0.002066)
102) slope2x<44.7999	299	255.800	A	(0.85620	0.140500	0.003344)
204) vmf<0.0543498	160	162.900	A	(0.79370	0.206200	0.000000)*
205) vmf>0.0543498	139	78.400	A	(0.92810	0.064750	0.007194)
410) streams<34.25	69	10.450	A	(0.98550	0.000000	0.014490)*
411) streams>34.25	70	53.710	A	(0.87140	0.128600	0.000000)*
103) slope2x>44.7999	185	22.090	A	(0.98920	0.010810	0.000000)*
13) vmf>0.272017	241	0.000	A	(1.00000	0.000000	0.000000)*
7) baseero>47.0346	122	211.100	A	(0.59840	0.327900	0.073770)
14) baseero<84.8319	101	142.400	A	(0.70300	0.267300	0.029700)*
15) baseero>84.8319	21	36.910	D	(0.09524	0.619000	0.285700)*

* denotes terminal node

1.B. Bull Trout Presence/Absence

A. Summary

Variables actually used in tree construction:

slope	hucorder	elev	pprecip	eru	ero
baseero	bank	alsi2	slope2x	mtemp	con1
con2	vegclus	con3	streams	drnden	hk
anadac					

Number of terminal nodes: 42

Residual mean deviance: 0.7381 = 1974 / 2675

Misclassification error rate: 0.1671 = 454 / 2717

B. Tree Structure

Node) Split Criterion	Sample Size	Deviance	Mode	Absent	Present
1) root	2717	3710.000	A	(0.57200	0.428000)
2) slope<20.6815	1325	1467.000	A	(0.75770	0.242300)
4) hucorder<0.5	621	420.600	A	(0.89370	0.106300)
8) elev<5449	495	192.100	A	(0.95150	0.048480)
16) pprecip<735.726	330	34.180	A	(0.99090	0.009091)*
17) pprecip>735.726	165	125.800	A	(0.87270	0.127300)
34) eru:6,9	9	9.535	P	(0.22220	0.777800)*
35) eru:1,2,5,7,8,13	156	94.210	A	(0.91030	0.089740)*
9) elev>5449	126	160.400	A	(0.66670	0.333300)
18) pprecip<575.577	45	22.040	A	(0.93330	0.066670)*
19) pprecip>575.577	81	112.200	A	(0.51850	0.481500)
38) eru:3,6,9	38	45.730	P	(0.28950	0.710500)*
39) eru:1,10,13	43	50.920	A	(0.72090	0.279100)
78) ero<0.256	22	30.320	P	(0.45450	0.545500)*
79) ero>0.256	21	0.000	A	(1.00000	0.000000)*
5) hucorder>0.5	704	921.800	A	(0.63780	0.362200)
10) baseero<10.7147	197	146.000	A	(0.87820	0.121800)
20) bank<76.4444	68	82.390	A	(0.70590	0.294100)*
21) bank>76.4444	129	35.660	A	(0.96900	0.031010)*

11) baseero>10.7147	507	698.900	A	(0.54440	0.455600)
22) eru:1,2,3,8,9	112	140.700	P	(0.32140	0.678600)
44) alsi2<14.8035	91	95.850	P	(0.21980	0.780200)*
45) alsi2>14.8035	21	23.050	A	(0.76190	0.238100)*
23) eru:5,6,7,10,13	395	529.200	A	(0.60760	0.392400)
46) baseero<37.9108	367	478.300	A	(0.64310	0.356900)
92) alsi2<63.8306	348	443.000	A	(0.66670	0.333300)
184) slope2x<55.2053	314	412.500	A	(0.63380	0.366200)
368) mtemp<7.2905	199	274.100	A	(0.54770	0.452300)
736) con1<38.3993	124	157.400	A	(0.66940	0.330600)*
737) con1>38.3993	75	96.800	P	(0.34670	0.653300)*
369) mtemp>7.2905	115	120.400	A	(0.78260	0.217400)
738) hucorder<13	65	30.050	A	(0.93850	0.061540)*
739) hucorder>13	50	68.030	A	(0.58000	0.420000)
1478) eru:7,10	18	0.000	A	(1.00000	0.000000)*
1479) eru:5,6,13	32	41.180	P	(0.34380	0.656200)*
185) slope2x>55.2053	34	9.023	A	(0.97060	0.029410)*
93) alsi2>63.8306	19	19.560	P	(0.21050	0.789500)*
47) baseero>37.9108	28	22.970	P	(0.14290	0.857100)*
3) slope>20.6815	1392	1868.000	P	(0.39510	0.604900)
6) hucorder<1.5	857	1187.000	A	(0.52040	0.479600)
12) elev<5274.5	370	458.600	A	(0.68920	0.310800)
24) baseero<88.4119	347	403.400	A	(0.73200	0.268000)
48) con2<95.2886	186	251.600	A	(0.59140	0.408600)
96) pprecip<790.366	36	15.450	A	(0.94440	0.055560)*
97) pprecip>790.366	150	207.900	A	(0.50670	0.493300)*
49) con2>95.2886	161	108.600	A	(0.89440	0.105600)
98) baseero<54.2576	133	54.850	A	(0.94740	0.052630)*
99) baseero>54.2576	28	36.500	A	(0.64290	0.357100)*
25) baseero>88.4119	23	8.227	P	(0.04348	0.956500)*
13) elev>5274.5	487	652.300	P	(0.39220	0.607800)
26) vegclus:C,D,E,F,G,J,K	139	186.600	A	(0.60430	0.395700)
52) slope2x<31.3738	31	37.350	P	(0.29030	0.709700)
104) con3<20.3357	25	18.350	P	(0.12000	0.880000)*
105) con3>20.3357	6	0.000	A	(1.00000	0.000000)*
53) slope2x>31.3738	108	132.900	A	(0.69440	0.305600)
106) eru:6,8,9	23	28.270	P	(0.30430	0.695700)*
107) eru:10,13	85	85.070	A	(0.80000	0.200000)*
27) vegclus:B,H,I,L	348	429.500	P	(0.30750	0.692500)
54) streams<13.9	27	34.370	A	(0.66670	0.333300)*
55) streams>13.9	321	379.000	P	(0.27730	0.722700)
110) drnden<1.1253	118	93.660	P	(0.13560	0.864400)*
111) drnden>1.1253	203	265.200	P	(0.35960	0.640400)
222) hk<0.20045	63	47.960	P	(0.12700	0.873000)
444) mtemp<2.717	51	9.844	P	(0.01961	0.980400)*
445) mtemp>2.717	12	16.300	A	(0.58330	0.416700)*
223) hk>0.20045	140	193.400	P	(0.46430	0.535700)
446) mtemp<1.712	58	74.730	A	(0.65520	0.344800)
892) con1<13.976	40	33.820	A	(0.85000	0.150000)*
893) con1>13.976	18	19.070	P	(0.22220	0.777800)*
447) mtemp>1.712	82	103.900	P	(0.32930	0.670700)*
7) hucorder>1.5	535	527.000	P	(0.19440	0.805600)
14) slope<29.1495	268	331.700	P	(0.30970	0.690300)
28) baseero<58.8053	243	312.000	P	(0.34160	0.658400)
56) anadac<0.5	142	195.800	P	(0.45770	0.542300)
112) eru:7,9	54	54.590	P	(0.20370	0.796300)*
113) eru:1,6,8,10,13	88	117.400	A	(0.61360	0.386400)
226) bank<58.4523	24	8.314	A	(0.95830	0.041670)*
227) bank>58.4523	64	88.660	P	(0.48440	0.515600)*
57) anadac>0.5	101	94.670	P	(0.17820	0.821800)*
29) baseero>58.8053	25	0.000	P	(0.00000	1.000000)*
15) slope>29.1495	267	147.100	P	(0.07865	0.921300)
30) eru:1,6	38	50.020	P	(0.36840	0.631600)*
31) eru:5,7,8,9,13	229	62.610	P	(0.03057	0.969400)*

* denotes terminal node

2.A. Westslope Cutthroat Trout Status

A. Summary

Pruned Classification tree:

Variables actually used in tree construction:

eru	mngclus	roaddn	hk	bank	alsi4
sdt2	mtemp	alsi1	elev	drnden	sdt3
con2	slope	solar	pprecip	vmf	vegclus
sdt1	hucorder				

Number of terminal nodes: 37

Residual mean deviance: 0.9993 = 1602 / 1603

Misclassification error rate: 0.197 = 323 / 1640

B. Tree structure

Node) Split criterion	Sample Size	Deviance	Mode	Relative Frequencies Absent	Depressed	Strong
1) root	1640	3108.000	D	(0.196300	0.60240	0.20120)
2) eru:7,8,9	1047	1474.000	D	(0.078320	0.75930	0.16240)
4) mngclus:FG,FH,FM,FW	620	889.400	D	(0.036860	0.70990	0.25320)
8) roaddn<3.5	249	388.900	D	(0.024100	0.55420	0.42170)
16) hk<0.3722	220	336.900	D	(0.027270	0.61360	0.35910)
32) hk<0.207	39	21.150	D	(0.000000	0.92310	0.07692)*
33) hk>0.207	181	292.200	D	(0.033150	0.54700	0.41990)
66) bank<52.972	31	38.100	S	(0.064520	0.12900	0.80650)*
67) bank>52.972	150	225.800	D	(0.026670	0.63330	0.34000)
134) alsi4<76.2131	132	191.500	D	(0.030300	0.68180	0.28790)
268) sdt2<42.6506	124	172.500	D	(0.032260	0.71770	0.25000)
536) mtemp<3.116	63	51.670	D	(0.000000	0.85710	0.14290)
1072) alsi1<84.55	45	9.591	D	(0.000000	0.97780	0.02222)*
1073) alsi1>84.55	18	24.730	D	(0.000000	0.55560	0.44440)*
537) mtemp>3.12	61	105.600	D	(0.065570	0.57380	0.36070)*
269) sdt2>42.6506	8	6.028	S	(0.000000	0.12500	0.87500)*
135) alsi4>76.2131	18	21.270	S	(0.000000	0.27780	0.72220)*
17) hk>0.3722	29	19.290	S	(0.000000	0.10340	0.89660)*
9) roaddn>3.5	375	438.600	D	(0.045330	0.81330	0.14130)
18) elev<4044.5	127	70.810	D	(0.031500	0.93700	0.03150)
36) drnden<1.10835	29	23.270	D	(0.137900	0.86210	0.00000)*
37) drnden>1.10835	98	33.420	D	(0.000000	0.95920	0.04082)*
19) elev>4044.5	248	342.600	D	(0.052420	0.75000	0.19760)
38) bank<60.8877	69	113.500	D	(0.173900	0.69570	0.13040)
76) sdt3<0.12755	58	82.360	D	(0.086210	0.75860	0.15520)*
77) sdt3>0.12755	11	14.420	A	(0.636400	0.36360	0.00000)*
39) bank>60.8877	179	202.100	D	(0.005587	0.77090	0.22350)
78) con2<99.8966	135	128.200	D	(0.007407	0.83700	0.15560)*
79) con2>99.8966	44	60.180	D	(0.000000	0.56820	0.43180)
158) slope<25.468	7	0.000	S	(0.000000	0.00000	1.00000)*
159) slope>25.468	37	46.630	D	(0.000000	0.67570	0.32430)
318) solar<238.392	17	20.600	S	(0.000000	0.29410	0.70590)*
319) solar>238.392	20	0.000	D	(0.000000	1.00000	0.00000)*
5) mngclus:NP,PA,PF,PR,TL	423	447.300	D	(0.139500	0.83220	0.02837)
10) pprecip<425.26	32	44.240	A	(0.531200	0.46880	0.00000)*
11) pprecip>425.26	391	371.200	D	(0.107400	0.86190	0.03069)
22) drnden<1.53125	310	247.100	D	(0.067740	0.89680	0.03548)*
23) drnden>1.53125	81	102.900	D	(0.259300	0.72840	0.01235)
46) mngclus:NP,PA,PF	66	69.470	D	(0.166700	0.81820	0.01515)*

47) mngclus:PR,TL	15	19.100	A	(0.666700	0.33330	0.00000)*
3) eru:1,5,6,13	593	1287.000	A	(0.404700	0.32550	0.26980)
6) vmf<0.10069	491	1072.000	D	(0.289200	0.38490	0.32590)
12) mngclus:BR,FG,FH,FM, PA,PF,PR	307	632.500	D	(0.309400	0.49510	0.19540)
24) solar<277.369	88	183.100	A	(0.465900	0.19320	0.34090)
48) pprecip<1114.58	53	79.450	A	(0.735800	0.09434	0.16980)
96) slope<23.4005	31	14.830	A	(0.935500	0.00000	0.06452)*
97) slope>23.4005	22	46.620	A	(0.454500	0.22730	0.31820)
194) solar<262.553	10	12.220	S	(0.000000	0.30000	0.70000)*
195) solar>262.553	12	10.810	A	(0.833300	0.16670	0.00000)*
49) pprecip>1114.58	35	58.590	S	(0.057140	0.34290	0.60000)*
25) solar>277.369	219	401.100	D	(0.246600	0.61640	0.13700)
50) drnden<1.31305	105	223.700	D	(0.333300	0.43810	0.22860)
100) mtemp<1.926	30	58.210	S	(0.133300	0.33330	0.53330)*
101) mtemp>1.926	75	143.400	D	(0.413300	0.48000	0.10670)*
51) drnden>1.31305	114	147.500	D	(0.166700	0.78070	0.05263)
102) vegclus:E,F,H,J	71	115.800	D	(0.239400	0.67610	0.08451)
204) sdt1<0.28845	39	50.160	D	(0.076920	0.79490	0.12820)*
205) sdt1>0.28845	32	51.580	D	(0.437500	0.53120	0.03125)*
103) vegclus:B,C,D, I,K,L	43	16.180	D	(0.046510	0.95350	0.00000)*
13) mngclus:FW,TL	184	368.900	S	(0.255400	0.20110	0.54350)
26) hucorder<20	156	288.600	S	(0.153800	0.23080	0.61540)
52) slope<27.0375	41	85.500	D	(0.219500	0.48780	0.29270)
104) solar<307.385	21	28.680	D	(0.000000	0.57140	0.42860)*
105) solar>307.385	20	40.420	A	(0.450000	0.40000	0.15000)
210) mtemp<2.297	14	24.980	A	(0.642900	0.14290	0.21430)*
211) mtemp>2.297	6	0.000	D	(0.000000	1.00000	0.00000)*
53) slope>27.0375	115	177.000	S	(0.130400	0.13910	0.73040)
106) pprecip<1046.32	70	116.900	S	(0.100000	0.22860	0.67140)
212) sdt1<14.2349	49	52.190	S	(0.000000	0.22450	0.77550)*
213) sdt1>14.2349	21	44.980	S	(0.333300	0.23810	0.42860)*
107) pprecip>1046.32	45	42.120	S	(0.177800	0.00000	0.82220)*
27) hucorder>20	28	31.280	A	(0.821400	0.03571	0.14290)*
7) vmf>0.10069	102	33.750	A	(0.960800	0.03922	0.00000)*

* denotes terminal node

2.B. Westslope Cutthroat Trout Presence/Absence

A. Summary

Pruned Classification tree:

Variables actually used in tree construction:

eru slope2x sdt3 mngclus elev ero
con2 vegclus slope hk anadac pprecip
bank drnden streams hucorder mtemp

Number of terminal nodes: 24

Residual mean deviance: 0.4153 = 671.1 / 1616

Misclassification error rate: 0.075 = 123 / 1640

B. Tree structure

Node) Split Criterion	Sample Size	Deviance	Mode	Absent	Present
1) root	1640	1470.000	P	(0.16520	0.83480)
2) eru:5	87	53.420	A	(0.90800	0.09195)
4) slope2x<35.9634	64	0.000	A	(1.00000	0.00000)*
5) slope2x>35.9634	23	29.720	A	(0.65220	0.34780)
10) sdt3<18.464	11	12.890	P	(0.27270	0.72730)*
11) sdt3>18.464	12	0.000	A	(1.00000	0.00000)*
3) eru:1,6,7,8,9,13	1553	1162.000	P	(0.12360	0.87640)
6) mngclus:BR,FM,FW,NP	852	352.300	P	(0.05282	0.94720)
12) elev<6248	621	141.300	P	(0.02415	0.97580)
24) ero<0.274	70	45.510	P	(0.10000	0.90000)
48) con2<81.2661	26	30.290	P	(0.26920	0.73080)*
49) con2>81.2661	44	0.000	P	(0.00000	1.00000)*
25) ero>0.274	551	83.600	P	(0.01452	0.98550)*
13) elev>6248	231	178.400	P	(0.12990	0.87010)
26) vegclus:B,C,E,F	50	64.100	P	(0.34000	0.66000)
52) slope<22.2285	9	0.000	A	(1.00000	0.00000)*
53) slope>22.2285	41	40.470	P	(0.19510	0.80490)*
27) vegclus:D,H,I,J,K,L	181	93.520	P	(0.07182	0.92820)
54) hk<0.20035	99	11.180	P	(0.01010	0.98990)*
55) hk>0.20035	82	68.270	P	(0.14630	0.85370)*
7) mngclus:FG,FH,PA,PF,PR,TL	701	720.000	P	(0.20970	0.79030)
14) anadac<0.5	482	366.100	P	(0.12660	0.87340)
28) pprecip<425.26	30	41.590	A	(0.50000	0.50000)
56) bank<65.6722	20	22.490	A	(0.75000	0.25000)*
57) bank>65.6722	10	0.000	P	(0.00000	1.00000)*
29) pprecip>425.26	452	297.400	P	(0.10180	0.89820)
58) drnden<1.597	390	201.400	P	(0.07179	0.92820)
116) streams<23.45	124	102.700	P	(0.14520	0.85480)*
117) streams>23.45	266	85.240	P	(0.03759	0.96240)*
59) drnden>1.597	62	74.700	P	(0.29030	0.70970)
118) hucorder<4.5	41	56.230	P	(0.43900	0.56100)*
119) hucorder>4.5	21	0.000	P	(0.00000	1.00000)*
15) anadac>0.5	219	293.400	P	(0.39270	0.60730)
30) ero<1.9505	174	208.700	P	(0.28740	0.71260)
60) vegclus:A,E,F,H,J	127	169.400	P	(0.38580	0.61420)
120) streams<38.55	88	121.800	P	(0.47730	0.52270)
240) mngclus:FG,FH,PA,PF	80	110.700	A	(0.52500	0.47500)
480) mtemp<4.9615	61	82.570	P	(0.40980	0.59020)
960) pprecip<746.659	24	18.080	P	(0.12500	0.87500)*
961) pprecip>746.659	37	49.960	A	(0.59460	0.40540)
1922) slope2x<36.5642	11	0.000	A	(1.00000	0.00000)*
1923) slope2x>36.5642	26	35.430	P	(0.42310	0.57690)*
481) mtemp>4.9615	19	12.790	A	(0.89470	0.10530)*
241) mngclus:PR,TL	8	0.000	P	(0.00000	1.00000)*
121) streams>38.55	39	36.710	P	(0.17950	0.82050)*
61) vegclus:B,C,I,K,L	47	9.679	P	(0.02128	0.97870)*
31) ero>1.9505	45	45.040	A	(0.80000	0.20000)*

*denotes terminal node

3.A. Yellowstone Cutthroat Trout Status

A. Summary

Pruned Classification tree:
Variables actually used in tree construction:
eru mtemp hucorder solar hk ero drnden pprecip sdt1
Number of terminal nodes: 11
Residual mean deviance: 0.7893 = 301.5 / 382
Misclassification error rate: 0.1501 = 59 / 393

B. Tree structure

Node) Split criterion	Sample Size	Deviance	Mode	Relative Frequencies Absent	Depressed	Strong
1) root	393	846.400	S	(0.27230	0.2952	0.43260)
2) eru:5,11	111	157.400	A	(0.71170	0.2523	0.03604)
4) mtemp<6.1345	59	105.500	D	(0.45760	0.4746	0.06780)
8) hucorder<2.5	31	37.350	A	(0.70970	0.2903	0.00000)*
9) hucorder>2.5	28	47.530	D	(0.17860	0.6786	0.14290)*
5) mtemp>6.1345	52	0.000	A	(1.00000	0.0000	0.00000)*
3) eru:10,12	282	510.200	S	(0.09929	0.3121	0.58870)
6) solar<329.144	35	51.890	A	(0.65710	0.3143	0.02857)
12) hk<0.36925	17	27.480	D	(0.29410	0.6471	0.05882)
24) ero<0.1895	5	0.000	A	(1.00000	0.0000	0.00000)*
25) ero>0.1895	12	6.884	D	(0.00000	0.9167	0.08333)*
13) hk>0.36925	18	0.000	A	(1.00000	0.0000	0.00000)*
7) solar>329.144	247	351.600	S	(0.02024	0.3117	0.66800)
14) drnden<1.1257	120	83.960	S	(0.01667	0.0750	0.90830)*
15) drnden>1.1257	127	199.100	D	(0.02362	0.5354	0.44090)
30) pprecip<217.365	23	0.000	D	(0.00000	1.0000	0.00000)*
31) pprecip>217.365	104	166.000	S	(0.02885	0.4327	0.53850)
62) hucorder<13.5	88	138.100	D	(0.02273	0.5114	0.46590)
124) sdt1<9.79875	19	12.790	S	(0.00000	0.1053	0.89470)*
125) sdt1>9.79875	69	105.500	D	(0.02899	0.6232	0.34780)*
63) hucorder>13.5	16	7.481	S	(0.06250	0.0000	0.93750)*

* denotes terminal node

3.B. Yellowstone Cutthroat Trout Presence/Absence

A. Summary

Pruned Classification tree:
Variables actually used in tree construction:
mtemp solar hk ero hucorder con1 alsi3
Number of terminal nodes: 9
Residual mean deviance: 0.1734 = 66.6 / 384
Misclassification error rate: 0.02036 = 8 / 393

B. Tree structure

Node) Split Criterion	Sample Size	Deviance	Mode	Absent	Present
1) root	393	447.900	P	(0.25700	0.74300)
2) mtemp<6.1345	340	280.400	P	(0.14410	0.85590)
4) solar<327.01	38	47.400	A	(0.68420	0.31580)
8) hk<0.36925	20	26.920	P	(0.40000	0.60000)
16) ero<0.1895	6	0.000	A	(1.00000	0.00000)*
17) ero>0.1895	14	11.480	P	(0.14290	0.85710)*
9) hk>0.36925	18	0.000	A	(1.00000	0.00000)*
5) solar>327.01	302	162.600	P	(0.07616	0.92380)
10) mtemp<4.7385	242	32.300	P	(0.01240	0.98760)*
11) mtemp>4.7385	60	76.380	P	(0.33330	0.66670)
22) hucorder<2.5	30	38.190	A	(0.66670	0.33330)
44) con1<4.6376	14	18.250	P	(0.35710	0.64290)
88) alsi3<21.3968	8	0.000	P	(0.00000	1.00000)*
89) alsi3>21.3968	6	5.407	A	(0.83330	0.16670)*
45) con1>4.6376	16	7.481	A	(0.93750	0.06250)*
23) hucorder>2.5	30	0.000	P	(0.00000	1.00000)*
3) mtemp>6.1345	53	9.922	A	(0.98110	0.01887)*

* denotes terminal node

4.A. Redband Trout Status

A. Summary

Pruned Classification tree:

Variables actually used in tree construction:

mngclus slope eru bank vmf hucorder mtemp alsi3 anadac vegclus con3 pprecip con1 streams elev solar baseero ero drnden

Number of terminal nodes: 35

Residual mean deviance: 1.138 = 2001 / 1758

Misclassification error rate: 0.2426 = 435 / 1793

B. Tree structure

Node) Split criterion	Sample Size	Deviance	Mode	Relative Frequencies Absent	Depressed	Strong
1) root	1793	3578.000	A	(0.463500	0.39710	0.139400)
2) mngclus:BR,FM,PA,PR	1254	2107.000	A	(0.598100	0.34370	0.058210)
4) slope<9.9835	757	961.500	A	(0.741100	0.24170	0.017170)
8) eru:4,7,10	464	460.500	A	(0.836200	0.14870	0.015090)
16) bank<69.2355	64	103.500	A	(0.515600	0.45310	0.031250)*
17) bank>69.2355	400	312.800	A	(0.887500	0.10000	0.012500)
34) vmf<0.0142501	8	15.590	S	(0.125000	0.37500	0.500000)*
35) vmf>0.0142501	392	258.800	A	(0.903100	0.09439	0.002551)
70) hucorder<1.5	272	104.400	A	(0.952200	0.04779	0.000000)*
71) hucorder>1.5	120	131.200	A	(0.791700	0.20000	0.008333)*
9) eru:1,2,5,6,13	293	444.200	A	(0.590400	0.38910	0.020480)
18) mtemp<10.1715	232	368.900	A	(0.495700	0.47840	0.025860)
36) alsi3<17.6948	84	126.300	A	(0.690500	0.26190	0.047620)

72) mtemp<8.2175	45	53.210	A	(0.822200	0.08889	0.088890)*
73) mtemp>8.2175	39	53.830	A	(0.538500	0.46150	0.000000)*
37) alsi3>17.6948	148	216.500	D	(0.385100	0.60140	0.013510)*
19) mtemp>10.1715	61	23.920	A	(0.950800	0.04918	0.000000)*
5) slope>9.9835	497	964.000	D	(0.380300	0.49900	0.120700)
10) hucorder<144	460	887.500	D	(0.330400	0.53910	0.130400)
20) anadac<0.5	368	684.500	D	(0.255400	0.60330	0.141300)
40) vegclus:C,E,F,H,J,K	155	231.600	D	(0.109700	0.74190	0.148400)
80) con3<56.3276	114	114.600	D	(0.035090	0.85090	0.114000)
160) bank<81.3688	68	95.030	D	(0.058820	0.75000	0.191200)*
161) bank>81.3688	46	0.000	D	(0.000000	1.00000	0.000000)*
81) con3>56.3276	41	87.720	D	(0.317100	0.43900	0.243900)*
41) vegclus:A,B,D,L	213	419.700	D	(0.361500	0.50230	0.136200)
82) hucorder<0.5	119	236.000	A	(0.470600	0.39500	0.134500)
164) eru:7	18	16.220	A	(0.833300	0.00000	0.166700)*
165) eru:4,5,6,8, 10,13	101	199.100	D	(0.405900	0.46530	0.128700)
330)pprecip<420.582	51	80.140	A	(0.627500	0.33330	0.039220)*
331)pprecip>420.582	50	94.830	D	(0.180000	0.60000	0.220000)*
83) hucorder>0.5	94	168.300	D	(0.223400	0.63830	0.138300)*
21) anadac>0.5	92	158.300	A	(0.630400	0.28260	0.086960)
42) con1<24.2747	63	117.800	A	(0.507900	0.39680	0.095240)
84) streams<22.05	26	36.410	A	(0.769200	0.11540	0.115400)*
85) streams>22.05	37	64.970	D	(0.324300	0.59460	0.081080)
170) elev<2469.5	11	3.200	A	(0.818200	0.09091	0.090910)*
171) elev>2469.5	26	32.190	D	(0.115400	0.80770	0.076920)*
43) con1>24.2747	29	23.110	A	(0.896600	0.03448	0.068970)*
11) hucorder>144	37	0.000	A	(1.000000	0.00000	0.000000)*
3) mngclus:FG,FH,FW,PF,TL	539	1067.000	D	(0.150300	0.52130	0.328400)
6) anadac<0.5	420	716.600	D	(0.061900	0.58570	0.352400)
12) solar<290.698	51	83.320	S	(0.215700	0.09804	0.686300)
24) alsi3<0.4464	15	30.290	A	(0.533300	0.20000	0.266700)*
25) alsi3>0.4464	36	35.740	S	(0.083330	0.05556	0.861100)*
13) solar>290.698	369	568.900	D	(0.040650	0.65310	0.306200)
26) eru:2,3,4,5	100	130.700	D	(0.130000	0.79000	0.080000)*
27) eru:6,10,13	269	381.500	D	(0.007435	0.60220	0.390300)
54) baseero<29.5729	222	302.400	D	(0.009009	0.66220	0.328800)
108) alsi3<33.7782	148	182.000	D	(0.013510	0.75000	0.236500)
216) con1<2.1399	82	106.500	D	(0.000000	0.64630	0.353700)
432) hucorder<1.5	51	70.680	S	(0.000000	0.49020	0.509800)
864) ero<0.253	17	12.320	D	(0.000000	0.88240	0.117600)*
865) ero>0.253	34	41.190	S	(0.000000	0.29410	0.705900)*
433) hucorder>1.5	31	19.710	D	(0.000000	0.90320	0.096770)*
217) con1>2.1399	66	57.750	D	(0.030300	0.87880	0.090910)*
109) alsi3>33.7782	74	102.500	S	(0.000000	0.48650	0.513500)*
55) baseero>29.5729	47	58.870	S	(0.000000	0.31910	0.680900)*
7) anadac>0.5	119	252.400	A	(0.462200	0.29410	0.243700)
14) ero<0.3105	37	62.670	D	(0.378400	0.56760	0.054050)
28) baseero<9.6972	7	0.000	A	(1.000000	0.00000	0.000000)*
29) baseero>9.6972	30	46.190	D	(0.233300	0.70000	0.066670)*
15) ero>0.3105	82	166.300	A	(0.500000	0.17070	0.329300)
30) alsi3<27.8208	57	104.100	A	(0.631600	0.17540	0.193000)
60) eru:1,7	23	37.990	A	(0.565200	0.04348	0.391300)*
61) eru:2,5,13	34	53.240	A	(0.676500	0.26470	0.058820)
122) drnden<1.19945	19	7.835	A	(0.947400	0.00000	0.052630)*
123) drnden>1.19945	15	25.600	D	(0.333300	0.60000	0.066670)*
31) alsi3>27.8208	25	45.040	S	(0.200000	0.16000	0.640000)*

* denotes terminal node

4.B. Redband Trout Presence/Absence

A. Summary

Pruned Classification tree:
Variables actually used in tree construction:
pprecip baseero eru mtemp bank hk
hucorder slope solar alsi3 mngclus anadac
drnden sdt2 slope2x streams
Number of terminal nodes: 20
Residual mean deviance: 0.7844 = 1391 / 1773
Misclassification error rate: 0.1846 = 331 / 1793

B. Tree structure

Node) Split Criterion	Sample Size	Deviance	Mode	Absent	Present
1) root	1793	2474.00	P	(0.46010	0.53990)
2) pprecip<380.296	840	1021.00	A	(0.70360	0.29640)
4) baseero<5.637	432	372.80	A	(0.84490	0.15510)
8) eru:2,5,6,7	99	126.00	A	(0.66670	0.33330)
16) mtemp<10.1	71	98.07	A	(0.53520	0.46480)*
17) mtemp>10.1	28	0.00	A	(1.00000	0.00000)*
9) eru:4,10	333	219.60	A	(0.89790	0.10210)
18) bank<91.5758	175	160.40	A	(0.82860	0.17140)
36) hk<0.25335	110	128.90	A	(0.72730	0.27270)*
37) hk>0.25335	65	0.00	A	(1.00000	0.00000)*
19) bank>91.5758	158	37.31	A	(0.97470	0.02532)*
5) baseero>5.637	408	560.90	A	(0.55390	0.44610)
10) mtemp<8.707	254	349.50	P	(0.44880	0.55120)
20) hucorder<0.5	115	152.00	A	(0.62610	0.37390)*
21) hucorder>0.5	139	170.30	P	(0.30220	0.69780)
42) hucorder<153.5	132	152.70	P	(0.26520	0.73480)
84) slope<8.109	26	33.54	A	(0.65380	0.34620)*
85) slope>8.109	106	96.58	P	(0.16980	0.83020)*
43) hucorder>153.5	7	0.00	A	(1.00000	0.00000)*
11) mtemp>8.707	154	180.50	A	(0.72730	0.27270)*
3) pprecip>380.296	953	1062.00	P	(0.24550	0.75450)
6) solar<277.231	258	357.40	A	(0.51550	0.48450)
12) alsi3<31.4241	193	255.00	A	(0.62690	0.37310)
24) eru:1,5,7,8	172	233.90	A	(0.58140	0.41860)*
25) eru:2,6,13	21	0.00	A	(1.00000	0.00000)*
13) alsi3>31.4241	65	62.18	P	(0.18460	0.81540)*
7) solar>277.231	695	576.20	P	(0.14530	0.85470)
14) mngclus:FG,FH,FM,PA,PF	428	206.80	P	(0.06542	0.93460)
28) anadac<0.5	362	98.52	P	(0.03039	0.96960)
56) drnden<0.22875	5	0.00	A	(1.00000	0.00000)*
57) drnden>0.22875	357	60.93	P	(0.01681	0.98320)*
29) anadac>0.5	66	75.31	P	(0.25760	0.74240)
58) sdt2<14.3508	19	23.70	A	(0.68420	0.31580)*
59) sdt2>14.3508	47	27.36	P	(0.08511	0.91490)*
15) mngclus:BR,FW,PR,TL	267	313.30	P	(0.27340	0.72660)
30) slope2x<16.4708	26	25.46	A	(0.80770	0.19230)*
31) slope2x>16.4708	241	251.40	P	(0.21580	0.78420)
62) streams<18.45	27	36.50	A	(0.59260	0.40740)*
63) streams>18.45	214	193.90	P	(0.16820	0.83180)*

* denotes terminal node

5. Steelhead Status

A. Summary

Pruned Classification tree:
Variables actually used in tree construction:
hucorder eru vmf slope baseero solar
pprecip drnden vegclus alsi3 mngclus hk
sdt2 streams elev bank con1 dampass
Number of terminal nodes: 35
Residual mean deviance: 0.5769 = 761.5 / 1320
Misclassification error rate: 0.1137 = 154 / 1355

B. Tree structure

Node) Split criterion	Sample Size	Deviance	Mode	Relative Frequencies Absent	Depressed	Migration	Strong
1) root	1355	2400.00	D	(0.13140	0.68710	0.166800	0.014760)
2) hucorder<21.5	1064	1419.00	D	(0.16730	0.78480	0.029140	0.018800)
4) eru:2,6	337	243.70	D	(0.01484	0.91990	0.026710	0.038580)
8) vmf<0.0135926	58	61.72	D	(0.00000	0.77590	0.000000	0.224100)
16) slope<19.466	37	15.56	D	(0.00000	0.94590	0.000000	0.054050)*
17) slope>19.466	21	29.06	S	(0.00000	0.47620	0.000000	0.523800)
34) baseero<33.4816	13	11.16	S	(0.00000	0.15380	0.000000	0.846200)*
35) baseero>33.4816	0	0.00	D	(0.00000	1.00000	0.000000	0.000000)*
9) vmf>0.0135926	279	129.30	D	(0.01792	0.94980	0.032260	0.000000)
18) solar<284.659	53	76.38	D	(0.09434	0.75470	0.150900	0.000000)
36) pprecip<561.617	26	53.37	D	(0.19230	0.50000	0.307700	0.000000)
72) hucorder<0.5	7	11.15	A	(0.71430	0.14290	0.142900	0.000000)*
73) hucorder>0.5	19	25.01	D	(0.00000	0.63160	0.368400	0.000000)*
37) pprecip>561.617	27	0.00	D	(0.00000	1.00000	0.000000	0.000000)*
19) solar>284.659	226	12.84	D	(0.00000	0.99560	0.004425	0.000000)*
5) eru:1,5,7,13	727	1057.00	D	(0.23800	0.72210	0.030260	0.009629)
10) hucorder<0.5	377	580.30	D	(0.37670	0.60210	0.010610	0.010610)
20) drnden<0.9504	52	47.92	A	(0.82690	0.17310	0.000000	0.000000)
40) slope<30.351	45	16.36	A	(0.95560	0.04444	0.000000	0.000000)*
41) slope>30.351	7	0.00	D	(0.00000	1.00000	0.000000	0.000000)*
21) drnden>0.9504	325	479.80	D	(0.30460	0.67080	0.012310	0.012310)
42) vegclus:A,E,I,J,K	145	225.00	D	(0.44830	0.53100	0.020690	0.000000)
84) alsi3<52.6848	103	163.80	A	(0.55340	0.41750	0.029130	0.000000)
168) mngclus: FG,FM,FW,PR	49	78.22	D	(0.34690	0.61220	0.040820	0.000000)
336) pprecip<1389.84	43	63.87	D	(0.25580	0.69770	0.046510	0.000000)
672) solar<318.167	25	16.71	D	(0.04000	0.92000	0.040000	0.000000)*
673) solar>318.167	18	30.76	A	(0.55560	0.38890	0.055560	0.000000)
1346) hk<0.2403	10	16.04	D	(0.20000	0.70000	0.100000	0.000000)*
1347) hk>0.2403	8	0.00	A	(1.00000	0.00000	0.000000	0.000000)*
337) pprecip>1389.84	6	0.00	A	(1.00000	0.00000	0.000000	0.000000)*
169) mngclus: BR,FH,PA,PF,TL	54	69.01	A	(0.74070	0.24070	0.018520	0.000000)*
85) alsi3>52.6848	42	40.90	D	(0.19050	0.80950	0.000000	0.000000)*
43) vegclus:B,C,D,F,H,L	180	223.00	D	(0.18890	0.78330	0.005556	0.022220)
86) sdt2<98.9962	145	167.00	D	(0.22760	0.76550	0.006897	0.000000)
172) streams<35.5	101	135.00	D	(0.30690	0.68320	0.009901	0.000000)
344) mngclus: BR,FG,FH,PA,PF	49	67.91	D	(0.48980	0.51020	0.000000	0.000000)*
345) mngclus:							

FM,FW,PR,TL	52	50.68	D	(0.13460	0.84620	0.019230	0.000000)*
173) streams>35.5	44	16.27	D	(0.04545	0.95450	0.000000	0.000000)*
87) sdt2>98.9962	35	33.71	D	(0.02857	0.85710	0.000000	0.114300)
174) pprecip<1160.34	25	0.00	D	(0.00000	1.00000	0.000000	0.000000)*
175) pprecip>1160.34	10	18.87	D	(0.10000	0.50000	0.000000	0.400000)*
11) hucorder>0.5	350	381.50	D	(0.08857	0.85140	0.051430	0.008571)
22) elev<1428.5	14	23.25	M	(0.07143	0.28570	0.642900	0.000000)*
23) elev>1428.5	336	316.90	D	(0.08929	0.87500	0.026790	0.008929)
46) solar<247.677	15	20.19	A	(0.60000	0.40000	0.000000	0.000000)*
47) solar>247.677	321	269.40	D	(0.06542	0.89720	0.028040	0.009346)
94) baseero<24.9986	155	111.30	D	(0.11610	0.88390	0.000000	0.000000)
188) bank<78.3389	87	85.95	D	(0.19540	0.80460	0.000000	0.000000)
376) vegclus:C,D,H	29	0.00	D	(0.00000	1.00000	0.000000	0.000000)*
377) vegclus:A,B,E,F,I,K,L	58	70.17	D	(0.29310	0.70690	0.000000	0.000000)
754) con1<4.7448	37	25.35	D	(0.10810	0.89190	0.000000	0.000000)*
755) con1>4.7448	21	27.91	A	(0.61900	0.38100	0.000000	0.000000)*
189) bank>78.3389	68	10.42	D	(0.01471	0.98530	0.000000	0.000000)*
95) baseero>24.9986	166	129.20	D	(0.01807	0.90960	0.054220	0.018070)
190) baseero<42.0739	104	87.88	D	(0.02885	0.88460	0.086540	0.000000)
380) hk<0.2419	67	17.99	D	(0.00000	0.97010	0.029850	0.000000)*
381) hk>0.2419	37	55.40	D	(0.08108	0.72970	0.189200	0.000000)*
191) baseero>42.0739	62	24.02	D	(0.00000	0.95160	0.000000	0.048390)*
3) hucorder>21.5	291	369.00	M	(0.00000	0.32990	0.670100	0.000000)
6) hucorder<121	127	170.30	D	(0.00000	0.60630	0.393700	0.000000)
12) eru:1,6	46	22.18	D	(0.00000	0.93480	0.065220	0.000000)*
13) eru:5,7,13	81	110.20	M	(0.00000	0.41980	0.580200	0.000000)
26) hk<0.33435	54	73.00	D	(0.00000	0.59260	0.407400	0.000000)
52) mngclus:BR,FH,FW,PA	37	49.96	M	(0.00000	0.40540	0.594600	0.000000)*
53) mngclus:FG,FM,PF,PR	17	0.00	D	(0.00000	1.00000	0.000000	0.000000)*
27) hk>0.33435	27	14.26	M	(0.00000	0.07407	0.925900	0.000000)*
7) hucorder>121	164	117.60	M	(0.00000	0.11590	0.884100	0.000000)
14) dampass<2.5	16	19.87	D	(0.00000	0.68750	0.312500	0.000000)*
15) dampass>2.5	148	62.24	M	(0.00000	0.05405	0.945900	0.000000)*

* denotes terminal node

6. Stream-type Chinook Salmon Status

A. Summary

Variables actually used in tree construction:

hucorder	pprecip	dampass	streams	mtemp	eru	
mngclus	alsi1		solar		alsi3	con3

Number of terminal nodes: 26

Residual mean deviance: 0.8282 Misclassification error rate: 0.1672 = 211 / 1262

B. Tree structure

Node) Split criterion	Sample Size	Deviance	Mode	Relative Frequencies Absent	Depressed	Migration	Strong
1) root	1262	2718.00	A	0.43900	0.36450	0.190200	0.006339
2) hucorder < 30	991	1652.00	A	0.54990	0.41370	0.028250	0.008073
4) hucorder = 0	500	622.40	A	0.75800	0.22200	0.020000	0.000000
8) pprecip < 601	145	93.04	A	0.92410	0.03448	0.041380	0.000000 *
9) pprecip > 601	355	473.80	A	0.69010	0.29860	0.011270	0.000000
18) dampass < 4	23	13.59	D	0.08696	0.91300	0.000000	0.000000 *
19) dampass > 3	332	418.60	A	0.73190	0.25600	0.012050	0.000000
38) streams < 23	145	112.40	A	0.88280	0.11030	0.006897	0.000000 *
39) streams > 23	187	274.20	A	0.61500	0.36900	0.016040	0.000000
78) mtemp < 6.9	158	242.70	A	0.54430	0.43670	0.018990	0.000000
156) streams < 43.6	122	177.00	A	0.63110	0.35250	0.016390	0.000000
312) pprecip < 960.7	52	50.68	A	0.84620	0.13460	0.019230	0.000000 *
313) pprecip > 960.7	70	106.00	D	0.47140	0.51430	0.014290	0.000000 *
157) streams > 43.6	36	49.04	D	0.25000	0.72220	0.027780	0.000000
314) streams < 64.1	31	32.40	D	0.12900	0.83870	0.032260	0.000000 *
315) streams > 64.1	5	0.00	A	1.00000	0.00000	0.000000	0.000000 *
79) mtemp > 6.9	29	0.00	A	1.00000	0.00000	0.000000	0.000000 *
5) hucorder > 0	491	841.50	D	0.33810	0.60900	0.036660	0.016290
10) eru: 5,7	116	117.80	A	0.81900	0.17240	0.008621	0.000000
20) mngclus: BR,PA,PF,PR	106	85.95	A	0.87740	0.11320	0.009434	0.000000
40) alsi1 < 1.56	77	18.55	A	0.97400	0.02597	0.000000	0.000000 *
41) alsi1 > 1.56	29	45.20	A	0.62070	0.34480	0.034480	0.000000 *
21) mngclus: FG,FH,FM,TL	10	10.01	D	0.20000	0.80000	0.000000	0.000000 *
11) eru: 1,2,6,13	375	568.10	D	0.18930	0.74400	0.045330	0.021330
22) mngclus :BR,PA,PR	68	129.60	A	0.45590	0.44120	0.102900	0.000000
44) mtemp < 10.54	62	94.79	A	0.50000	0.48390	0.016130	0.000000 *
45) mtemp > 10.54	6	0.00	M	0.00000	0.00000	1.000000	0.000000 *
23) mngclus: FG,FH,FM,FW,PF,TL	307	394.20	D	0.13030	0.81110	0.032570	0.026060
46) dampass < 4	56	82.10	D	0.10710	0.75000	0.000000	0.142900
92) sola r< 330.6	30	8.77	D	0.03333	0.96670	0.000000	0.000000 *
93) solar > 330.6	26	53.37	D	0.19230	0.50000	0.000000	0.307700
186) pprecip < 535.2	10	13.86	A	0.50000	0.50000	0.000000	0.000000 *
187) pprecip > 535.2	16	22.18	D	0.00000	0.50000	0.000000	0.500000 *
47) dampass > 4	251	280.20	D	0.13550	0.82470	0.039840	0.000000
94) hucorder <4	130	149.20	D	0.22310	0.76920	0.007692	0.000000 *
95) hucorder > 3	121	105.00	D	0.04132	0.88430	0.074380	0.000000
190) mngclus: FG,FM	51	0.00	D	0.00000	1.00000	0.000000	0.000000*
191) mngclus: FH,FW,PF	70	88.31	D	0.07143	0.80000	0.128600	0.000000*
3) hucorder > 29	271	334.40	M	0.03321	0.18450	0.782300	0.000000
6) hucorder < 58	74	138.00	M	0.09459	0.39190	0.513500	0.000000
12) eru: 5,7	10	12.22	A	0.70000	0.00000	0.300000	0.000000 *
13) eru: 1,6,13	64	88.16	M	0.00000	0.45310	0.546900	0.000000
26) alsi3 < 59.7	52	65.73	M	0.00000	0.32690	0.673100	0.000000
52) alsi1 < 0.37	9	6.28	D	0.00000	0.88890	0.111100	0.000000 *
53) alsi1 > 0.37	43	44.12	M	0.00000	0.20930	0.790700	0.000000 *
27) alsi3 > 59.7	12	0.00	D	0.00000	1.00000	0.000000	0.000000 *
7) hucorder > 57	197	155.60	M	0.01015	0.10660	0.883200	0.000000
14) dampass < 3	16	19.87	D	0.00000	0.68750	0.312500	0.000000*
15) dampass > 2	181	99.13	M	0.01105	0.05525	0.933700	0.000000
30) con3 < 0.49	90	19.18	M	0.02222	0.00000	0.977800	0.000000*
31) con3 > 0.49	91	63.00	M	0.00000	0.10990	0.890100	0.000000*

* denotes terminal node

6. Ocean-type chinook salmon status

A. Summary

Pruned Classification tree:
Variables actually used in tree construction:
hucorder vmf dampass ero elev pprecip slope
Number of terminal nodes: 12
Residual mean deviance: 0.4289 = 90.92 / 212
Misclassification error rate: 0.07589 = 17 / 224

B. Tree structure

Node) Split criterion	Sample		Size	Relative Frequencies			
Migration Strong				Deviance	Mode	Absent	Depressed
1) root	224	569.400	A	(0.41520	0.23210	0.26340	0.08929)
2) hucorder<1080	161	356.600	A	(0.57760	0.22360	0.08075	0.11800)
4) hucorder<5.5	82	79.090	A	(0.85370	0.02439	0.12200	0.00000)
8) vmf<0.234099	61	17.600	A	(0.96720	0.03279	0.00000	0.00000)*
9) vmf>0.234099	21	29.060	A	(0.52380	0.00000	0.47620	0.00000)
18) dampass<3.5	9	6.279	M	(0.11110	0.00000	0.88890	0.00000)*
19) dampass>3.5	12	10.810	A	(0.83330	0.00000	0.16670	0.00000)*
5) hucorder>5.5	79	187.900	D	(0.29110	0.43040	0.03797	0.24050)
10) dampass<7.5	34	75.770	S	(0.23530	0.14710	0.05882	0.55880)
20) ero<2.349	14	27.780	A	(0.50000	0.35710	0.00000	0.14290)
40) dampass<2.5	6	7.638	D	(0.00000	0.66670	0.00000	0.33330)*
41) dampass>2.5	8	6.028	A	(0.87500	0.12500	0.00000	0.00000)*
21) ero>2.349	20	20.730	S	(0.05000	0.00000	0.10000	0.85000)
42) elev<1495	5	10.550	M	(0.20000	0.00000	0.40000	0.40000)*
43) elev>1495	15	0.000	S	(0.00000	0.00000	0.00000	1.00000)*
11) dampass>7.5	45	66.050	D	(0.33330	0.64440	0.02222	0.00000)
22) elev<3145.5	30	23.320	D	(0.06667	0.90000	0.03333	0.00000)
44) pprecip<304.361	5	10.550	A	(0.40000	0.40000	0.20000	0.00000)*
45) pprecip>304.361	25	0.000	D	(0.00000	1.00000	0.00000	0.00000)*
23) elev>3145.5	15	11.780	A	(0.86670	0.13330	0.00000	0.00000)*
3) hucorder>1080	63	81.080	M	(0.00000	0.25400	0.73020	0.01587)
6) slope<24.69	47	9.679	M	(0.00000	0.00000	0.97870	0.02128)*
7) slope>24.69	16	0.000	D	(0.00000	1.00000	0.00000	0.00000)*

* denotes terminal node

APPENDIX 4F

Summary of Self-Sustaining Trout Waters in the Basin Managed With Special Angling Regulations, by State and River Basin, 1995

Idaho[1]

Kootenai: headwaters of Kootenai River, Moyie River below Meadow Creek

Pend Oreille: Pend Oreille Lake and tributaries, Priest and Upper Priest lakes and tributaries

Spokane: Coeur d'Alene Lake and tributaries, Hayden Lake and tributaries, Coeur d'Alene River and tributaries, St. Joe River and tributaries, St. Maries River and tributaries, Spokane River below Post Falls Dam.

Clearwater: Fish Lake, Little North Fork Clearwater River and tributaries, North Fork Clearwater River and tributaries, Ten Mile Creek and tributaries, Lochsa River and tributaries above Wilderness Gateway, Selway River and tributaries above Meadow Creek

Salmon: Salmon River from Little Salmon River to Horse Creek, Partridge and French creeks, Little Salmon River and tributaries to headwaters, South Fork Salmon River and tributaries, Salmon River tributaries from Horse Creek to North Fork except Panther Creek, North Fork Salmon River, Middle Fork Salmon River and tributaries, Salmon River tributaries from North Fork to Hell Roaring Creek, Salmon River and tributaries from Hell Roaring Creek to headwaters, Alturas Lake, East Fork Salmon River and tributaries, Jimmy Smith Lake, Lemhi River and tributaries except Hawley Creek, Pahsimeroi River and tributaries

Snake River below Shoshone Falls: Wildhorse River; Indian, Reynolds and Castle creeks; Billingsly, Riley, and Box Canyon creeks, Banbury Springs

Weiser: Weiser River to Little Weiser River; Little, Middle Fork, and West Fork Weiser rivers and tributaries

Payette: Payette River from Black Canyon to Middle Fork, South Fork to Deadwood River, North Fork and tributaries from Banks to Cascade Dam, North Fork from Payette Lake to headwaters, Lake Fork Creek and tributaries to Browns Pond, Middle Fork upstream from Silver Creek, Deadwood River to Dam, South Fork above Helende, Bull Trout Lake

Boise: Boise River from Eagle Road to Eagle Island, Boise River from North Fork to Atlanta, Boise River and tributaries above Wilderness Boundary, South Fork from Arrowrock Reservoir to Anderson Ranch Dam, Big and Little Smokey creeks and other tributaries to South Fork Boise above Anderson Ranch Reservoir, North Fork to Rabbit Creek and above Hunter Creek to headwaters

Bruneau: North Fork Owyhee River and tributaries; Deep, Battle, and Blue creeks and tributaries; Bruneau River and tributaries from diversion Dam to West Fork; West Fork and tributaries, Jarbidge River and tributaries

Snake River above Shoshone Falls: Devils Corral and Vinyard creeks; Snake River from Eagle Rock to American Falls Dam, Rock Creek and triutaries, Snake River from American Falls Dam to South Fork, entire South Fork and tributaries; Portneuf River from American Falls Reservoir to Chesterfield Reservoir; Rapid, Toponce, and Pebble creeks; entire Blackfoot River drainage above lower Diversion Dam except

[1]Source: IDFG 1991; and, Personal communication. 1995. B. Horton, Idaho Department of Fish and Game, Boise, ID.

Dike Lake; Willow Creek and tributaries above Ririe Reservoir; entire Henrys Fork Snake drainage except Island Park Reservoir, Sand Creek WMA, and lakes; entire Teton River drainage except lakes

Wood: Big Wood River to I-84, Big Wood River from Glendale to North Fork, Little Wood River through Bear Track Williams State Park and upstream from Little Wood Reservoir, Silver Creek and tributaries

Salmon Falls: Shoshone Creek and tributaries upstream from and including Big Creek, upper Goose and Big Cottonwood creeks, Tributaries to Sublett Reservoir

Sinks Drainages: Big Lost River from Moore Diversion to Mackay Dam and from Chilly bridge to West Fork, Little Lost River and tributaries, Medicine Lodge Creek and tributaries, Camas Creek and tributaries above the National Wildlife Refuge, Beaver Creek and tributaries

Idaho—Waters managed by the Shoshone-Bannock Tribes[2]

Snake River above Shoshone Falls: tributaries and springs to American Falls Reservoir including Spring, Clear, Jeff Cabin and Diggie creeks; Portneuf River upstream from Chesterfield Reservoir and downstream from Siphon

Montana[3]

Clark Fork: Bitterroot River from Tucker Crossing to Florence and from 1.6 km below Darby to Como Bridge, East Fork Bitterroot River to Marten Creek, West Fork Bitterroot River to Painted Rocks Reservoir; Blackfoot River and tributaries; Clark Fork River from Anaconda settling ponds to Perkins Lane Bridge; entire Rock Creek; Georgetown, Lower, Middle, and Upper Thompson lakes

Flathead: Flathead, Little Bitterroot, Mary Ronan, and Notellum lakes; entire Flathead River; entire Middle and North forks Flathead River; South Fork Flathead River from Meadow Creek to Spotted Bear bridges; Swan Lake; Swan River from Piper Creek Bridge to Swan Lake

Kootenai: Kootenai River from Libby Dam to Kootenai Falls and From Libby Dam to Hyw. 37 Bridge

Nevada[4]

Nevada has no special regulation salmonid waters in the CRB

Oregon[5]

Deschutes: Metolius River, Deschutes River from mouth to Pelton Dam and above Crane Prairie; Crooked River below Bowman Dam and Deep Creek; Billy Chinook, Hosmer, East, Paulina, Fall, and Big Lava lakes; Crane Prairie and Wickiup Reservoirs

Hood: Hood River

Klamath: Upper Klamath, Blue, and Agency lakes; Klamath River

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[2]Source: Personal communication. 1995. C. Colter, Shoshone-Bannock Tribal Fish Biologist, Fort Hall, Idaho.

[3]Source: Personal communication. 1995. J. Vashro, Montana Department of Fish, Wildlife, and Parks, Kalispell, MT.

[4]Source: Personal communication. 1995. G. Johnson, Nevada Department of Wildlife, Elko, NV.

[5]Source: Personal communication. 1995. D. Hohler, Deshutes National Forest, Bend, OR; and D. Nolte, Trout Unlimited Oregon.

Malheur-Harney: Mann Lake, Upper Malheur River and North Fork; Chickahominy Reservoir

John Day: John Day River

Snake: South Fork Burnt River, Grande Ronde River, Imnaha River, Lakes in the Eagle Cap Wilderness

Other: Blitzen River, Trout Creek (Alvord Basin); Ana River (Summer Basin); Willow Creek

Washington[6]

Lower Columbia River below Snake River: Klikitat River, White Salmon River

Mid Columbia River from Snake River to Okanogan River: Entiat River, Wenatchee River, Icicle Creek, Methow River, Twisp River, Chelan River, Stehekin River, Chelan Lake and tributaries, Okanogan River, Similkameen River, Chewuch River

Yakima: Yakima River above Rosa Dam, Bumping River, Naches River, Leech Lake

Lost: Lost River

Upper Columbia River above Okanogan River: Kettle River, Spokane River, Colville River, Calispell Creek

Snake: Asotin River, Grande Ronde River

Other: Lenore and Bayley lakes

Wyoming[7]

Salt: Salt River from Afton to Thane

Greys: Greys River from Murphy to Corral, Stump and Barstow lakes

Gros Ventre: Gros Ventre River within the upper Gros Ventre Wilderness

Snake: Snake River from Jackson Lake to Wilson, Flat Creek within the National Elk Refuge, Green and Jackson lakes, Lake in the Woods, Grassy Lake Reservoir

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[6]Source: Personal communication. 1995. D. Fletcher, Washington Department of Wildlife, Olympia, WA.

[7]Source: Personal communication. 1995. R. Huddelson, Wyoming Game and Fish Department, Jackson, WY.

APPENDIX 4G

Historical Ranges Defined for Rare and Sensitive Fishes Within the Basin

Our estimates of the historic ranges of the rare and sensitive species were based on known historic distributions in published literature, available historic accounts, and speculative distributions based on personal interviews, expanded to include any occurrences in the status survey that were not included in the historic distributions.

White Sturgeon

Data sources include Brannon and Setter (1991) and Apperson and Anders (1991). In the Basin white sturgeon were known to exist historically in the Snake River from the mouth to Shoshone Falls. Historic photos demonstrate that white sturgeon occurred in the Salmon River upstream to at least the town of Salmon.[1] It is possible that the species was anadromous in much of the Basin before the construction of many dams on the Snake River. Kootenai Falls was a natural barrier to the upstream migration of white sturgeon above Kootenai Lake on the Kootenai/Kootenay River.

Klamath River Lamprey

Data sources are Vladykov and Kott (1979), and Moyle and others (1989). The Klamath River lamprey occurs in the Klamath River and Upper Klamath Lake in Oregon and California.

River Lamprey

The data source is Kan (1975). In the Columbia River, the river lamprey has been reported from the Bonneville Dam and locations downstream.

Pacific Lamprey

Pacific lamprey were believed to have migrated into all waters that supported anadromous fish. Kan (1975) stated that the primary consideration for occurrence of lamprey was access rather than distance from the ocean. The best records are available for Clearwater, Salmon, and Snake rivers. Their distribution in these systems lends support to the probability that lamprey were also found in the other accessible Snake River tributaries in Idaho. Anecdotal information suggests they were found in the Weiser[2] and Bruneau[3] rivers. No definitive records or collections were found for the Boise, Owyhee, or Payette river basins. Wallace and Ball (1978) documented landlocked lamprey that became parasitic above Dworshak Dam and Beamish (1980) similarly reported freshwater feeding. Beamish and Northcote (1989), however, reported that landlocked forms stopped attacking fish about seven years after dam construction and a transition to a freshwater form did not occur. As a result, Pacific lamprey are most likely extinct in landlocked areas that historically supported lamprey. Information for Oregon was compiled by P. Howell of

[1]Personal Communication. 1995. R. Thurow, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Boise, ID.

[2]Personal communication. 1995. R. Wallace, University of Idaho, Moscow, ID.

[3]Personal communication. 1995. B. Parker, Columbia River Intertribal Fish Commission, Portland, OR.

the Deschutes National Forest in Ukiah, Oregon and includes Fulton (1968, 1970), ODFW unpublished data, personal communications with various biologists, Howell and others (1985), Bakke and Felstner (1990). Information for Washington was compiled by K. MacDonald, Wenatchee National Forest, Wenatchee, Washington. Other sources include Schoning (1947), Scott and Crossman (1973), Simpson and Wallace (1978), and IDAFS (1995).

Goose Lake Lamprey

Data sources include Moyle and others (1989) and Long and Bond (1979). The Goose Lake Lamprey is unique to the Goose Lake Basin, having been isolated during the early Pleistocene from the Pacific Lamprey, of which it is a subspecies.

Pit-Klamath Brook Lamprey

Data sources are Hubbs (1971) and Kan (1975). The species is reported from the North Fork Pit River, Pit River, Fall River, and Hat Creek, in California, the Sprague, North Fork Sprague, Sycan, and Williamson rivers, and Crooked and Meryl creeks in Oregon.

Sockeye Salmon

The 10 major watersheds and 23 lakes identified as part of the historic range for this species were based primarily on Fulton 1970, Wydoski and Whitney 1979, and Waples and others 1991a. Loon and Warm lakes within the South Fork Salmon River support what are believed to be native kokanee with anecdotal accounts of anadromous adults in those drainages[4] and are included but recognized as speculative. The Wilderness Society shows the Klamath basin as historic range for this species, while other speculate that the range may have extended to the Klamath or further south (Burgner 1991; Wydoski and Whitney 1979). We could find no evidence that sockeye ever occurred in the Klamath basin and several biologists experienced in the zoogeography of that basin were confident that they did not.[5] We therefore excluded the Klamath from the historic range.

Chum Salmon

Data sources are Fulton (1970) Nehlsen and others (1991). Chum salmon were distributed in the lower portions of lower tributaries upstream to the Umatilla River in Oregon and the Walla Walla River in Washington (Nehlsen and others 1991). Former spawning areas above Bonneville Dam included lower portions of the Little White Salmon River, Hamilton, Rock, and Herman Creeks, and areas along the margin of river banks in the main Columbia River (Fulton 1970).

Coho Salmon

Historic distribution are based on information listed in Howell and others (1984), Fulton (1970), Schoning (1947), Lane and Nash (1981), Parkhurst (1950), and Richards (1967). Personal communications with B. House, Bureau of Land Management, Boise, Idaho; Chuck Huntington, Clearwater Biostudies, Inc., Portland, Oregon; Monte Richards, retired, and Stacy Gebhards, retired, Idaho Department of Fish and Game, Boise, Idaho; Bob Schoning, retired, Bureau of Fisheries, Corvallis, Oregon

[4]Personal communication. 1995. D. Anderson, Idaho Department of Fish and Game, McCall, ID.

[5]Personal communication. 1995. J. Williams, Bureau of Land Management, Boise, ID.

further defined historic ranges from historic records or anecdotal accounts. Personal communication between B. House, Bureau of Land Management, Boise, Idaho and Chris Frissell, University of Montana, Missoula regarding the wider historical distribution of coho salmon shown on Wilderness Society maps, assembled by Frissell, revealed that distribution was based on the assumption that coho salmon distribution overlapped to a great degree with spring chinook salmon distribution. Communications with Richards and Gebhards and the historical review of chinook salmon distributions strongly discount the occurrence of coho as a late spawning salmon in the Snake River above Hells Canyon.

Coastal Cutthroat Trout

Data sources include Behnke (1979a) and Nehlsen and others (1991). Within the Basin, coastal cutthroat trout occurred in Oregon to Fifteenmile Creek and in Washington to Rock Creek, including the Willamette River basin to its headwaters. The distribution also included populations in the Wind and Klickitat rivers of Washington, which are now extinct.

Lahontan Cutthroat Trout

Data sources include the USFWS (1993a, 1993b). Historically, Lahontan cutthroat trout were widespread throughout the basins of the Pleistocene Lake Lahontan.

Pygmy Whitefish

Data sources include Brown (1971), Draft System Operation Overview (1994), and Simpson and Wallace (1978). The historic distribution includes lakes of known current distribution, with no documented reports below Grand Coulee Dam on the Columbia River. During the last ice age, this species may have been widely distributed across North America. However, receding of glaciers most likely left the species as isolated populations (Wydoski and Whitney 1979).

Burbot

Data sources include IDAFS (1995) and the Idaho Conservation Data Center (1994). In Idaho, the Burbot historic range is limited to the Kootenai River drainage. Currently we have no information on other states within the Columbia River Basin.

Sand Roller

Data sources include Reimers (1963), Gray and Dauble (1979), Lee and others (1980), Simpson and Wallace (1982), Wydoski and Whitney (1979), and Pratt and Whitt (1952). The known historic distribution was limited, but occupation of the Columbia River is documented from Horseshoe Island Slough upstream to West Bar (south of Wenatchee), as well as in the lower Clearwater River in Idaho. Other rivers included the Yakima, Umatilla, Walla Walla and Willamette. Their complete historic distribution has not been documented, and their seclusive behavior during daylight hours suggests that the sand roller could have populations which had not been detected.

Pit Roach (California Roach)

The Pit Roach is the only subspecies of the California Roach known to occur in Oregon waters. The Pit Roach is in the upper Pit River system and the tributaries to Goose lake, which last overflowed into the Pit River in 1881 (Moyle 1976; Phillips and Van Denburgh 1971). Only their present distribution is listed here as historic information is virtually unknown.

Alvord Chub

The data source is Hubbs and Miller (1972). The Alvord chub was described in 1972 based on specimens collected from Trout Creek in the Alvord Basin, Oregon. The species is restricted to the Alvord Basin of southeastern Oregon and northwestern Nevada, but occurs rather widely within springs, creeks, and lakes of this area.

Borax Lake Chub

Data sources include Hubbs and Miller (1972), and Williams and Bond (1980). This species is known only from Borax Lake and associated waters in Harney County, Oregon. The Borax Lake Chub is closely related to the Alvord chub from which it became isolated as the waters of the pluvial Lake Alvord receded.

Catlow Tui Chub

Data sources include ODFW (1992), and Kunkel (1976). The Catlow tui chub was limited to the Catlow Valley in south-central Oregon, being found in Threemile, Skull, Home and Rock creeks which flow into the Catlow Valley.

Oregon Lakes Tui Chub

Data sources are Synder (1908) and Bills (1977). The Oregon Lakes tui chub is endemic to the Abert Lake Basin of south-central Oregon.

Summer Basin Tui Chub

Data sources are Synder (1908) and Bills (1977). Summer Basin tui chubs occurred at various localities within the Summer Lake Basin, including springs at the Summer Lake Post Office, Ana River, and source springs of the Ana River.

Sheldon Tui Chub

The data source is Williams and Bond (1981). The Sheldon tui chub is restricted to isolated waters of the Guano Basin of southeastern Oregon and northwestern Nevada.

Hutton Tui Chub

Sources include Bills (1977). This species has only been found in the two surface flow areas of Hutton Spring. These areas have very limited quantities of water. Hutton tui chub are believed to have been collected from the area as early as 1908.

Leatherside Chub

The data source is IDAFS (1995). Some have questioned whether this chub was historically found in Idaho or transplanted as a bait minnow so these distributions must be considered highly speculative. The areas listed represent confirmed (tributaries to the Raft, Goose, and upper Snake rivers and the Little Wood River) and unconfirmed (the Blackfoot, Big Wood, and Bruneau rivers and the Snake River near Payette).

Foskett Speckled Dace

The data source is Bond (1974). The Foskett speckled dace historically occurred only at Foskett Spring, located along the west side of Coleman Lake bed in Lake County, Oregon.

Jenny Creek Sucker

Data sources include Hohler (1981), J. Rossa,[6] U.S.Fish and Wildlife Service as reported in the USFWS Jenny Creek Sucker status report. The Jenny Creek sucker is a dwarf form of the Klamath smallscale sucker which has not yet been given official subspecific identification. It is morphologically different and reproductively isolated from the Klamath smallscale sucker by a series of three 30-foot high rock waterfalls. Current information reports that distribution is limited to the 26 miles of Jenny Creek and four of its tributaries, and those watersheds listed above. These are the only possible historical watersheds within the Basin. All occur just outside the assessment area.

Lost River Sucker

Sources include Andreasen (1975) and USFWS (1993b). In the Columbia River basin, large sucker populations were supported by the Upper Klamath and Agency lakes, and most associated tributaries. Historical occurrences were also documented in the mainstem of the Williamson and Sprague rivers. Sucker spawning likely occurred in the tributaries of these rivers as well,[7] but these watersheds are not included here due to speculation.

Warner Sucker

Data sources include Williams and others (1990), Andreason (1975), and Coombs and others (1979). This sucker was once common throughout the Warner Basin, with residents reporting having seen large runs of Warner suckers.

Goose Lake Sucker

The Goose Lake sucker is endemic to the Goose Lake Basin or south-central Oregon and northeastern California. Currently it is found in the lake and most of the tributaries, so much of the subbasin is included.

Shortnose Sucker

Data sources include Moyle and others (1989) and USFWS (1993b). The shortnose sucker is endemic to the Upper Klamath Basin of Oregon and California, known to be historically abundant within its range. Documented distributions include Upper Klamath Lake and its tributaries and Clear Lake, indicating that the sucker is native to the Lost River system. Spawning habitat potentially included any tributary to Upper Klamath and Agency lakes, which would include the Williamson and Sprague rivers, not listed here.

---

[6]Personal communication. 1995. J. Rossa, U.S. Fish and Wildlife Service, Klamath Falls, OR.

[7]Personal communication. 1995. T. Noel, U.S. Forest Service, Pacific Northwest Research Station, Corvallis, OR.

Klamath Largescale Sucker

Sources include Ford and Thomas (1993). In the Columbia River Basin, large sucker populations were present in the Upper Klamath and Agency lakes, and most associated tributaries. Historical occurrences were also documented in the mainstem of the Williamson and Sprague rivers. Sucker spawning likely occurred in the tributaries of these rivers as well (see previous footnote), but these watersheds are not included here due to speculation.

Torrent Sculpin

Data sources include Scott and Crossman (1973), Maughan (1976), Wydoski and Whitney (1979), Northcote (1954), Wallace (1980), Simpson and Wallace (1982), Page and Burr (1991), Robins and others (1991), Reimers and Bond (1967) and Eddy and Underhill (1978) as listed by IDAFS (1995). In the watersheds where specific historic occurrence was unclear the range included all of the appropriate subbasin because torrent sculpin have been found to be widely distributed within their current range.

Shorthead Sculpin

Data sources include Bailey and Bond (1963), Reimers and Bond (1967), McPhail (1967), Maughan (1976), Maughan and Saul (1979), Wydoski and Whitney (1979), Hughes and Peden (1984), Bilby and Bisson (1992), Wallace (1982), Scott and Crossman (1973), Cannamela and Gasser (1978), Johnson and others (1983), Arthur and others (1984), Reynolds and others (1986), Simpson and Wallace (1982), and IDAFS (1995). The Shorthead sculpin has been collected from many watersheds in the Basin and has been shown to occur in the upper reaches and tributaries of large river systems. They also have been found in the sinks of the Arco desert.

Pit Sculpin

Data sources include Moyle (1976), and Long and Bond (1979). Although the Pit sculpin was widely distributed throughout the Pit River system (from the Goose Lake Basin to the Sacramento River), its occurrence in the Goose Lake Basin on the Oregon side only included a few tributaries, such as Cottonwood, Drews, and Thomas creeks (Long and Bond 1979). The sculpin has never been found in the lake itself, although it is unknown how widely distributed it was in the Goose Lake Basin historically.

Slender Sculpin

Data sources include Ford and Thomas (1993). Historical distribution was restricted to the Upper Klamath Basin above Klamath Falls. This included Upper Klamath and Agency lakes, and tributaries, and parts of the Williamson and Sprague rivers.

Margined Sculpin

Data from Lonzarich (1993) produced current distribution, listed here. Historical distribution data are lacking. Some historical records are available, but are unreliable due to the sculpin's similar morphology and overlapping distribution with *C. beldingi*.

Wood River Sculpin

Data sources include IDAFS (1995) and the Idaho Conservation Data Center (1994). The suggested historic range includes all permanent connecting waters from the Malad River falls at I-84 upstream into the Little Wood and Big Wood rivers and all connecting tributaries. The Wood River sculpin was probably the only species of sculpin present historically, in 1992 the Piute sculpin *C. beldingi* was collected in Silver Creek.

Shoshone Sculpin

The data source is IDAFS (1995). This sculpin's range was limited to canyon wall springs along the Snake River between Kanaka Rapids and Bliss, Idaho. They are only found where spring water excludes Snake River water.

Malhuer Sculpin

Data sources include Bailey and Bond (1963), Bisson and Bond (1971), and Bond (1974). The Malhuer sculpin is endemic to streams in the Harney Basin including the Silvies, Silver, and Blitzen river systems. Historic data suggest broad distribution throughout this restricted range.

Continue

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CHAPTER 5

Terrestrial Ecology Assessment



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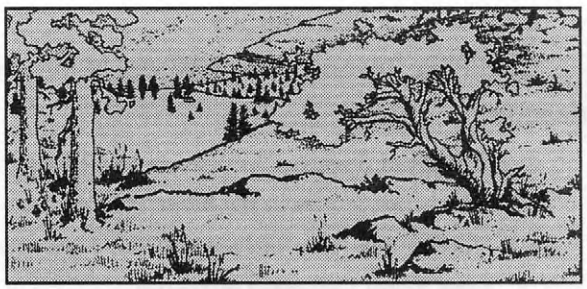
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TABLE OF CONTENTS



Introduction 1507

Plants and Allies Considered in this Assessment 1511

Invertebrates Considered in this Assessment 1512

Vertebrates Considered in this Assessment 1513

Methods 1515

Collecting Existing Information 1515

Problems and Opportunities of "Combining Information" 1516

Using Expert Panels 1516

Confidence in Knowledge of Species 1517

Methods Specific to Plants and Allies 1519

Lichens 1519

Bryophytes 1519

Vascular Plants 1519

Plant Species of Tribal Concern 1521

CRBFLORA Database 1521

Methods Specific to Invertebrates 1521

Methods Specific to Vertebrates 1522

Ungulates, Neotropical Migratory Birds, and Carnivores 1523

Threatened, Endangered, and Candidate Species 1523

Shifts in Habitat Area for Vertebrate Species 1523

Modeling of Mid-scale Habitat Patch Trends 1524

Building Data and Models of Species-environment Relations 1527

Assessment of Endemism, Biodiversity, and the Role of Natural Areas 1529

Biodiversity Estimates 1529

Centers of Endemism and High Biodiversity 1529

Natural Areas 1530

Assessment of Biogeography 1530
Identifying Research, Inventory, and Monitoring Needs 1530
Results 1531
Assessment of Species Occurrence and Listing Status 1531
Number of Species in the Basin 1531
Number of Species Included in This Assessment 1532
Legal Status Categories of Species 1533
Influences on Biodiversity 1533
Plants and Allies 1535
Fungi 1535
Kinds of Fungi and Their Relation to Fire, Dung, and Host Plants 1535
Fungi Conservation 1535
Lichens 1536
Forest Lichens 1536
Rangeland Lichens 1536
Bryophytes 1537
Ecological Groups of Bryophytes 1538
Rare or Sensitive Bryophyte Species 1541
Vascular Plants 1542
Rare Plant Communities 1543
Plant Species of Concern to Tribes 1543
Ex Situ and *In Situ* Conservation of Rare Plants 1550
Invertebrates 1550
Unique or Representative Habitats 1554
Functional Roles of Invertebrates 1554
Detritivory and Nutrient Cycling 1554
Wood decomposition 1556
Herbivory functions of snails and slugs 1556
Predation 1556
Pollination 1559
Grassland herbivory 1560
Forest Herbivory 1561
Implications of Managment Practices on Invertebrates 1563
Habitat composition and structures 1563
Soil structure and soil chemistry 1564

Exotic Organisms 1564
Implications for Invertebrates Associated with Detritivory and Nutrient Cycling 1564
Implications for Arthropod Predators 1565
Implications for Bees 1566
Implications for Grassland Herbivores 1567
Implications for Forest Herbivores 1568
Vertebrates 1568
Amphibians 1568
Reptiles 1569
Birds 1570
Neotropical Migrant Birds 1570
Mammals 1571
Small Mammals 1571
Bats 1571
Carnivores 1572
Ungulates 1573
Threatened, Endangered and Candidate Species 1575
Endangered Vertebrate Species 1575
Threatened Vertebrate Species 1578
Species of Tribal Interest 1579
Areas Containing Populations of Large, Wide-Ranging Carnivores 1579
Implications of Management Activities on Terrestrial Vertebrates 1581
Amphibians 1582
Reptiles 1582
Mammals and Birds 1583
Trends in Vegetation Cover Types and Structural Stages 1585
Shifts in Habitat Area for Vertebrate Species 1585
Implications of Broad-Scale Vegetation Changes for Species Using Native Grasslands 1586
Implications of Broad-scale Vegetation Changes for Species Using Native Shrublands 1588
Implications of Broad-scale Vegetation Changes for Species Using Old Forests 1588
Discussion of Rankings and Habitat Fragmentation 1589
Modeling of Mid-scale Habitat Patch Trends 1590
Forest Mid-to-Old Structural Stages 1590
Old Forest 1590

General Species Trends 1590
Species Associated with Forest Canopy Conditions 1591
Species Associated with Mistletoe Brooms 1600
Species Associated with Dead Parts Of Live Trees 1600
Species Associated with Trees With Exfoliating Bark 1600
Species Associated with Snags, Including Cavity-users 1600
Species Associated with Down Wood 1600
Species Associated with Litter And Duff 1601
Species Associated with Fire Processes And Insect Outbreaks 1601
Species associated with Recreation Activities, Roads, and Trails 1601
Key Ecological Functions of Species 1608
Major Biomass 1608
Herbivory 1608
Nutrient Cycling 1609
Interspecies Relations 1610
Soil Productivity 1613
Wood Decomposition 1614
Bioindicators of Water Quality 1614
Identifying Keystone Species 1614
Use of Ecologically Functional Equivalents 1615
Endemism, Biodiversity, and Natural Areas 1615
Natural Areas Characterization 1626
Biogeography 1627
Landforms 1627
Disjunct Distributions 1627
Local Endemics 1628
Other Patterns Of Endemism And Distribution 1628
Conclusions and Interpretations 1643
Major Findings 1644
Biological Diversity 1644
Species at Risk 1644
Species and Habitat Trends 1645
Implications for Ecosystem Management 1646
Research Information Needs 1648

Basic Systematics of Major Species Groups 1648
Monitoring for Population Status of Species and Health of Ecosystems 1648
Plants and Allies 1649
Fungi 1649
Lichens 1649
Bryophytes 1650
Vascular Plants 1651
Invertebrates 1652
Microorganisms 1652
Predators 1652
Pollinators 1652
Grassland Herbivores 1653
Forest Herbivores 1653
Research and Monitoring Priorities for All Invertebrate Groups 1654
Vertebrates 1655
Amphibians 1655
Reptiles 1656
Neotropical Migratory Birds 1656
Other Birds 1656
Bats 1656
Carnivores 1656
Other Mammals 1656
Caveats 1656
Acknowledgments 1659
References 1661
Glossary 1675
Appendix 5A–Disposition of species groups 1677
Appendix 5B–Contract and internal reports 1678
Appendix 5C–Experts consulted for information on species ecology 1682
Appendix 5D–Taxa with five or fewer occurrences 1687
Appendix 5E–Neotropical migratory landbirds 1703
Appendix 5F–Key environmental correlates 1704
Appendix 5G–Key ecological functions 1710
Appendix 5H–Locally or regionally endemic vertebrates 1713

LIST OF TABLES

Table 5.1	Assessment elements and questions addressed in the terrestrial ecology analysis of the Basin.	1508
Table 5.2	A list of species taxonomic groups occurring within the assessment area and how they were addressed in the assessment. Species taxonomic groups are listed here as occurring in terrestrial environments or aquatic/riparian environments.	1508
Table 5.3	Counts or estimates of total species biota of the Basin, with numbers considered individually in this assessment and numbers in the terrestrial Species-Environment Relations (SER) database from this project.	1510
Table 5.4	The staggering global diversity of organisms. Invertebrates play a major role in biodiversity.	1512
Table 5.5	Lichen functional groups by function and major substrate type.	1520
Table 5.6	Primary habitat, home range, and landscape use classes used to group vertebrates for habitat pattern analysis of mid-scale watersheds in the Basin.	1526
Table 5.7	Preliminary groups of mosaic vertebrate species identified for habitat pattern analysis of mid-scale watersheds in the Basin.	1527
Table 5.8	Numbers of taxa (species, subspecies, fish stocks) by Federal listing status, extirpated, and of special interest to American Indian tribes.	1529
Table 5.9	Plant species analyzed individually in the Terrestrial Ecology chapter, their U.S. Fish and Wildlife Service candidate status and their geographic distribution category.	1544
Table 5.10	A list of 205 plant taxa found by the Science Integration Team to be of particular interest to Native American tribes within the Basin.	1548
Table 5.11	Rare and endemic invertebrate species	1551
Table 5.12	Threatened (T), endangered (E), and candidate (C1 and C2) vertebrate species of the Basin.	1576
Table 5.13	Past and current habitat area for vertebrates closely associated with mid- to late-seral (old forest) structural stages of forest development in the Basin.	1592
Table 5.14	Past and current habitat area for vertebrates closely associated with old forest structural stages of forest development in the Basin.	1594
Table 5.15	Plant species associated with various aspects of fire dynamics.	1602
Table 5.16	A simple classification of ecological subsystems found in the Basin.	1609
Table 5.17	Hot spots of species rarity and endemism	1619
Table 5.18	Hot spots of species biodiversity	1621
Table 5.19	Unique vertebrate assemblages found in various Ecological Reporting Units (ERUs) within the Basin.	1639

LIST OF FIGURES

Figure 5.1 Degree of confidence of panelists in the level of scientific knowledge about taxa addressed in the expert panels, expressed as the proportion of taxa with each confidence level calculated for plants, invertebrates, and vertebrates. 1518

Figure 5.2 Species influence diagram. 1528

Figure 5.3 Trends in primary habitat change for vertebrates since the early 1800s in the Basin. 1585

Figure 5.4 Trends in primary habitat change for vertebrates since the early 1800s in ecological reporting units (ERUs) within the Basin. 1587

Figure 5.5 Distribution of versatility scores for species associated with grassland and herbland structure. 1588

Figure 5.6 Distribution of versatility scores for species associated with range shrubland structure. 1588

Figure 5.7 Distribution of versatility scores for species associated with old-forest structure. 1589

Figure 5.8 Cumulative percentages of vertebrate species by home range area, as compared with cumulative percentages of natural areas by size. 1626

Figure 5.9 Numbers of endemic taxa of plants and allies by endemism category, and taxonomic or species group. 1637

Figure 5.10 Numbers of endemic taxa of vertebrates by endemism category and taxonomic class. 1638

Figure 5.11 Schematic for a Bayesian belief model of species-environment relations. 1658

LIST OF MAPS

Map 5.1a Ranges of two locally endemic subspecies on the edges of their parent species' ranges: Potholes meadow vole *(Microtus pennsylvanicus kincaidi)* and its parent species, meadow vole (*M. pennsylvanicus*). 1596

Map 5.1b Ranges of two locally endemic subspecies on the edges of their parent species' ranges: White Salmon pocket gopher (*Thomomys talpoides limosus*) and its parent species, northern pocket gopher (*Thomomys talpoides*). 1597

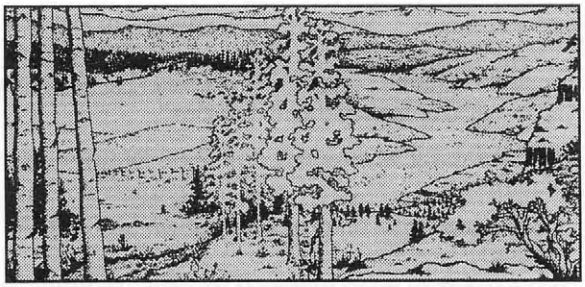
Map 5.2a Examples of vertebrate species with disjunct ranges within and adjacent to the interior Columbia River Basin Assessment Area: Woodhouse's toad, green frog and Northern bobwhite. 1598

Map 5.2b Examples of vertebrate species with disjunct ranges within and adjacent to the interior Columbia River Basin Assessment Area: California mountain kingsnake, ground snake and wild turkey. 1599

Map 5.3a Vertebrate species with key ecological function of herbivory: Meadow vole and Blacktailed jackrabbit. 1616

Map 5.3b Vertebrate species with key ecological function of herbivory: Greater white-fronted goose and Ross' goose. 1617

Map 5.4	Distribution of hot spots of species rarity and endemism and centers of biodiversity, with Ecological Reporting Units.	1624
Map 5.5	Distribution of centers of concentration of species rarity and endemism of plants and animals.	1625
Map 5.6	Distribution of carpenter ant (*Camponotus modoc*) over landforms.	1629
Map 5.7	Distribution of pronghorn (*Antilocapra americana*) over landforms.	1630
Map 5.8	Distribution of pronghorn (*Antilocapra americana*) over precipitation.	1631
Map 5.9a	Distribution of mountain goat (*Oreamnos americanus*) over elevation.	1632
Map 5.9b	Distribution of mountain goat (*Oreamnos americanus*) over precipitation.	1633
Map 5.9c	Distribution of mountain goat (*Oreamnos americanus*) over topographic relief.	1634
Map 5.10a	Examples of vertebrates that are locally endemic peripherally or within the interior Columbia River Basin Assessment Area: Coeur d'Alene Salamander, Idaho ground squirrel, Washington ground squirrel, Larch Mountain salamander, Oregon slender salamander.	1635
Map 5.10b	Examples of vertebrates that are locally endemic peripherally or within the interior Columbia River Basin Assessment Area: White Salmon pocket gopher, Idaho giant salamander.	1636



INTRODUCTION

The purpose of this chapter is to present an assessment of terrestrial (land-based) ecology of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) assessment area, also called the Basin.[1] We describe prehistoric, historic, and current conditions and trends in terrestrial habitats, environments, selected individual species, species groups, ecological communities, and terrestrial ecosystems. The purpose is to meet the objectives described by the ICBEMP Charter.

This chapter does not explicitly analyze viability of species, but much of the base ecological information provided herein is essential for subsequent analyses. Although inferring population viability from habitat conditions has been advanced by others (for example, Boyce and others 1994), additional factors of demography, population genetics, interspecies relations, and disturbance dynamics need to be considered.

In this chapter we address the following nine elements: (1) information that will be necessary to assess species viability under future scenarios or planning alternatives; (2) species rarity, endemism, and biodiversity; (3) biogeography; (4) the role of natural areas; (5) ecological functions of species; (6) species of interest to American Indian tribes; (7) federally listed threatened, endangered, and candidate species; (8) selected conservation issues including rangelands and old forests; and, (9) further information needs. Questions relating to these elements are shown in table 5.1.

This chapter addresses the following taxonomic groups (appendix 5A, table 5.2).

- Plants and allies: lichens, fungi, bryophytes (mosses and liverworts), vascular plants.
- Invertebrates: soil and general bacteria, soil and general protozoa, soil and general nematodes, soil and general rotifers, arthropods, mollusks.
- Vertebrates: amphibians, reptiles, birds, mammals.

Not every species of every taxonomic group was individually analyzed because of time and funding constraints and because little or no scientific research has been conducted on the vast majority of species in the assessment area (table 5.3). Entire taxonomic groups, particularly many invertebrates, still need even basic systematics research; many species remain undescribed. In this chapter, invertebrates, ranging from bacteria through arthropods and insects, are treated as functional species groups with selected individual species providing only individual examples. Among plants, all nonvascular

[1]The ICBEMP assessment area includes those portions of the Columbia River basin east of the crest of the Cascades and within the United States and those portions of the Klamath River basin and Great Basin in Oregon. This area is here referred to as the Basin.

Table 5.1— Assessment elements and questions addressed in the terrestrial ecology analysis of the Basin.

species viability — What are the historical and current status of species? In what ways are species susceptible to management activities?
species rarity, endemism, and biodiversity — Where are areas of species rarity, endemism, and high biodiversity?
biogeography — What major biophysical conditions account for the distribution of species or species groups?
conservation areas — What is the potential contribution to species persistence from various kinds of designated natural areas?
ecological functions — What are the ecological roles of species and species groups, and how do they influence productivity, diversity, and sustainability of ecosystems?
harvestability — How are species that are harvested or gathered by American Indian tribes distributed among environments?
threatened, endangered, and candidate species — What are the status and condition of environments and populations of threatened, endangered, and candidate species?
selected conservation issues — What are the ecological conditions of rangelands and old-growth forests?
information needs — What are the areas of scientific uncertainty, key assumptions, and inventory, monitoring, and research needs pertaining to terrestrial ecology?

Table 5.2— A list of species taxonomic groups occurring within the assessment area and how they were addressed in the assessment. Species taxonomic groups are listed here as occurring in terrestrial environments or aquatic/riparian environments. Most species taxonomic groups were assessed by either the Terrestrial Ecology Staff (TS) or the Aquatic/Riparian Staff (ARS) of the Science Integration Team. The TS assessments are included in this chapter. (n/a = not applicable; general = refers to broad taxonomic discussions rather than species-specific analyses). Literature cited in the last column refers to the contract reports listed in appendix 5B.

Species Group	Terrestrial Environment	Aquatic/Riparian Environment	Which are Included in this Terrestrial Ecology Assessment
		Plants and Allies	
Fungi	TS	TS	rare species are treated individually, as identified by Mike Castellano; also Ingham (1995)
Lichens	TS	TS	functional groups of species, as identified by Roger Rosentrettor
Bryophytes	TS	TS	functional groups of species, as identified by Christy and Harpel (1995)
Algae	TS (cryptogamic crusts only)	ARS (general)	covered in contract reports on cryptogamic crusts by Kaltenecker and Wicklow-Howard (1994), Williams (1994); also see Landscape Dynamics chapter
Vascular plants	TS (incl. terrestrial, emergent, and riparian)	ARS (by selected species, submergents, floating)	C1 & C2 candidate species treated individually; selected others by species lists or communities; as identified by Lisa Croft and the Plant Task Group

Table 5.2 (continued).

Species Group	Terrestrial Environment	Aquatic/Riparian Environment	Which are Included in this Terrestrial Ecology Assessment
Invertebrates and Microorganisms			
Bacteria	TS - soil & general	TS - general	general functional groups of soil bacteria, as identified in contract reports by Ingham (1995) and Muehlchen (1994)
Protozoa	TS - soil & general	[not covered]	general functional groups of soil protozoa, as identified in contract reports by Ingham (1995)
Nematodes	TS - soil & general	[not covered]	general functional groups of soil nematodes, as identified in contract reports by Ingham (1995)
Platyhelminths	[not covered]	[not covered]	[not covered]
Rotifers	TS - soil & general	[not covered]	general functional groups of soil rotifers, as identified in contract reports by Ingham (1995)
Arthropods	TS	ARS	single species as representatives or examples of functional groups of species, as identified by the expert panels and the Invertebrate Task Group Leaders Chris Niwa and Roger Sandquist
Mollusks	TS	ARS (listed, C1, C2, & general)	discussed in the contract report by Frest and Johannes (1995)
Other Invertebrates	TS - Oligochaeta	ARS - Hemiptera, Oligochaeta	single species as representatives or examples of functional groups of species, as identified by the expert panels and the Invertebrate Task Group Leaders Chris Niwa and Roger Sandquist
Vertebrates			
Fish	n/a	ARS	(see Aquatic Species and Habitats Chapter)
Amphibians	TS	TS	all species covered by Vertebrate Task Group leader Robert Naney
Reptiles	TS	TS	all species covered by Vertebrate Task Group leader Robert Naney
Birds	TS	TS	all species covered by Vertebrate Task Group leader Robert Naney
Mammals	TS	TS	all species covered by Vertebrate Task Group leader Robert Naney

Table 5.3— Counts or estimates of total species biota of the Basin, with numbers considered individually in this assessment and numbers in the terrestrial Species-Environment Relations (SER) database from this project. Fish are further addressed in the "Aquatic Species and Habitats" chapter. Figures are number of taxa (mostly species with a few subspecies of particular conservation concern); grp = species groups considered in addition to individual species; ? = no firm estimate; see text for discussion on bacteria, protozoa, nematode, and microfungi diversity. The final SER database includes lichens and bryophytes mostly in species groups, and does not include mollusks at this time. Viruses, algae, phytoplankton, zooplankton, and most aquatic arthropods are not included in this table. Fungi numbers here represent macrofungi.

Taxonomic Group	Total in Assessment Area		Number Considered in Terrestrial Assessment[1]	Number in SER Database
	--Known--	--Estimated--		
Plants & allies				
Fungi	3,000	9,000	3,000	394
Lichens	736	736	736 (39 grp)	2 (39 grp)
Bryophytes	811[2]	860	811 (11 grp)	0 (11 grp)
Vascular plants	8,250	8,350	8,078 [3]	280 (32 grp)
Total	**12,797**	**18,946**	**12,625 (50 grp)**	**676 (82 grp)**
Invertebrates				
Bacteria	?	?	0 (6 grp)	0 (6 grp)
Protozoa	?	?	0 (1 grp)	0 (1 grp)
Rotifers	?	?	0 (1 grp)	0 (1 grp)
Nematodes	?	?	0 (3 grp)	0 (3 grp)
Mollusks	380[4]	770[5]	380	0
Arthropods[6]	3,400	23,500	335	195
Total	**3,780**	**24,270**	**715 (11 grp)**	**195[7] (11 grp)**
Vertebrates				
Fish - natives	[87]	[87]	[87]	*see Aquatic Species*
Fish - exotics	[54]	[54]	[54]	*and Habitats chapter*
Amphibians	26	26	26	26
Reptiles	27	27	27	27
Birds	283	283	362 [8]	291
Mammals	132	132	132	132
Subtotal (excluding fish)	458	468	547	476
Total (including fish)	**609**	**609**	**688**	**476**
Total Among All Taxa (including fish)	**17,186**	**43,825**	**14,028 (61 grp)**	**1,347 (93 grp)**

[1]Numbers considered in this assessment and numbers in the SER database, include a few subspecies with legal status or special conservation concern.

[2]Christy and Harpel (1995).

[3]Includes 920 species listed in an ancillary Paradox database.

[4]The 380 known mollusks include 200 freshwater gastropods, 30 freshwater bivalves, 25 slugs, and 125 land snails (T. Frest, presentation 12 June 1995, American Malacological Union, Mollusk Conservation Symposium, Hilo, HI).

[5]The 770 suspected mollusks include 425 freshwater gastropods, 35 freshwater bivalves, 30 slugs, and 280 land snails (T. Frest, presentation 12 June 1995, American Malacological Union, Mollusk Conservation Symposium, Hilo, HI).

[6]Insects and other arthropods. Source: Personal communication. 1995. J. Lattin, Oregon State University.

[7]Individual invertebrate species and species groups, provided as examples of a much larger biota.

[8]Birds not included in the SER database include accidental and casual species.

and vascular species currently listed as a C1 or C2[2] candidate, as endangered, or as threatened under Section 7(C) of the Endangered Species Act of 1973 (PL 93-20, as amended) or those for which there is a conservation concern are assessed individually; the vast majority of all other species are treated in communities or not included individually in this assessment. Like most of the invertebrates, they await future research and the development of databases. Among vertebrates, all species of amphibians, reptiles, birds, and mammals are treated individually.

A wealth of information was gathered for this project; this chapter presents only a summary of results. The base information consists of several dozen contract reports (see appendix 5B); databases on species-environment relations; and plant, invertebrate, and vertebrate task group reports. This material is referenced as "background" material or material "on file" [Terrestrial Ecology Staff (TS) 1995][3], and is available as part of the science record for the Interior Columbia Basin Ecosystem Management Project.

These sources include a wealth of additional data tables and information. However, the empirical scientific information available on species taxonomic groups varied tremendously. This is reflected in the variation in the depth of information provided on each species group in the sections that follow. Whereas vertebrates have often been studied, even if only by superficial inventories, most invertebrates and many rare vascular plant distributions are not well known; also, many invertebrate groups are poorly known taxonomically. Considerations specific to each taxonomic group follow.

Plants and Allies Considered in this Assessment

Vascular plants are the most ubiquitous and taxonomically diverse macroorganisms in the Basin. As primary producers they are critical components in the maintenance of dynamic, functional ecosystems. Vascular plants and allies (fungi, lichens, and bryophytes) provide foods for animals, stabilize watershed functions, provide habitat and cover for numerous organisms, influence climatic patterns on local and regional scales, contribute to soil development and stabilization, have specialized relationships with pollinators and seed dispersers, and provide a variety of other critical ecological functions such as nitrogen fixation. In addition to these essential ecological functions, vascular plants and plant communities provide the foundation for the economic and social fabric of the Basin. Commercial resources critical to the Basin's economy, including timber, forage, and other special plant products, are provided by vascular plants. In addition, vascular plants are an important part of the cultural history of native peoples in the Pacific Northwest.

[2]This chapter reports on analyses conducted through October 1995. Since that time, USDI Fish and Wildlife Service has published a change in their species status program, essentially replacing the three candidate species categories with a single category of candidates for listing with a 1-year review period of this program change (U.S. Government 1996a). In this change, most of the species that were classified as Category 2 or 3, and 303 taxa that were Category 1 candidates, are no longer included in the list of candidate species. A number of plant and animal species addressed in this assessment were denoted as Candidate Category 1 or 2 when the data were gathered. Of those 131 Category 1 or 2 plants, four became Candidates in the Federal Register notice: *Castilleja christii*, *Erigeron basalticus*, *Sidalcea oregana* var. *calva*, and *Thelypodium howellii* spp. *spectabilis*. Of those 34 Category 2 animals (none had been designated Category 1 in the assessment area), only mountain plover (*Charadrius montanus*) and spotted frog (*Rana luteiventris*) were still designated as Candidates. All other plants and animals were dropped from the list of candidates. However, this assessment chapter retains the listings for two reasons: (1) our analyses and data collection preceded the ruling change; and (2) our charge was to address species' ecologies and conservation status, and the C2 status in particular still helps to denote species of potential conservation concern deserving attention in this charge.

[3]Terrestrial Ecology Staff (TS). 1995. Terrestrial ecology staff files. Unpublished material on file with: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 112 East Poplar Street, Walla Walla, WA 99362.

Table 5.4— The staggering global diversity of organisms. Invertebrates play a major role in biodiversity. Much of this pattern (although smaller numbers) can be expected in the Basin [Source: R. Sandquist].

Taxonomic Group	Number of Species Currently Described	Number Including Undiscovered Species
Plants and allies		
Algae	40,000	200,000 to 10 million
Fungi	70,000	1 to 1.5 million
Plants	250,000	300,000 to 500,000
Invertebrates		
Protozoans	40,000	100,000 to 200,000
Viruses	5,000	perhaps 500,000
Bacteria	4,000	400,000 to 3 million
Roundworms	15,000	500,000 to 1 million
Mollusks	70,000	200,000
Insects	950,000	8 to 100 million
Spiders and mites	75,000	750,000 to 1 million
Crustaceans	40,000	150,000
Vertebrates	45,000	50,000

Invertebrates Considered in this Assessment

Terrestrial invertebrates are the greatest source of biological diversity within the Basin. Globally, invertebrate species may number to more than 100 million and greatly outnumber the diversity of other taxa (table 5.4). Whereas vertebrates and plants are relatively well known (approximately 90% of the vertebrates and 50-80% of the plants are known specifically from the assessment area), only roughly 1 to 3 percent of the invertebrate taxa are known. However, invertebrates other than pest insects have received little consideration in prior planning efforts (Everett and others 1994; Gast and others 1991). Invertebrates occur in vast numbers (species and individuals) and occupy a tremendous number of niches with prodigious fecundity. Studying invertebrates provides many advantages for assessing ecosystem health (Samways 1993), since they function as easily monitored indicators of ecosystem health.

Ginsberg (1993) believes that invertebrates are appropriate study organisms for better understanding population ecology and ecosystem health because:

- Most global biodiversity consists of invertebrates. Insects and other invertebrates constitute the bulk of the biosphere faunal biomass.
- Invertebrates are important in the production and processing of energy and essential materials and in recycling and processing of nutrients in ecosystems.
- Invertebrates are ideal study organisms for research, assessment, or monitoring because of the short generation times and rapid population growth capabilities of many species.

- Short generation times and high reproductive potential make invertebrates excellent indicators and "early warning" organisms.
- Invertebrate populations play important roles in soil development; in pollination and fruit set of crops and wildland plants; as natural enemies of important pest species; as major food items (for example, shrimp, lobsters, crabs); and as agricultural and health pests.
- Invertebrates serve as vectors and reservoir hosts for diseases that have major impacts on the health of human populations.

Vertebrates Considered in this Assessment

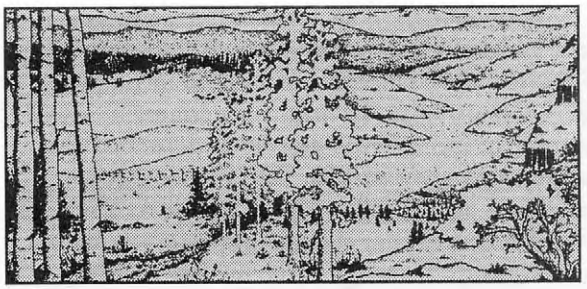
Vertebrate species within the Basin occupy widely diverse vegetative and environmental conditions ranging from deserts in south central Oregon to alpine conditions in the Rocky Mountains and Cascade Mountains. Many vertebrate species rely on invertebrate or other vertebrate abundance for prey, others represent the condition of aquatic systems, and some are indicators (presence or absence) of degraded environments. Vertebrates also play ecological roles in seed dispersal, herbivory, dead wood decomposition, disease transmission, and predation.

Some groups of vertebrates, such as birds and mammals, have been well studied and their taxonomy and distribution are known (Ceballos and Brown 1995). Other vertebrate groups including ungulates, neotropical migratory birds, and carnivores are of particular management or social interest; these are given greater focus in this assessment.

Many vertebrate species are important economically to local communities. The economic contribution of elk hunting within the Basin, for example, represents approximately $225,300,000 and 3,467 jobs (Teisl and Southwick 1995). Other big game species are also important to local communities for hunting and general recreation. Wildlife viewing and other "non-consumptive" uses of vertebrates contributed approximately $14.3 billion to the national economy in 1985 (USDI 1988). Others are economically important as agricultural pests.

Implementing regulations for the National Forest Management Act (36 CFR 219.19) state: "...maintain viable populations of existing native and desired non-native vertebrates in the planning area." Under the ICBEMP mandate, viability of each of these species is of regulatory interest to both the Forest Service and Bureau of Land Management.

Many vertebrates, including the northern spotted owl, the grizzly bear, and the gray wolf, have emotional appeal to many people. Some of these same species demand public interest because of concerns for their viability.



METHODS

Collecting Existing Information

The general approach to meeting the study elements entailed gathering existing information on the ecology of individual species, species assemblages, and ecological communities in the assessment area, and on developing computer models that describe species-environment relations. Two interesting dilemmas arose in this general approach. First, limited information was available from a wide variety of sources, including experts in panels and individual contract reports, scientific publications, agency management plans, and other sources; how could all this be meaningfully combined? Second, much of the existing information has not been formally published and resides in the files and heads of experts; how could this knowledge be gathered? To meet the first challenge we turned to various methods of combining information. To meet the second, we contracted for technical reports from species experts, and gathered information in panels of experts. It is imperative to note, however, that formalizing expert knowledge from panels of experts is not a substitute for open publication that has undergone peer review. Rather, knowledge gathered in this assessment could be used to create tentative working hypotheses that need explicit empirical testing and validation (for example, Doak and Mills 1994).

Collectively, the information we gathered on species-environment relations and the interpretations we made on possible trends of species and their ecological roles in the ecosystem constitute an ecological risk analysis (for example, Calabrese and Baldwin 1993; Norton and others 1988). We evaluated trends of potentially suitable environments of species from historic to current times, given the changes in vegetation cover types and structural stages and the occurrence of stochastic events such as wildfire. From this, we estimated the resultant likelihoods that populations of plants and animals have increased, declined, or not changed over that time, and how such changes might influence the ecosystems in which the species reside.

Important in combining information from disparate sources is depicting its quality. The most reliable species and community data for this assessment came from well-designed empirical field studies with ample sample sizes and time periods. Such studies are rare. Rather, most of the information we used in this assessment was gathered from unpublished (in scientific journals) or ongoing studies, or from expert judgment.

One kind of error that is inescapable when dealing with biological systems, particularly at the geographic extent and time durations addressed in this project, is that of natural variation of conditions. Although much of the data collection for this project seems deterministic (unvarying), it is collected and interpreted with the full understanding that ecosystems and populations are inherently inconstant.

Other kinds of errors are those of human judgment and understanding: uncertainty and ambiguity (see Cleaves 1994). Uncertainty refers to incompleteness of knowledge. To help us determine how well non-plant species' ecologies are understood, we asked each expert panelist (see Methods section on expert panels, following) to denote on a scale of 1 to 5 how well they thought a species was known scientifically. We assigned the median certainty level to each species, then tallied the number of species under each of the five certainty levels for each taxonomic group. We also explored the variation in certainty levels among panelists for a given species to measure within-species (among panelists) certainty variation. Ambiguity refers to differences in interpretation of direction and information among experts. We produced what we hoped was clear direction in contracts, and held standard pre-panel briefings so that all experts began from the same knowledge level of the project.

A final potential source of error is motivational bias. This occurs when someone is asked to provide information on value-laden categories or terms, rather than on more neutrally phrased terms. For example, a reply is more apt to highlight problems when the category is "threats causing extinction" than when it is "likely events that may affect populations." To help avoid errors associated with motivational bias, we strived to ensure a clinical, neutral tone in panel proceedings and other contacts with experts.

Problems and Opportunities of "Combining Information"

A new area of statistics has recently emerged which deals with the problem of making meaningful inferences from disparate sources of information. This area is dubbed "combining information" or CI (Draper and others 1992). We used several CI techniques. CI helped us to think hierarchically, such as by first denoting ecological attributes of individual species, and then searching for similar ecological functions among groups of species. When combining separate sources of judgmental information, process is important to allay bias and to ensure consistency in interpretation. Building tentative working hypotheses, such as on species fitness or viability or community productivity, is a plausible and useful approach even if the base information is taken from widely disparate sources. We used this approach.

Another arena that helped us develop our approach to gathering existing information is that of expert system programming. In a sense, much of the information we gathered is in the form of expert system rules. In our context, these "rules" are information bases that describe conditions suitable to meet the needs of individual species or species groups.

Using Expert Panels

To collect and combine expertise, we convened a total of 26 panels of leading species experts. Panelists were chosen individually for their expertise in specific taxonomic groups and geographic areas and collectively for their coverage of all groups and areas. Panelists chosen were recognized as the leading experts, or among the leading experts, in their fields. Often, as with invertebrates and plants and allies, the leading experts were essentially the *only* scientists conducting primary field research on the organisms of interest. The process we used generally followed that of two previous scientific assessments of biodiversity and species viability (FEMAT 1993; also see Kangas and others 1993; Thomas and others 1993). This was a modified Delphi process as follows. Panelists followed a standard protocol consisting of: individually providing information on species ecologies on standardized forms; discussing initial results to uncover overlooked or new information; and refining the final submitted information. This is a modification of the standard Delphi process in that discussions and final recording of information were not meant to achieve a group consensus, due to the mandates of the Federal Advisory Committee Act as interpreted by the Science Integration Team (SIT) and legal counsel. Also, retaining individual information allowed us to pool the

diversity of expertise among panelists and to poll their opinions of confidence levels of the scientific knowledge of each species. In the end, each panelist provided separate information, and we merged the panelists' contributions.

The panelists were asked to record key environmental correlates—those requirements that contribute to high realized fitness, and by inference, viability, of each species. The panelists also recorded key ecological functions of each species and their degree of confidence in the current scientific understanding of correlates and functions of each species. We deviated from the approaches of previous assessments (namely, FEMAT 1993, Thomas and others 1993) by having the panels provide information on basic ecology and species-environment relations, rather than a final judgment on species viability, effects of management scenarios, and planning alternatives. This change was made because (1) the EIS alternatives had not yet been formulated, (2) one purpose of the current exercise was to expose the ecological relations to help us interpret and project viability effects, (3) another purpose was to build an explicit information base on species-environment relations, which is lacking for the assessment area, and (4) we wished to avoid having to reconvene expert panels for every change in EIS alternatives. Information from the panelists and contractors helped us to build basic and explicit ecological databases, including range and distribution maps, from which we developed repeatable and explicit ecological risk analyses.

An advantage of this approach is that it helps reduce the potential problem of motivational bias. On the other hand, one disadvantage of the "modified" paneling approach is that it is more difficult (but not impossible) for many technical experts to explain how they think than it is for them to provide only a summary judgment on a condition (such as on potential species viability effects). Because of this, we peer-reviewed and revised the information.

Environmental "dependencies" are not listed in the resulting species information database *per se*. Rather, the aim of collecting expert knowledge was to list key factors influencing realized fitness of each species. For some panelists or experts this meant listing all environmental factors whether critical to maintaining populations or only incidentally used; for others, it meant listing only those that contributed to "core" populations (those with births exceeding deaths). This was quite difficult to quality-control during the panel and information-gathering process, as it meant different things to different panelists. This is one reason that the resulting information base must be viewed as a "first approximation" of species-environment relations and must be interpreted in light of local biological information and knowledge.

Confidence in Knowledge of Species

As part of the species data-collection process (modified Delphi panel process), we asked experts to rank their confidence in how complete scientific knowledge is for each individual species on a scale of 1 (low confidence) to 5 (high confidence). We clarified that scores of low confidence should correspond to few or no empirical scientific studies of the species within the Basin assessment area, whereas scores of high confidence should correspond to adequate studies for predicting population response to environmental conditions.

Different experts may have interpreted this scale in slightly different ways. Some ranked their own empirical experience, whereas others ranked the collective knowledge of the scientific community. However, in the final pass these two interpretations should be the same, as the best experts available were engaged on the panels.

Some general trends emerged. The median confidence levels (among panelists ranking the same species) on the whole were greater with plants (51% of species rated a median confidence rank of 4 or 5) than with vertebrates (37%), and greater with vertebrates than with invertebrates (23%) (fig. 5.1). The plants and plant groups included in this tally are the rarer species with Federal or proposed listing status, and may be those more intensely studied. This does not represent

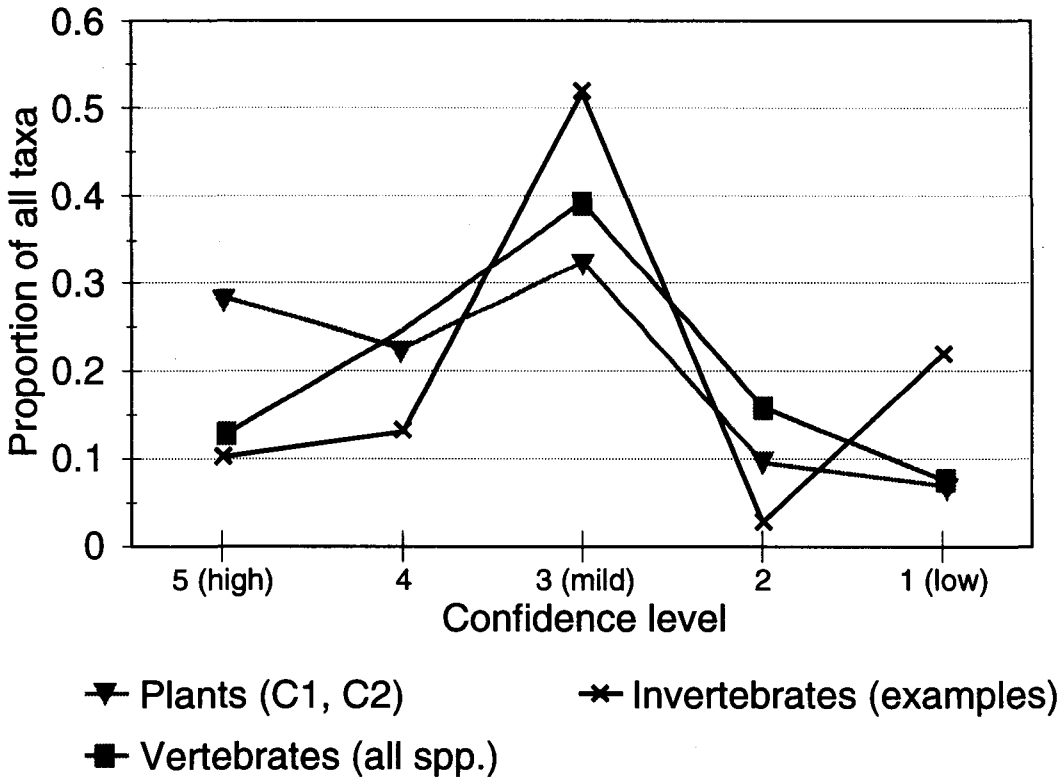


Figure 5.1— Degree of confidence of panelists in the level of scientific knowledge about taxa addressed in the expert panels, expressed as the proportion of taxa with each confidence level calculated for plants, invertebrates, and vertebrates. For example, scientific knowledge on about half of the invertebrate taxa was rated as level 3 (mid). These sums are based on medians of confidence levels as expressed by one or more expert or panelist. Thus, this is an expression of the variation of median confidence levels, among species within each taxonomic group.

knowledge levels of all plant species. Also significant is how poorly known the invertebrates are; twenty-two percent of the example species addressed were ranked as Confidence Level 1, as compared with 8 percent of the vertebrates and 7 percent of the plants. Overall, these median confidence ranks should be interpreted as denoting that few species' taxonomic groups have been completely studied, that further basic biological research is needed on many groups, and that conclusions drawn on a species' historic trend and current response to environmental conditions should be treated as management hypotheses to be tested.

Where more than one panelist provided information on a species, we calculated median confidence scores for each species among panelists. Where only one panelist provided information on individual species (often the case with lesser-known taxa including fungi, lichens, bryophytes, many rare plants, most invertebrates, and some amphibians and reptiles), we used that score. To compare overall confidence in knowledge among taxa, we plotted the confidence mean among species (as proportions) for each confidence level for each taxonomic group (plants and allies, invertebrates, and vertebrates).

The following sections describe general methods used to evaluate habitat trends and functions of plants, invertebrates, and vertebrates. Detailed accounts of methods and results are available in the contract reports (appendix 5B), and in on-file material.

Methods Specific to Plants and Allies

Lichens

We divided the 736 lichen species found within the assessment area into 40 functional groups based on their ecological relations (table 5.5). We grouped lichens into functional species groups rather than addressing individual species both because of the large number of species and to emphasize their ecological functions. Functional species groups were then sorted into four major groups by the substrates upon which they occur: (1) dead organic matter, (2) corticate and decorticate wood, (3) rock, and (4) soil.

Bryophytes

We compiled a list of bryophyte species that are rare in the entire Basin, not just rare in individual states. Taxa considered rare in one state may be more common elsewhere in the study area, so our list differs from those of individual states. State Heritage Programs in Idaho, Montana, and Oregon have listed and are tracking occurrences of rare or sensitive bryophytes. A list for Washington is being compiled. The Bureau of Land Management, the Forest Service, and the Oregon Department of Agriculture have included some or all of these species on their lists of sensitive plants.

Vascular Plants

Vascular plant species addressed in this report include species that are currently listed under Section 7(C) of the Endangered Species Act of 1973 as threatened, endangered, or candidate (C1 or C2) species, along with additional species that could, according to the plant panelists, achieve potential candidate status (see footnote 2). Collectively, these species comprise vascular plants that are sensitive or of conservation concern to the panels. Because of time and budget constraints, other vascular plants were not specifically analyzed in this analysis.

To assess the status of vascular plant species and plant communities of conservation concern adequately, the Basin was divided into 13 "vascular plant analysis areas." This was necessary because of the large number of species and habitats needing evaluation and the large size of the Basin. The vascular plant analysis areas, while not clearly conforming to Ecological Reporting Units (ERUs) or physiographic province boundaries in every case, were used to most efficiently examine the status of the vascular flora and plant communities. The 13 vascular plant analysis areas were Western Montana, Western Wyoming, Idaho South, Idaho North, Northwest Utah, Northern Nevada, Oregon Basin and Range/Owyhee Uplands, Blue Mountains, High Lava Plains, East Cascades South, East Cascades North, Columbia Basin, and Okanogan Highlands.

The analysis for vascular plants consisted of the following primary components:

- Identification of vascular plant taxa of rangewide conservation concern,
- Analyses of rare species habitat groups,
- Identification of rare plant communities,
- Description of centers of endemism and floristic diversity,
- Listing the plant taxa of cultural importance,
- Description of research, development, and applications issues,
- Listing the flora of the Columbia River basin,
- Discussion of conservation issues, and
- Description of species and habitat modeling for taxa of rangewide conservation concern.

The first four analysis components were completed by the vascular plant expert panels; the remainder was accomplished by members of the SIT vascular plant task group, other terrestrial staff members, or by independent contractors.

We inventoried available conservation information and measures for vascular plant species. These included species conservation agreements, conservation strategies, listing packages, recovery plans,

Table 5.5— Lichen functional groups by function and major substrate type.

Dead Organic Matter	Epiphytes on Wood	Rocks	Soil
Charred snags	N-fixing epiphytes	Aquatic rocks	N-fixing soil lichens
Fencepost lichens	N-fixing riparian epiphytes	Calcareous rock indicators	Calcareous steppe indicators
Oceanic logs	Other riparian epiphytes	Metal-rich rock indicators	Steppe soil crusts
Rotten logs and tree bases	Aspen specialists	Sheltered ledges and overhangs	Pioneer soil stabilizers
Moss and detritus binders	Excess nitrogen indicators	Seepage rocks	Tundra forage lichens
	Urban pollution-tolerants	N-fixing rocks	Tundra sod builders
	Forage epiphytes	Tundra rocks	Vagrant ground lichens
	Oceanic forage epiphytes	Rock crusts	Soils
	Oceanic leaf epiphytes	Rock mats and cushions	
	Oceanic tree crusts	Oceanic rocks	
	Oceanic fruticose epiphytes	Rock macrolichens	
	Fruticose tree lichens		
	Pin epiphytes		
	Tree crusts		
	Leaf lichens		
	Bog lichens		

and status reports. In addition, a review of *ex situ* conservation approaches for vascular plants was completed under a contract with the Berry Botanic Garden of Portland, Oregon.

A survey was distributed to botanists on national forests and BLM districts throughout the Basin to collect information regarding the abundance, trend, and viability assessments needed for sensitive plant species. This survey also requested botanists to describe existing conservation strategies, management guides, or similar plans for these taxa. Based on the survey results, we decided to pursue assessments of species and habitat groups in five taxonomically complex genera by issuing separate contracts by individual experts. These genera were *Allium, Botrychium, Carex, Mimulus,* and *Penstemon*. These assessments subsequently underwent peer review by members of the professional botanical community and were then incorporated into our Species-Environment Relations (SER) database and vascular plant databases.

Plant Species of Tribal Concern— The SIT compiled descriptions of plant taxa of particular cultural significance to American Indian tribes in the assessment area. In this assessment, we focused on plant species that the SIT considered the most important to the seventeen tribal groups whose area of interest lies within the project area. Some of these species are very local in use or occurrence whereas others are more widespread. The primary range and use of some species lie outside the assessment area but are important enough to one or more of the tribes to warrant inclusion.

CRBFLORA Database— CRBFLORA is a PC database file (Paradox® format[4]) listing plant species found in the Basin (TS 1995). The data were compiled by Peter Rice, University of Montana, from three sources containing U.S. Department of Agriculture (USDA) Forest Service Region 1 and Region 6 species; the USDA Soil Conservation Service (SCS) "PLANTS" database; and lists of plant species in Wyoming, and Utah and Nevada, compiled by Walter Fertig and Duane Atwood, respectively.

The master plant list contains 8,078 taxon records. Approximately 928 of these records are species that were designated and tracked as sensitive species by either the Forest Service (FS) or the Bureau of Land Management (BLM). Noxious weeds account for another 119 species; an additional 858 are plants exotic to North America. Nomenclature follows that of Hitchcock and Cronquist (1973). Synonyms and varietals were excluded. The content of the database includes codes for genus and species and type of plant, genus name, species name, taxonomic sublevel, sublevel name, and origin.

Habitat affinities were entered into the Species-Environment Relations (SER) plants database for listed, suggested-listed, and candidate plant species only. No analysis was conducted on environmental correlates of the other 7,900 plant taxa in the assessment area.

Methods Specific to Invertebrates

Much of the initial information on invertebrates was gathered through contract reports written by experts. Contractors were directed to:

- Identify species that should be of special concern to land management agencies, reasons for concern, species-habitat relations, distributions, population trends, and ecology.
- Describe the range of habitat attributes for vegetation association, successional stage, and stand structure conditions across the Columbia River basin, and identify a few (ultimately, 510) representative species.
- Identify three to six key environmental factors (these are key environmental requirements, referred to in the database as key environmental correlates or KEC) that directly determine distribution and abundance of invertebrate species functional groups.

[4]The use of trade or firm names in this publication is for reader information only, and is not an endorsement or recommendation by the U.S. Department of Agriculture, the U.S. Department of the Interior, the ICBEMP, or any of the affiliated agencies.

- Identify three to six key functional roles that each group performs within the ecosystem (these are key ecological functions).
- Discuss biogeography of functional groups, species of special concern, or representative species, including identifying geographical areas of high diversity or endemism.
- Provide information on any specific habitats for functional groups such as microhabitat substrates, macrohabitat conditions, and environmental factors that, if protected, would help conserve species or the taxonomic group.
- Provide a literature review on distribution, status, and ecology for the functional groups relevant to the Basin.

A series of science panels was then conducted to consider the effects of potential management practices on terrestrial invertebrates and their ecological functions. Panels were assembled to discuss soil ecosystems and nutrient cycling; rangeland herbivores; litter and coarse-wood invertebrates and detritivores; parasites and predators; forest herbivores; and pollinators. In this discussion, mitigation measures were noted as well as opportunities for research and monitoring. Research and monitoring were discussed in the context of providing useful information to land managers on priority management issues. The experts participating in the panel discussions are listed in appendix 5C.

Methods Specific to Vertebrates

Terrestrial vertebrates within the Basin were listed using state (Montana, Idaho, Wyoming, Nevada, Utah, Washington, and Oregon) Natural Heritage databases, published reports, and state GAP Program databases. These lists were refined through the expert panel process and other reviews. Exotic species, those not native to the study area, were included in the assessment because they occupy space and compete with native species for habitat and because National Forest Management Act (NFMA) regulations on viability address "desired non-native" vertebrates.

Rare species were considered in the assessment and are defined as species that are seldom reported but that have regular occurrence. Accidental species were those that occur in the study area only on an irregular basis; these were not addressed in the assessment. Accidentally occurring species were not considered to depend on habitat within the assessment area for nesting, wintering, or transition or migration between seasonal habitats. A total of 547 terrestrial vertebrate species was evaluated for the assessment (table 5.3).

Ranges of most species were determined from available publications. Draft range maps were refined by experts individually or during the panel process, contract reports, or peer reviews. The Nature Conservancy provided their database on species associated with their Global Ranking System and habitat information associated with each species. This information also contained records that assisted in validating species ranges.

Most of the base information, which was gathered as contract reports, panel information from experts, and range maps of species, as well as selected species models and database information, was reviewed by experts not involved in the initial information collection. The interagency Partners in Flight reports provided additional information on primary habitats and Breeding Bird Survey trends of neotropical migratory bird species; this information was used to validate and improve the vegetation cover types depicted in our database. (See appendix 5C for specifics.)

In many cases, the leading—sometimes the only—experts on particular species within the Basin participated on panels or wrote the contract reports. Mammals were divided into four groups for the panels: bats, ungulates, carnivores, and small mammals. Divisions were based on management and public interest issues and the degree of information available for the group.

Vegetation cover type and structure for each species were reviewed by experts on amphibians, reptiles, birds, and mammals (as they were for plants and invertebrates). The reviewers were

instructed to include only the primary cover types required for fitness of each species and to exclude marginal or sink habitat conditions.

The panels identified key environmental correlates and key ecological functions for the terrestrial vertebrates: amphibians, reptiles, birds, small mammals, bats, carnivores, and ungulates. Amphibian, reptile, bat, carnivore and ungulate panels were able to consider individual species and identify key environmental correlates and key ecological functions for each species. The small mammal panel grouped some of the species into functional groups and identified specific environmental correlates for each species only where they significantly differed. Several contracts were awarded to obtain information on birds that was not compiled during the bird panels.

Identifying primary habitats for many birds was difficult because some species used areas for only breeding or wintering or as migrants, and other species were year-long residents. Grouping bird species into guilds based on foraging strategies was considered, but because individual species in guilds may respond differently to changes of the same environmental correlate (for example, cover type and structure) the approach was not applicable for this assessment.

Ungulates, Neotropical Migratory Birds, and Carnivores

Current management issues, concern for viability or population decline, and conflicting scientific views of species' status and habitat relations suggested that a more in-depth evaluation be conducted on three groups of vertebrates: ungulates, neotropical migratory birds, and carnivores. Each of these groups was assigned to species experts who: (1) described the current issues; (2) reviewed and documented current literature on each species; and (3) identified existing models available for assessing habitat or population of each species, the scale at which each was applicable, and the most important environmental correlates. The status and habitats of neotropical migratory landbird species (NTMB) were evaluated to help interpret population trends within the assessment area.

Threatened, Endangered, and Candidate Species

The U.S. Department of Interior Fish and Wildlife Service (USFWS) provided status summaries on all species listed as threatened, endangered, and Category 2 candidate species. Each report detailed the current status of the species, a description of habitat needs, population size, identification of potential or existing threats, recovery areas, and literature citations.

Additionally, information from the Prelisting Conservation Program in Idaho was used to supplement published species information and information gathered from expert panels and reports. This program has developed conservation strategies for several species. Initially, the strategies were to address Idaho only, but through meetings with ICBEMP staff, it was agreed that the entire assessment area would be addressed. Committees of experts on each species were assigned tasks to complete species status reviews and conservation assessments. Also, we coordinated with the South Okanogan Conservation Strategy of British Columbia, Canada, to gain information on species requirements (Harper and others, n.d.).

Shifts in Habitat Area for Vertebrate Species

We linked habitat relations data in the Species-Environment Relations database, species range maps, and broad-scale vegetation maps to estimate historic and current habitat area for each vertebrate species in the entire Basin and for each ERU. Broad scale refers to (1) characterization of vegetation conditions (modal existing vegetation cover types and structural stages) within one square kilometer (1 km^2) cells and (2) modal conditions within 4th-field hydrologic unit codes (subbasins) within the Basin. Broad-scale assessments of this type are often referred to as coarse-filter assessments in the ecosystem management literature (see Kaufmann and others 1994), although the term coarse-filter is also used to connote assessment of species by assemblages or guilds; thus, we do not use the term coarse-filter in this chapter.

Habitat was described by experts using cover types and structural stages (for example, Douglas-fir, multi-story old forest) as mapped by the Landscape Ecology assessment (see Landscape Dynamics, Chapter 3). We considered primary habitats as source (birth rates meet or exceed death rates) rather than sink (death rates exceed birth rates) habitats. Range maps of each species' current distribution were drawn from the literature and reviewed by taxonomic experts. Broad-scale vegetation maps depicted cover type/structural stage habitats over the entire Basin at a grain (pixel) size of 100 hectares. Historic vegetation was modeled to represent conditions in the early 1800s before extensive European settlement (see Landscape Dynamics, Chapter 3); current conditions were interpreted from supervised classification of satellite imagery.

We overlaid current range maps with the vegetation maps to determine the historical and current assessment area for each species. Maps of historical (early 1800s) ranges of species were not available. The species assessment area was defined by the ERU boundaries in which the current species range occupied greater than 10 percent of the ERU area. Although likely overestimating the range of some species, this practice identified the major ecological units in which the species occurs and somewhat compensated for uncertainty in current distribution and for difficulty in mapping historical ranges for many species. For example, the current distribution of Pacific fisher (*Martes pennanti)* is perhaps smaller than the historical range, which likely encompassed the entire area of ERUs in which they are currently found. Species with peripheral ranges and occasional or accidental occurrence in the assessment area were not considered.

The area of primary cover type/structural stage habitats used by a species was summed by ERU and for all ERUs within the species' range. Net change in habitat over the Basin was expressed both as a percentage of the historic area and as a percentage of the entire area. Net change in habitat areas from historic to current time in each ERU was expressed as a percentage of the total ERU area. Change over time was categorized as negative if the habitat area declined more than 10 percent, as positive if the habitat area increased by over 10 percent, or as no change. Basin-wide habitat estimates were reviewed by panels of species experts to judge the capability of the habitat relations data and vegetation classification to depict habitat change. The direction of habitat change was modified if the species-habitat depictions were judged fair to poor and the estimated direction of change judged incorrect. Also, species with ranges that intersected less than 10 percent of all ERUs within their range were not included in these analyses.

Modeling of Mid-scale Habitat Patch Trends

Analysis was conducted to determine the effects of mid-scale changes in vegetation quantity and pattern on habitats of vertebrate species in the Basin. Simple enumeration of habitat area does not account for the effects of the spatial distribution, juxtaposition, or fragmentation of habitat patches. Determination of the suitability of a habitat patch should be conditioned on its size, shape, and relation with similar patches. Moreover, the effects of pattern vary with the spatial scale at which the species uses habitat. For example, individual voles use habitat across a landscape at a smaller scale of spatial resolution (that is, a smaller environmental grain size) than do raptors.

Quantitative habitat suitability models of individual species would have been difficult to build because specific data were lacking. Moreover, the computation requirements for a Basin-wide analysis of the habitat for over 466 listed vertebrate species in 338 mid-scale watersheds (actually 676 watershed maps representing historical and current conditions) would have been prohibitive. Instead, methods to group species by habitat, scale, and type of landscape use were necessary. We adapted the methods of Mellen and others (1995a) for grouping vertebrate species by vegetation structural types, home

range area classes, and type of landscape, and we used their approach and computer programs for estimating the area of habitat for each species group.

We used information from the Species-Environment Relations (SER) database to group terrestrial species (aquatic, riparian, and wetland habitats are covered in the Biophysical Environment, Landscape Dynamics, and Aquatic Species and Habitats chapters) by primary habitat categories—mainly vegetation structural stages or non-forest types as used in the mid-scale landscape analysis—by species home range area classes and by the way species used landscapes based on their vagility (movement and dispersal ability) and behavior, following Mellen and others (1995a). We used the SER database to determine the structural stages used by each species, then combined similar groups of species associated with vegetation structural classes (for example, open and closed herb, grassland+shrub). We examined the outcome for each species and changed its structure group when known secondary habitats or anomalous types associated with the vegetation classification system had been included in the database.

Habitat area for structural stages used by species groups was further separated by community cover types (for example, lower montane, montane, subalpine community types as used in the Landscape Dynamics chapter) after the spatial habitat model described above helped determine the suitability of patches. This relatively general level of detail in the vegetation-use classes was chosen because of the great analytical complexity of modeling many combinations of cover type and structural stages, multiplied by four home ranges, in numerous watersheds.

Species with home ranges from 5 to 1,300 hectares were analyzed to get a sufficiently large number of home range samples within the average 8,000-hectare mapped watershed. Four home range classes were determined by examining clumpings in the frequency distribution of home range data for 160 species taken from a variety of published literature (for example, Holling 1992, Thomas 1979). Those classes were: 5 to 50 hectares, 51 to 300 hectares, 301 to 650 hectares, and 651 to 1,300 hectares. Species with home ranges less than 5 hectares were classed as patch species, whose habitat could be estimated by a simple summation of area without pattern constraints, and were not analyzed. Only mosaic species, which use an aggregation of patches across a landscape in the selected habitat and home range classes, were analyzed because they would be the most sensitive to landscape pattern of all the landscape-use classes.

We developed 15 primary classes of vegetation structural stages/cover types based on the species-habitat relations data in the SER database (table 5.6; also see information on file, TS 1995). Five species groups of major interest for an analysis of temporal changes in habitat area were species of forest in mid-to-old stages of structural development, old forests, forest and range grasslands, range grasslands/shrublands, and range woodlands. Combining these five species groups with the four home range categories produced 20 potential classes for further analysis, but only 13 combinations had enough species for analysis (table 5.7). Grassland and woodland groups occurred only with the smallest home range; results of those analyses are not presented because effect of home range classes could not be shown. Also, the range grasslands/shrublands category ultimately proved difficult to analyze and is not presented because of the ubiquitous nature of a combined grass/shrub habitat type regardless of the historical period and management history. Another difficulty of working with the grasslands/shrublands class was that conversions to exotic species did not show well in the mid-scale database. Results for only the three forest habitats are presented in this paper.

Computer programs developed by Mellen and others (1995a, 1995b) were used to estimate effective habitat area for each of the 13 species groups (table 5.7) in each of the 338 6th-field hydrologic units mapped for the mid-scale landscape analysis. Both past and current habitat area was estimated in each watershed by separate

Table 5.6— Primary habitat, home range, and landscape use classes used to group vertebrates for habitat pattern analysis of mid-scale watersheds in the Basin.

Primary Vegetation Classes:

- Aquatic: Primarily water. (41 vertebrate species)
- Aquatic/herbaceous: Both water bodies and herbaceous areas (meadows, grasslands, agriculture) used for feeding or resting. (42 vertebrate species)
- Aquatic/riparian: Water and riparian vegetation for feeding or resting. (53 vertebrate species)
- Generalist: All forest and range habitats. (55 vertebrate species)
- Open generalist: All stages of range and forest stand initiation cover types. (24 vertebrate species)
- Forest generalist: All stages of forest development (stand initiation, stem exclusion, understory reinitiation, young forest, and old forest). (52 vertebrate species)
- Forest mid- to late-seral: Understory reinitiation, young forest and old forest stages of forest development. (53 vertebrate species)
- Forest old-forest: Old single or multi-story forest stands. (10 vertebrate species)
- Range generalist: All structural stages of range grasslands, shrubland, or woodland cover types. (67 vertebrate species)
- Range and forest grassland: Herbaceous grassland cover types. (8 vertebrate species)
- Range herb/shrub : Range herbaceous and shrub cover types. (27 vertebrate species)
- Range shrub/woodland: Range shrub and woodland cover types. (5 vertebrate species)
- Range Woodland : Range woodlands. (8 vertebrate species)
- Riparian woodlands: Cottonwood and willow riparian woodlands. (18 vertebrate species)
- Urban: Urban areas. (3 vertebrate species)

Home Range Classes:

- <=4 ha (209 vertebrate species)
- 5-50 ha , median=20 ha (49 vertebrate species)
- 51-300 ha , median=250 ha (43 vertebrate species)
- 301-650 ha , median=500 ha (25 vertebrate species)
- 651-1,300 ha , median=1,300 ha (12 vertebrate species)
- 1,301-10,000 ha, median=4,000 (23 vertebrate species)
- 10,001-50,000 ha, median=34,000 (3 vertebrate species)

Landscape Use Classes:

- Patch: Individuals live primarily in a single patch of habitat to life history requirements. (180 vertebrate species)
- Mosaic : Individuals traverse areas of unsuitable vegetation to use >1 patch of habitat. (98 vertebrate species)
- Contrast: Individuals require two different habitats to fulfill different life history needs, e.g., old forest for denning or roosting and open or stand initiation patches for feeding. (9 vertebrate species)
- Generalist: Uses nearly all types of forest or range habitats. (52 vertebrate species)

Table 5.7— Preliminary groups of mosaic vertebrate species identified for habitat pattern analysis of mid-scale watersheds in the Basin.

Vegetation/Habitat Class	Home Range Classes			
	5-50 hectares	51-300 hectares	301-650 hectares	651-1300 hectares
Forest Mid- to Old- Stages	X	X	X	X
Old Forest Stages	X	X	X	
Range and Forest Grasslands	X			
Range Grasslands/Shrublands	X	X	X	X
Range Woodlands	X			

program runs. Habitat patches of each structural class were mapped at a minimum 4-hectare resolution. The computer program examined the neighborhood of each 4-hectare habitat pixel in a window and used a set of decision rules to determine if that pixel contained suitable habitat conditions. The window size was determined by the median home range area for the species group. Rules defined the minimum patch size and the minimum amount (50%) of the patch or total habitat area in the window to rank habitat suitability of the central pixel on a 6-point scale. The minimum patch size was set at the grain size of the map data (4 ha) because data on which to base larger minimum patch size requirements were not available for any species. We collapsed the 6-point suitability scale to describe pixels simply as suitable or not. Habitat area derived from this analysis is not an absolute area but accounts for habitat patch size and pattern relative to the home range scale of analysis and the spatial constraints in this model. See Mellen and others (1995b) for details on the analytical procedure.

Building Data and Models of Species-environment Relations

We captured the base information on species ecology collected from the expert panels and contract reports (appendix 5B) in PC Paradox® relational databases which collectively constitute the Species-Environment Relations (SER) Model. We developed two hierarchical classifications: one for key ecological functions (KEF) of species, and one for key environmental correlates (KEC). Each category in each KEF and KEC classification was given a unique code, and each species was assigned the appropriate codes for functions and correlates. Querying the databases of the SER Model helped us identify groups of species sharing common KECs or KEFs and to evaluate relations of species or groups with vegetation cover types, structural stages, and other key environmental correlates. Identifying unique assemblages and species groups, here based on KECs and KEFs, is consistent with biodiversity assessment procedures as discussed by Samson and Knopf (1993), who call for relying less on biodiversity assessments based on individual species and more on species groups (but see Paige 1990 on individual species responses of western North American songbirds).

In general, we built the SER databases for vertebrates based on what may be termed a species influence diagram (fig. 5.2), which denotes the major KECs and KEFs affecting species, subspecies, or species group of interest. KECs include environmental factors either associated with, or required by (selected by), given species. KECs include vegetation cover types, vegetation structural stages, other physical substrates, presence of other species, human activities, and a host of other factors. KECs can be influenced by management

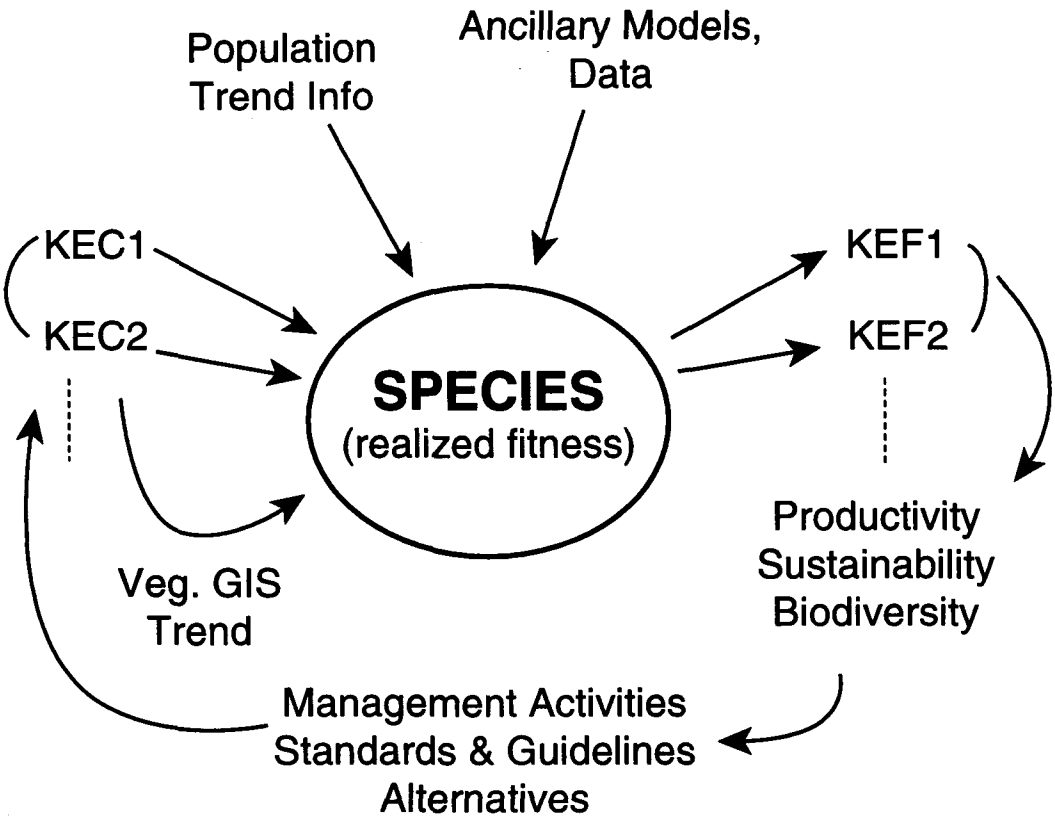


Figure 5.2— Species influence diagram. This is the basic arrangement of information used in the Species-Environment Relations (SER) Models built for the terrestrial assessment. The central box represents the realized fitness of selected individual species or species groups. Fitness is influenced by a series of key environmental correlates (KECs), which include vegetation cover types and structural stages, as well as other substrate-specific aspects of the species habitat and other environmental features not necessarily traditionally included in habitat evaluations. Along with additional information on population trends and ancillary models and data sources, the KECs provide a means by which an indirect inference can be made to population fitness by tracking patterns and trends in potentially suitable environments for the species. KECs are influenced by management activities. Each species in turn performs a set of key ecological functions (KEFs) such as aiding nutrient cycling, providing a source of carrion, or excavating burrows. These KEFs ultimately influence the sustainability, productivity, and biodiversity of the ecosystem. Under a paradigm of ecosystem management, understanding these relations should help in developing management standards and guidelines and planning alternatives.

activities. In the case of vertebrates, KECs were listed for each species. With rare plants and invertebrates, which are not known well enough to list KECs, we deferred to the expert panels' listing of potential adverse influences of general management activities. This assumed that the unknown KECs for plants and invertebrates would be influenced.

KEFs include a wide range of roles, including nutrient cycling, predation, soil aeration, and many other functions. Ultimately, KEFs affect the productivity and biodiversity of an ecosystem and the degree to which humans can sustainably use associated renewable resources.

Assessment of Endemism, Biodiversity, and the Role of Natural Areas

Biodiversity Estimates

The Convention on Biodiversity of 5 June 1992 defined biodiversity as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Harrod and others, in press). We adopted this broad definition.

Biodiversity in the Basin was analyzed as (1) a count of species, by taxonomic class, known to regularly occur within the assessment area, and (2) an extrapolated estimate on the number of species based on potentially undiscovered or unknown species. Counts were developed from compiling species lists from experts and existing publications, such as floras, field guides, and databases. Extrapolated estimates were made by taxonomic group as noted in table 5.3. More specifically, species estimates were provided by experts as follows: fungi (M. Castellano), bryophytes (J. Christy), vascular plants (L. Croft), mollusks (T. Frest), and arthropods (J. Lattin). Extrapolations generally were based on experts' knowledge of species content in areas studied or surveyed within the assessment area. We assumed that all species of lichens (R. Rosentreter), fish (J. Sedell), and other vertebrates (B. Naney, B. Marcot) are known.

Estimates of biodiversity of microorganisms (bacteria, protozoa, nematodes, and soil microfungi) are not offered as specific numeric values, but rather as broad ranges of values within orders of magnitude. Even these estimates are likely wrong. This is because little specific empirical work has been done on biodiversity of these species groups, and experts (E. Ingham, M. Castellano) extrapolated potential species diversity from few, small samples of soil microorganisms. Obviously, much work remains to validate the extrapolations.

Centers of Endemism and High Biodiversity

The endemism analysis focused on locally endemic and regionally endemic species. Locally endemic species have populations restricted to a very small area (for example, one portion of a mountain range, or one canyon). Regionally endemic species have populations that inhabit a larger geographic area than do those of local endemics (such as southeast Oregon, or the Palouse country, but are restricted to the inland or Pacific Northwest). In addition, other individual species distributions were noted as being peripheral, disjunct, scattered, or common.

Expert panels of agency and non-agency scientists were convened between March and May of 1995 to identify areas of endemic populations of plant, invertebrate, and vertebrate species. The panels of experts produced maps showing areas of high numbers of locally or regionally endemic species and of areas having unusually high biodiversity (total number of species). Separate maps were created for plants and animals (aquatic and terrestrial invertebrates and vertebrates). We then overlaid the maps to determine particularly rich "hot spots" of endemism or biodiversity areas; hot spots were defined as areas where three or more endemism or biodiversity areas of individual taxonomic groups intersect. Thus, there are fewer hot spots than taxon-specific endemism or biodiversity centers.

Natural Areas

Natural areas were grouped by category (such as Wilderness, Research Natural Area, Wild and Scenic River), land area per discrete natural area, and total area by category. Natural areas were characterized by the types of human activities allowed. We examined management objectives and administrative designation of natural areas. We compared size distributions of natural areas to home range sizes of vertebrates to assess the potential contribution of natural areas to vertebrate species persistence.

Several additional analyses (TS 1995) were performed. Current, historic, and potential vegetation types for each natural area were compared with vegetation types found in the entire Basin to determine if natural areas represent all the major habitat types in proportion to their abundance and distribution on Federal lands within the Basin. Aquatic representation was assessed by overlaying maps of the natural areas with maps of streams and lakes within the Basin and determining the amount of the stream or lake included in natural areas (Mackey and others 1988). Natural areas were also categorized by natural disturbance regimes to determine whether disturbance regime types are well represented in the natural area system.

We analyzed the sizes of natural areas and vertebrate home ranges to determine the value of natural areas in maintaining vertebrate species. Natural areas and species were pooled without regard for differences in habitat composition and use. For this broad treatment, we made the simplifying assumption that natural areas were isolated from adjacent habitat that might increase the effective area for species conservation and management. In reality, this is not the case, and much of the land surrounding natural areas also would contribute suitable habitat for vertebrates analyzed here.

Assessment of Biogeography

Once species range maps and maps of centers of endemism and biodiversity were completed, we produced a series of simple variable and qualitative assessments of biogeography for selected species. The purpose was simply to demonstrate how a single or a few environmental factors, such as landforms or precipitation levels, correlate with some species' distributions and thus, at least partially, account for their occurrence.

The method used here consisted first of mapping categories of selected biophysical parameters throughout the Basin at a resolution of one pixel = one sq. kilometer. Biophysical parameters included elevation, relief, slope, landform, geology, precipitation (average high and average low), and air temperature (average high and average low). Final maps displayed parameters averaged within each 6th hydrologic unit code (HUC).

Then we used geographic information system (GIS) software (ArcVIEW II® and the UMAP program of the UTOOLS GIS series) to overlay selected individual species ranges and the maps of endemism and biodiversity centers qualitatively to test the null hypothesis that there is no correlation of a species' range with specific biophysical factors. Results were displayed as maps that illustrated cases where the null hypothesis was rejected and cases where it failed to be rejected based on simple visual inspection of the maps. Results at this stage should be treated as tentative working hypotheses to be tested quantitatively.

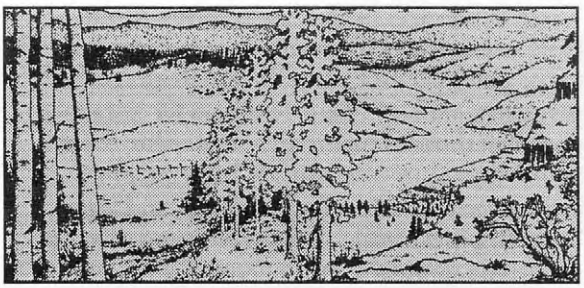
Identifying Research, Inventory, and Monitoring Needs

In the information gathered from panels, contract reports, publications, and other sources were further research, inventory, and monitoring needs. Summaries of such information needs were identified for plants, invertebrates, and vertebrates, and recorded in a Paradox® database. Entries were catalogued and made retrievable by key word topics. This information is in preparation for publication. A summary of information needs identified during this project is included in the section on Conclusions and Interpretations.

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RESULTS

Assessment of Species Occurrence and Listing Status

Results are presented as follows. Our assessments of numbers of species with legal listing status, overall biodiversity expressed as species richness by taxonomic group, and broad-scale influences on biodiversity patterns observed are presented first. We then present assessment results for each taxonomic class, including plants and allies, invertebrates, and vertebrates. In the plants section we discuss fungi, lichens, bryophytes, and vascular plants; and topics including listed species, use of plants as products, geographical and ecological distributions, conservation needs, species of concern to American Indian tribes, and databases. In the invertebrates section we discuss listed species, unique habitats, functional roles of invertebrates and functional species groups, implications of findings for management, and information needs. In the vertebrates section we discuss amphibians, reptiles, birds, and mammals, and topics including listed species, species of tribal interest, areas with carnivores, and implications for management.

Next, we present assessment results of trends in species' habitats and environments. These include shifts in habitat area for vertebrates; implications of broad-scale vegetation changes for species of native grasslands, shrublands, and old forests; habitat fragmentation; and mid-scale trends in distributions of old forests. We then summarize results of general trends of species ecological characteristics, including extinction patterns and species associated with specific substrates and environmental features. Finally, discussions of species' functional groups; patterns of species rarity, endemism, and biodiversity, and of relations to existing natural areas; and a brief discussion of species biogeography are presented.

Number of Species in the Basin

The Basin is a particularly diverse arena for plant and animal species. Excluding mostly microscopic life forms (see below), a grand total of 17,186 taxa (defined here as mostly species with a few subspecies included that are of particular conservation concern) are known to inhabit the assessment area. The bulk of the known and catalogued taxa are vascular plants and allies (approximately 12,797 known taxa or 74%) and insects and arthropods (approximately 3,400 known taxa or 20%) (see table 5.3). Only a small fraction (609 taxa or 3%) are vertebrates.

The number of estimated taxa, including extrapolations for species not yet described, is even greater, totaling approximately 43,825 (table 5.3). This excludes most microscopic life forms. Estimated numbers of macroinvertebrates dominate this sum (24,270 estimated taxa or 55%), with plants and allies second (18,946 estimated taxa or 43%). We assume that vertebrate species of the Basin have been fully described (609 taxa or 1%).[5]

[5]A similar analysis of taxonomic diversity at genus, family, and order levels was not conducted for this assessment but would prove enlightening. Understanding distribution, endemism, and evolutionary potential at these higher taxonomic levels is an important addition to the traditional analyses.

These figures will likely change, given further basic research and inventory efforts. Estimates of the potential number of invertebrate taxa, in particular, are based here on a broader extrapolation than those of plants and allies. Also, these figures do not include viruses, bacteria, protozoa, rotifers, nematodes, soil microfungi, and algae. Little empirical work on taxonomy and diversity of bacteria, protozoa, and microfungi has been conducted in the assessment area. The following figures are extrapolated, best-professional guesses and will certainly change—perhaps by orders of magnitude—if ever empirical field studies can validate them.

One estimate[6] gives the number of bacteria species in the assessment area as approximately 160,000 species in forests, a similar number of different species in grasslands, and in agricultural fields, totaling approximately 480,000 species in these three environments.[7] This estimate is very approximate and will certainly change with new (or any) field information.

No study has been conducted on the total number of bacteria species or even uniqueness of species in soils throughout the Basin. One study in the Palouse, however, has discovered a small set of unique helper bacteria that suppresses weeds; and another study is exploring the role of beneficial bacteria that aid crop plant growth.[8]

In one estimate,[9] there are between several hundred and perhaps a thousand species of protozoa in forest stands, a similar number of different species in pasture or grassland, and perhaps several hundred in agricultural fields, totaling very approximately one to two thousand or more species in all three environments. Species of testate amoebae have been found in samples taken in the Blue Mountains and the Wallowa Mountains that have never been seen in any other soils.[10]

Soil nematodes number perhaps 10 to 20 species in an unproductive ecosystem and perhaps 100 to 150 species in a healthy forest.[11] Many soil nematode species that are agriculturally important in the Basin are known and their distributions are fairly well understood.

Extrapolating from small soil samples, in one estimate[12] on the order of 100,000 soil ectomycorrhizal microfungi species occur each in forest and grassland ecosystems.[13] There may be roughly equal numbers of other forms of microfungi[14] but they are essentially unstudied in the Basin.

As with bacteria, soil microfungi are critical to ecosystem health. Although no study of soil microfungi biodiversity in the Basin seems to be available, unique mycorrhizal species are known to occur in larch and mixed conifer stands in the Blue Mountains. These species have probably adapted to enhance tree growth.[15]

Number of Species Included in This Assessment

A total of 14,028 species (including some subspecies) and 61 species groups were considered in this assessment (table 5.3). This includes native and exotic fish species (see Aquatic Species and Habitats chapter). Invertebrate species greatly outnumber plants or vertebrate species. However, a dearth of previous biodiversity analyses in the area and a lack of field studies on most taxa precluded much species-specific cataloguing of the invertebrates.

[6] Personal communication. 1995. E. Ingham, Oregon State University. Department of Botany and Plant Pathology, Corvallis, Oregon 97331.

[7] Extrapolations based on work by James Tiedje, Center for Microbial Ecology at Michigan State University.

[8] See footnote 6.

[9] See footnote 6.

[10] See footnote 6.

[11] See footnote 6.

[12] See footnote 6.

[13] Estimates based on work by T. Bruns, University of California, Berkeley.

[14] See footnote 7.

[15] See footnote 7.

Instead, invertebrates were treated in 11 functional groups and 715 individual species were addressed only as examples of a much larger biota. Most of the 14,028 species were plants and allies (12,625 species), particularly vascular plants (8,078 species) which were catalogued as part of the CRB-flora database on the assessment area's vascular flora. The CRB-flora database is in development.

A total of 1,347 species (including some subspecies) and 93 species groups were included in the terrestrial SER database developed for this assessment (excluding fish). The vascular plants included in the SER database are C1 and C2 candidate species and additional taxa identified by the plant panels as potentially deserving candidate status. Plant groups were derived from contract reports on taxonomically difficult genera: *Allium*, *Botrychium*, *Carex*, *Mimulus*, and *Penstemon*.

Legal Status Categories of Species

In the assessment area 233 terrestrial taxa (species or subspecies, excluding fish) occur that have official Federal status as threatened, endangered, candidate (Category 1 or 2), federally proposed as threatened, or federally proposed as endangered (table 5.8, minus fish). Most of the taxa are plants and allies (148 taxa or 64%) with the rest nearly equally distributed in numbers between aquatic and terrestrial invertebrates (43 taxa or 18%) and vertebrates (42 taxa or 18%) excluding fish.

Also, excluding fish, most of the 233 taxa are C2 Candidate species (184 taxa or 79%); some 112 taxa (61% of all C2 species) are C2 plants or allies. However, every taxonomic class has some C2 candidate taxa. The rest (excluding fish), in decreasing frequency, are C1 candidate (31 taxa or 13%, all plants), endangered (11 taxa or 5%), threatened (6 taxa or 3%), and federally proposed as Endangered (1 taxon or 0.4%, a plant). None is currently federally proposed as threatened.

Excluding fish, the FS has identified 410 species within the Basin as sensitive and the BLM has identified 193 species as sensitive. Only 66 species (12%) are jointly listed as sensitive by both agencies. Given this partial overlap in listings, a total of 538 species is listed by one or both agencies as sensitive. This total includes 451 plants and allies (84%), 25 invertebrates (5%), and 62 vertebrates (12%). Ten percent of plants and allies is listed in common. None of the invertebrates are listed in common as the FS has listed none as sensitive. Thirty-two percent of vertebrates, generally more vagile than plants and invertebrates, is listed in common. The agencies generally manage lands that are ecologically very different; this accounts for the low number listed in common by both agencies.

A total of 296 species is deemed by the SIT of particular interest to American Indian tribes within the assessment area (table 5.8). Most are plants and allies (209 species or 71%). Invertebrates (16 species or 5%) and vertebrates (71 species or 24%) comprise the rest. Only two species federally listed as threatened or endangered —bald eagle (*Haliaeetus leucocephalus*) and grizzly bear (*Ursus arctos*), both federally listed as threatened—also appear on the lists of species of tribal interest.

Influences on Biodiversity

The main influences on biodiversity within the Basin are that the area: (1) is large enough to encompass many distinct ecosystems and biomes, including those of the interior Columbia Basin and parts of the Klamath River basin and Great Basin and to span 13 Ecological Reporting Units (ERUs, topographically and geologically district regions within the assessment area), each of which has a distinctive biota; and (2) contains topographically diverse landscapes with at least nine major landform categories and a wide range of elevations and relief, thus affording a high diversity in micro- and mesosite conditions, climates, and habitats. Also, the area includes regions of geologically recent glaciation, volcanism, and aeolian (wind-driven) deposition, providing a great diversity of substrates. Pleistocene events such as the Bretz floods created major new landforms to be invaded by species, including locally endemic forms. The topics of biodiversity and species endemism are explored further below.

Table 5.8— Numbers of taxa (species, subspecies, fish stocks) by Federal listing status of special interest to American Indian tribes. Listing status classes: C1 = Category 1 candidate ; C2 = Category 2 candidate; Forest Service sensitive (in at least one state within the assessment area); Bureau of Land Management sensitive (in at least one state within the assessment area); Joint FS/BLM sensitive = same species listed by both FS and BLM as sensitive; Tribal = species identified by the ICBEMP Science Integration Team as of particular interest to American Indian tribes.

Class	U. S. Fish and Wildlife Service						Forest Service and Bureau of Land Management				Tribal
	C 1	C 2	Threatened	Endangered	Federally proposed threatened	Federally proposed endangered	FS sensitive	BLM sensitive	Joint FS/BLM	Total FS/BLM	
Nonvascular Plants	0	1	0	0	0	0	3	10	1	12	4
Vascular Plants	31	111	1	3	0	1	371	113	45	439	205
Invertebrates	0	38	1	4	0	0	0	25	0	25	16
Fish	2	19	5	5	0	0	(...see Aquatic Species and Habitats chapter...)				
Amphibians	0	6	0	0	0	0	2	5	2	5	0
Reptiles	0	1	0	0	0	0	1	5	0	6	2
Birds	0	13	3	2	0	0	22	23	12	34	34
Mammals	0	14	1	2	0	0	11	12	6	17	35
TOTAL	33	203	11	16	0	1	410	193	66	538	296

Plants and Allies

Fungi

The Basin is a huge geographic area that includes habitats ranging from alpine to desert. The complexity of the landscape makes assessing rare fungal species difficult. Riparian areas require special consideration because of the high diversity of ectomycorrhizal hosts found in these habitats. In addition, the Basin has many habitats (in this case, defined by soil types) which are largely unexplored and highly restricted in distribution.

The data gathered for this study were from collections that were the result of systematic, not ecological, research. Taxonomic studies tend to emphasize sporocarp (spore-bearing) morphology. As such, data on habitat structure are lacking and locations of collected fungi are often vague (for example, "from Priest River"). In addition, there are problems with nomenclature for many fungal species; some currently recognized taxa actually contain species complexes. Nonetheless, the data show some species trends and help identify areas of special concern (as emphasized in the endemism section, below). Specific taxonomic studies of these groups or individuals will better delineate the presence and extent of populations.

There is a lack of specific knowledge on the function or role that each fungal species plays in the ecosystem besides that of a general saprophyte or mycorrhizal symbiont. Variation in specific physiological functions among fungal species even within the same genus can be marked.

Information on population viability of listed fungal species does not exist. We, therefore, cannot make inferences about the effects of management activities on these species' population trends, except in the general category of mycorrhizal fungi that depend upon a host plant for survival. That is, removal of the host will negatively impact the mycorrhizal fungus or the saprophyte that is host specific. Effects of landscape fragmentation on dispersal of the fungi are also unknown.

Some fungal species, especially some *Boletus, Morchella,* and *Cantharellus* species, are important to recreational and commercial gatherers. Knowledge of their ecology and specific biology and life history is critical for their long term management.

Kinds of Fungi and Their Relation to Fire, Dung, and Host Plants—A number of fungi species are phoenicoid, fruiting after fire. Effects of fire intensity on their sporocarp phenology (seasonality) are poorly known.

Species that fruit on or in dung are transitory by nature. Spores are either deposited on vegetation that is then consumed by animals or deposited on dung. In either case, the dung is necessary for completion of the fungal life cycle.

Many mycorrhizal and saprophytic fungi are dependent on plant host species. If these fungi are to be conserved through management, then the site as well as the plant association for the host species would need to be protected from adverse disturbance.

Fungi Conservation—Some form of local protection of type localities of fungal species may be considered as a conservation measure. Type localities are specific locations for specimens that were initially used to describe the species for science, and as such they are important historically. Protection could more often than not be in the form of small, site-specific mycological preserves of varying size depending on habitat and life history of the species. The purpose of such preserves would be to protect known sites of potentially rare or at-risk species while further inventories or studies determine their true status. Biological and ecological information on macrofungal species is generally lacking. Thus, one approach to conservation (but not a fully satisfactory approach), may entail managing habitats where fungi of special concern occur or are likely to occur, particularly threatened habitats.

Lichens

Lichens are a widespread component of the Basin's forests and rangelands and are primary producers in the forest. Their biomass and nutrients contribute to the forest litter and duff, enriching the soil and increasing soil moisture-holding capacity. Arboreal lichens capture fog, retaining moisture within the forest. Many lichens fix atmospheric nitrogen. The forage lichens (some of the species found in tree canopies) are a major food source for animals such as flying squirrels, red-backed voles, and woodrats (Maser and others 1978). Forage lichens are also a secondary food source in the winter for deer and elk. They provide habitat and food for canopy-dwelling invertebrates (Thomas and others 1993). Birds and small mammals use lichens as nest-building material and camouflage. Air quality can be assessed by evaluating the types of lichens present (Geiser and others 1994, Richardson 1992). Lichens are sensitive to sulphur dioxide and other gases and are efficient accumulators of heavy metals.

In winter months when snow covers the ground, small mammals that normally eat fungi switch to arboreal lichens as a food source (Maser and others 1978). These small mammals are often prey for forest owls and other predators. Maintenance of the proper edible species of arboreal lichens may help maintain small mammal populations during the critical winter stress period.

Forest Lichens—The lichen flora of the forests of the Basin is dominated by arboreal black forage lichens, *Bryoria* spp., also commonly known as beard lichen or black tree lichen (TS 1995). Some of these forests are adapted for fire, although the natural fire frequency has been greatly altered by humans through fire suppression management (TS 1995). Fire suppression has often resulted in dense forests of different species composition than the open, park-like conditions that were maintained by natural fires. Dense, closed stands of trees contain fewer lichens than open stands of trees. American Indians used black tree lichens extensively for food, often mixing it with their pemmican.

Uneven-aged management of stands (preserving seed trees) would conserve the legacy of lichens and allow them to recolonize regenerated trees. Black tree lichens are fairly good dispersers into areas disturbed by fires. Natural forest burns generally leave clumps of unburned trees with intact lichens and even portions of lichens on burned trees and snags. These legacy stocks, which are typically absent from large clearcuts and dense forest stands, serve to "seed" the regenerating forests. Site treatments such as piling and slash burning also decrease the remnant lichen legacy.[16] Many managed forest stands in the Basin are surface-treated to yield dense regeneration, rather than managed to encourage natural regeneration. These treatments and other surface treatments, combined with overstocking of artificial plantings, produce dense forests that do not favor the growth of forage lichens. Such forest management practices have probably decreased the abundance of the forage lichens, but the application of uneven-age forest management and retention of clumps of legacy trees will help improve the potential for lichen regeneration.

The Northwest Forest Plan (based on FEMAT 1993) addressed the topic of lichen conservation for the forests west of the Cascades, but there have been no such scientific studies on this topic in the current assessment area. Basic lichen floristic surveys and practical applied research into maintaining lichens in managed forests of the Basin are sorely needed. Additional work will need to be done to elucidate effective strategies for maintaining and restoring lichens in harvested and burned portions of these forests.

Rangeland Lichens—In many habitats, the surface area covered by lichens is 30 percent or greater (Wicklow-Howard and Kaltenecker 1994). In sagebrush steppe and Columbia River grasslands, a mixture of bryophytes, lichens, and

[16] Personal observation. 1996. R. Rosentreter, U.S. Department of Interior, Bureau of Land Management, Idaho State Office, Boise, Idaho 83706.

cyanobacteria, occurring as microbiotic crusts, fill the interspaces between the shrubs and bunchgrasses. This association of species is similar in many other parts of the world, including Asia and Australia. These microbiotic crusts vary slightly by region but have many similar species that are well adapted for steppe and grassland conditions.

The nitrogen-fixing lichens and cyanobacteria that are part of the microbiotic crust improve soil fertility. Microbiotic crusts in general increase soil stability, influence water infiltration, and may improve seed germination for various plant species. Intact microbiotic crusts also may inhibit the establishment of exotic plants such as cheatgrass. Compared with many other groups of microorganisms, microbiotic crusts have been well studied. Nonetheless, details of the ecological role of microbiotic crust species as soil stabilizers and nitrogen fixers are still being elucidated (Belnap 1994). The role of microbiotic crusts as potential barriers to the establishment of cheatgrass needs to be studied further and correlated with patterns of land-use, disturbance histories, and soil properties.

Many microbiotic lichens found in the Basin are widespread globally, yet the area they now cover in the United States has been greatly reduced compared with historic times. The major threats to survival of microbiotic crusts in the Basin include: invasion of exotic annual grasses and associated increases in fire frequency; conversion of rangelands to agriculture and suburban developments; and livestock trampling. Increased fire frequency (more than 40 times historical frequencies) owing to the introduction of cheatgrass has led to dramatic changes in grassland ecosystem structure (Whisenant 1990). Much of the shrub steppe has been converted to a dense, closed stand of annual exotic grasses to the exclusion of microbiotic crust communities. Areas still containing shrubs and microbiotic crusts can be grazed by livestock when the soil is moist with little harm to the crusts (Wicklow-Howard and Kaltenecker 1994), but many areas have been severely affected by livestock trampling in the dry season. One microbiotic crust species, the woven-spored lichen (*Texosporium sancti-jacobi*), is now restricted to two general localities within the assessment area.

A second lichen group, the tumbleweed or vagrant ground lichens, grow, persist, and reproduce without attachment to a substrate (Rosentreter 1993). They are declining because of loss and fragmentation of habitat and herbivory by grazing domestic sheep. Their tumbleweed dispersal habit requires unfragmented habitat conditions. Numerous roads with drainage ditches collect lichens, leaf litter, and deep snow, which leads to conditions that eventually kill the lichens. These conditions combined with widespread habitat conversion to exotic annual grasses have led to the extirpation of vagrant ground lichens from many parts of the Basin. No sites currently are being managed to provide for the continual existence of these vagrant lichens. In fact, some species still remain unnamed by science.[17]

Bryophytes

Although Bailey and others (1994) divided the Columbia River Basin into 7 ecological provinces and 21 sections, the bryoflora has not been treated (prior to the current study) at such a fine level of resolution. Numerous papers specifically describe global distribution patterns of bryophytes, but few of these are at the resolution of ecological provinces. Schofield (1969) provided the most comprehensive distributional information suitable for the assessment area, treating endemic species and those with broader global distributional patterns by geographic areas within the Pacific Northwest. Schofield (1980) and Hong (1987) treated the region in a somewhat broader continental context. Detailed studies of neighboring regions that are useful for the current assessment include Schofield (1976, 1988), Tan (1980), McIntosh (1986, 1989) and Spence (1987). Vitt and others (1988) provided distribution maps for some species within the Basin. In addition to papers specifically focused on phytogeography, floristic and ecological papers provide additional information (information on herbaria housing bryophyte specimens is on file, TS 1995).

[17] Personal communication. 1995. Bruce Ryan, University of Arizona. Department of Botany. Temple, Arizona 85287.

The majority of bryophyte species in the Basin have widespread circumboreal or Arctic-alpine distributions. These sets of species are termed boreal and arctic-alpine bryofloras. Most of these bryophytes occur at higher elevations where temperature and precipitation are favorable for growth. Such mountainous tracts within the assessment area include the Cascade Range, the northern and central Rocky Mountains, the Blue Mountains, and the fault-block ranges within the northern Great Basin. Arctic-alpine species are generally restricted to areas at or above timberline, although they may occur below timberline in suitable microhabitats. Circumboreal species are best developed in coniferous forests and, to a lesser extent, shrub/steppe.

Another group of bryophytes in the Basin is the coastal and north Pacific bryoflora. A significant phytogeographical element of the assessment area is the inland extension of coastal and Cascadian species that follow a lobe of moderated climate inland along the United States-Canadian border. This phenomenon extends as far east as the west slope of the Rocky Mountains in Glacier National Park, and as far south as the Bitterroot Range. Known since the 1920s to have influenced the distribution of flowering plants, the "maritime extension" is also reflected in the distribution of non-vascular plants (DeBolt and McCune 1993, Elliott 1993, Elliot and Moore 1989, Hong 1975, McCune 1984). A few of the bryophyte species exhibiting this distributional pattern also extend along the north Pacific coast to Alaska, Russia, and Japan.

Another significant distributional pattern is the disjunct pattern of species common to both arid Eurasia and arid, low-elevation sites in the Columbia River basin and interior British Columbia (McIntosh 1986, 1989). This group consists of the arid North America and Eurasia bryoflora. Although the bryophyte flora of the arid lands is not rich, it contains species found nowhere else in the assessment area. It has been poorly collected because of the misconception that arid lands contain no bryophytes. Many of these species are important components of cryptogamic (also called cryptobiotic, microbiotic, or microphytic) soil crusts, most of which have been degraded or destroyed by agriculture and grazing.

Four taxa of bryophytes are endemic to the Columbia River basin or Rocky Mountain region of the assessment area. These are two mosses endemic to the northern or central Rocky Mountains (*Pseudoleskea incruvata* var. *tenviretis* and *P. radicosa* var. *pallida)* and two mosses endemic to the Columbia River basin *(Bryocrythrophyllum columbianum* and *Grimmia brittonize).*

Ecological Groups of Bryophytes—We listed bryophyte species for each substrate as ecological groups to broadly define some function in the ecosystem. The groups include: aquatic, submerged bryophytes; decaying wood, wet or dry bryophytes; epiphytic bryophytes; humus and duff bryophytes; bryophytes of peatlands, including fens and bogs; bryophytes of calcareous rock; bryophytes of other rocks; bryophytes of wet rock; bryophytes of alkali soil; bryophytes of dry soil; and bryophytes of wet soil.

Aquatic, submerged bryophytes occur mostly in montane areas where water is abundant, although specimens have been collected in arid areas from irrigation ditches, vernal pools and water troughs. Habitats range from perennially cold, clear water to organic mud in water with low or no flows. Many of these habitats dry up seasonally, but it is usually impossible to tell from the plant collection label data if this were the case for particular collection sites. Most species involved, except some aquatic liverworts such as *Chiloscyphus polyanthos*, can tolerate seasonal drying. Bryophytes may be abraded by waves, ice, and other debris, and in turn are habitat for a wide array of invertebrates, amphibians, and fish. They also are efficient sediment trappers, removing suspended particles, but cannot tolerate prolonged periods of turbidity. Upstream land-use patterns that affect water clarity can cause declines in these species.

Decaying wood, wet or dry bryophytes occur consistently as a group throughout the Basin, exclusively on decorticated to well-rotted logs and stumps. Cool to moist forest stands in deep shade are the most typical bryophyte habitat, and most occur in riparian areas and on stream terraces. The decaying wood, wet or dry bryophyte group contains the highest proportion of liverworts in the Basin and is composed of relatively common bryophyte species that are widespread in forested habitats throughout the region. Species diversity is richest in old-forest stands that provide cool, moist conditions and much decayed wood. The group is very sensitive to changes in light and moisture. Removal or thinning of the forest canopy results in elevated temperatures, desiccation, and increased light, all of which will diminish bryophyte viability. Their existence also depends on continued occurrence of rotten wood in various decay classes and diameters, which are used by the bryophytes as selected substrates. These logs are also sites for vertebrate and invertebrate habitat, nitrogen fixation, mycorrhizal activity, seedbeds, and the retention of water. The liverworts have their own mycorrhizal fungi whose functions are poorly understood. The liverworts may be associated with decomposer fungi or mycorrhizae of vascular plants.

Epiphytic bryophytes have not been well studied in the Basin except in Montana (Lesica and others 1991; McCune and Lesica 1992), and have generally been under-reported. We have listed 100 taxa as epiphytic, the majority occurring on the east slope of the Cascades (47 taxa), with a significant showing from the "maritime extension" zone, including the Palouse Prairie (26 taxa), the Idaho Batholith and Bitterroot Valley (27 taxa each), and the Okanogan Highlands (21 taxa). The remaining sections had fewer than 15 taxa reported from each. Epiphytic bryophytes are best developed in shaded, cool and humid forest conditions, especially in riparian areas and on stream terraces. Western red cedar, *(Thuja plicata)*, western hemlock, grand fir, subalpine fir (*Abies lasiocarpa*) and Engelmann spruce are the major tree species with good epiphyte cover. In drier sites, Douglas fir (*Pseudotsuga menziesii*) contains a sparse epiphyte flora that is relatively drought-tolerant and produces little bryophyte biomass. Steele (1978) found *Dicranum tauricum* to be the only true epiphyte in her study plots. Ponderosa pine *(Pinus ponderosa)*, lodgepole pine (*Pinus murrayana*), pinyon pine and juniper have a poor bryophyte flora because of drier habitat and flaking bark (Eversman 1982; Eversman 1990; Eversman and others 1987; Hong 1975).

Humus and duff bryophytes occur on shaded duff and humic soil in relatively dry forests at middle to upper elevations. They typically occur at midslope, on benches, or in concave microtopography subject to snow accumulation. All but *Brachythecium hylotapetum* are common and widespread. *Rhytidiopsis robusta* is collected commercially for the floral trade and may be depleted locally. Forest canopy removal increases light and temperature, and the ensuing desiccation leads to replacement of mesic bryophyte species by a suite of other more drought-tolerant bryophytes. Steele (1978) found that species of moss occurring in mesic forest associations were limited to those associations, but mosses of drier forests spanned several different associations.

Bryophytes of peatlands, including fens and bogs, have been neglected until recent work by Andrus and Layser (1976), Bursik and Moseley (1992a, 1992b), Bursik (1993), and Chadde and Shelly (1994). Peatlands occur in areas with impeded drainage, and in the assessment area are usually associated with glaciated basins. Incomplete decomposition of organic material, an artifact of anaerobic conditions in waterlogged soils, forms peat deposits favored by a distinctive array of vascular plants and cryptogams. Bogs form when peat builds up high enough to inhibit upward capillary movement of groundwater that has been in contact with mineral soil. In these cases, precipitation becomes the only source of nutrients available for plants growing on the peat. Rain and snow are a poor source of nutrients for these

plants, and sphagnum moss growing in these sites further depresses the pH by absorbing the scarce nutrients and giving off hydrogen ions in exchange. Fens, in contrast, are rich in nutrients because of calcareous soils or bedrock and because peat does not build up high enough to inhibit the effects of enriched groundwater. Distinctive groups of bryophyte species occur in each wetland type, all bryophyte species of which are circumboreal in distribution. The peatland flora encountered in the assessment area is more similar to that in the northern Rocky Mountains of Alberta and British Columbia than it is to peatlands in the Cascade Range. These habitats have not been explored adequately.

Bryophytes of calcareous rock also constitute a characteristic flora although many common rock-inhabiting taxa also occur on calcareous rocks. Calcareous outcrops are uncommon in the Columbia River basin, and few bryophytes have been collected from them. Sixty-one taxa were recorded from calcareous substrates, including well-known calciphiles such as *Eucladium verticillatum, Fissidens grandifrons, Gymnostomum aeruginosum* and two species of *Seligeria.*

Bryophytes of other rocks occur in the Basin, as rocks and rock outcrops are ubiquitous in the assessment area. Bryophytes of other rocks can be found from arid lands at low elevation to forested outcrops at middle to upper slopes and along ridge tops, and on rocks at or above timberline. A distinctive array of bryophytes occurs on rocks. These bryophytes tolerate extremes in heat, cold, and drought. Most such rock bryophytes are widespread throughout the Basin, and in many arid areas the bryophyte flora is composed exclusively of rock-dwelling species. In exposed areas at all elevations, most bryophyte cover occurs on shaded or otherwise protected rock faces where moisture persists longer (Lavin 1982, McCune 1977, Nash and others 1977, Spence 1981). Rock bryophytes may also be subject to nitrogen enrichment at bird roosts and packrat latrines, which can limit bryophyte growth on rock faces. Rock-dwelling species adapted to shade in forest stands, such as at the base of outcrops, are replaced by xerophytic species when the forest canopy is removed. Because of their position on slopes and ridges, stands at the base of outcrops are subject to catastrophic fire, and the bryophytes in this species group probably develop only after long periods of canopy stability.

Bryophytes of wet rock occur wherever there is perennial or seasonal water. Species may occur in the splash zone just above the level of mean summer flows, in small to large fast-flowing streams, or in the spray zone of rapids and waterfalls. They may also occur on seasonally wet rock outcrops where seepage occurs. Like aquatic bryophytes, these species are abraded by waves, ice, and other debris, and perform many of the same functions for invertebrate, amphibian, fish habitat, and sediment trapping. Although they are efficient sediment trappers, these bryophyte species cannot tolerate excessive turbidity or siltation. As with the aquatic group, species on wet rocks could be adversely affected by land-use patterns upstream.

Bryophytes of alkali soil have been poorly sampled or reported in the Basin. We found so few collections (four records, two taxa) consistently labeled as coming from alkaline habitats that, for purposes of data analysis, we lumped them in the dry soil category. Few collectors have worked in these areas, but given the widespread occurrence of alkali, there is probably a richer flora than that reported here. Some collectors probably did not realize that they were collecting in alkaline areas. The bryophyte flora of alkaline areas is poor, and is mostly restricted to where vascular plants such as *Sarcobatus, Atriplex, Kochia* and *Distichlis* can grow. Sites typically have some seasonal flooding that concentrates salts upon evaporation. Flowers (1933) noted that mosses can tolerate soil up to an average condition of about 0.8 percent alkali. He found no mosses on sodium carbonate, and tolerance up to 0.5 percent of sodium chloride, but a relative abundance of mosses on calcium phosphate. Flowers (1933, 1973) and McIntosh (1986) found some species characteristic of, or restricted to, alkaline sites (for example, *Desmatodon heimii, Pottia nevadensis),* while other species could tolerate alkali

but also grew in non-alkaline habitats (for example, *Bryum caespiticium, Ceratodon purpureus, Conardia compacta, Funaria hygrometrica, Leptobryum pyriforme, Pterygoneurum subsessile, Tortula brevipes, Tortula ruralis*). The latter species may occur on alkali because of the seasonal availability of water. The bryoflora of this habitat needs further investigation in the assessment area.

Bryophytes of dry soil occur on exposed or shaded mineral soil at all elevations. Primary succession on recently disturbed soil includes many common, opportunistic species that rapidly colonize sites, stabilize soil, and enhance invasions by other cryptogams or vascular plants. These are often drought-tolerant, short-lived assemblages that are replaced by others within one or two years. At low elevation in arid areas, bryophytes are a significant component of soil crusts, where they harbor nitrogen-fixing cyanobacteria, stabilize soil by trapping particles, reduce wind erosion, and enhance water infiltration and seed germination (Anderson and Rushforth 1976, Harper and Marble 1988). In contrast to pioneer associations on disturbed soil, these crusts take many years to form, are long-lived, and suffer long-term damage from fire, livestock trampling, and off-road vehicle traffic (Beymer and Klopatek 1992, Johansen and others 1984). At middle to higher elevations, soil-dwelling bryophytes occur in shaded forests, on root balls of windthrown trees, and on exposed soil of trails, roads, and earth slumps. Near timberline, they occur on glacial moraines and outwash, especially where protected by rocks in areas where snow may accumulate (Spence 1981). Some of these associations may also be long-lived rather than recent immigrants. The distribution of some soil-dwelling species is irregular and unpredictable.

Bryophytes of wet soil occur on moist to wet soils, with or without organic content. Most species of this group are widespread and occur wherever water is available. Habitats include edges of lakes and streams, moist organic soil over rocks in shrub thickets, margins of avalanche tracks, seepage areas, and the bases of talus slopes. Sites often have late-lying snow beds. In spite of the widespread occurrence of this habitat, distribution of associated species may be sporadic and unpredictable. Some species need the shaded, moist microclimate provided by a forest canopy and are very sensitive to desiccation. They are readily replaced by other species in more exposed situations. Common wet soil bryophytes in riparian areas, such as *Marchantia polymorpha* and *Philonotis fontana*, are readily extirpated by livestock trampling.

Rare or Sensitive Bryophyte Species— Schofield (1994) defined a rare bryophyte as "one that shows a restricted geographic range, usually of less than five square kilometers, or one that is known from fewer than five localities, even when these localities are widely distant from each other." This definition of rarity is essentially the same as that developed by The Nature Conservancy, used by Natural Heritage Programs and Conservation Data Centers to rank global and state or provincial rarity of organisms or plant communities (Andrus and others 1992, Master 1991). Using Paradox®, we tallied the total number of occurrences of each taxon in the assessment area and selected as potentially rare all taxa with five or fewer occurrences in the assessment area. Inherent in the interpretation of rarity in bryophytes is the problem of poorly collected areas. What looks rare on paper may actually be abundant in the field. A bryophyte's apparent rarity may only be an artifact of undercollecting.

A count of all taxa with five or fewer records in the assessment area yielded 411 taxa (appendix 5D), of which two were hornworts (0.2%), 106 were liverworts (26%), and 303 were mosses (74%). Such a large number, approximately half the total bryoflora of the study area, is consistent with similar tallies of bryophytes and lichens in Oregon, and reflects not the actual rarity of species, but only our ignorance about their distribution patterns (Christy 1991). Recognizing that this list is subject to change is important as few of these specimens have been verified with subsequent collection or identification.

To simplify interpretation of the survey results, the 411 taxa in appendix 5D were assigned to eight categories, some of which overlap, depending on type of category.

(1) endemic
  (a) western North American
  (b) Columbia River Basin
  (c) dry interior
  (d) central and northern Rocky Mountains
(2) Mediterranean climate in western North America
(3) eastern North America
(4) arid southern climate
(5) circumpolar
(6) discontinuous distribution, including:
  (a) bipolar disjuncts
  (b) North Pacific Ocean
  (c) humid interior "maritime extension"
  (d) western North America and western Europe
  (e) western North America and eastern North America
  (f) broken circumpolar
  (g) circumalpine
(7) cited in literature as rare
(8) problem taxa, including:
  (a) species status poorly known
  (b) needing verification, possibly representing range extensions
  (c) invalid names or probable misidentifications

Some 360 bryophyte taxa appear to be rare in the Basin (this set consists of the 411 taxa listed in appendix 5D less the 52 "problem taxa" listed in appendix 5D, section 8). Several other taxa are well documented as rare, even though they may have more than five records from the study area. Lists of taxa by state within the assessment area, physiographic province, and substrate are presented in Christy and Harpel (1995).

Vascular Plants

Due to large-scale vegetation shifts related to climatic changes, the presence of a high diversity of geological substrates, and barriers to gene flow caused by mountainous topography and other geographical barriers, western North America has been an area of very active evolution for vascular plants. The flora of the Basin reflects this divergent history. The native flora of the Basin includes a spectacular diversity of plant taxa that range from geographically restricted endemics, some known only from one or a few occurrences, to those that are common and widespread. Vascular plant life forms range from the largest terrestrial organisms in the assessment area (for example, trees up to 100 m in height) to the smallest flowering plants known (aquatic plants in the genus *Wolffia*, the individuals of which measure 1 mm or less).

The evolutionary history and resultant floristic diversity of the Basin is a reflection of the complexity of its biophysical environments. The influence of many of these environments on the flora has been manifested through natural selection of species in edaphically (soil-related) or physically unique habitats, such as chemically stringent substrates weathered from ultramafic (serpentine) or calcareous (limestone) bedrock, coarse-textured soils, and climatically harsh alpine environments. The presence of high environmental gradients with respect to temperature and moisture also has contributed to evolutionary diversification in the flora of the Basin. The Basin is unique in North America because it contains habitats that range from highly arid deserts to temperate humid forests, across elevations from near sea level to more than 4,000 meters. Owing to this floristic and environmental diversity, the Basin also contains a large number of seral and climax plant community types.

Compilation of a complete list of vascular flora for the assessment area is in progress, and contains a preliminary checklist of approximately 8,000 species. Especially noteworthy is the high number of endemic vascular plants whose ranges lie wholly

or partially in the assessment area (table 5.9). There are 82 such plant taxa that are local endemics; these taxa are restricted to very small geographic areas (for example, one portion of a mountain range, or one canyon). Local endemics also are often restricted to highly specific habitats (for example, chemically unique rock outcrops such as serpentine). In addition, 72 plant taxa are regional endemics (table 5.9); these taxa have larger geographic ranges than local endemics but are still confined to a relatively small region (for example, southeast Washington, northern Idaho, and northwest Montana for a Palouse grassland endemic). Regional endemics also may be closely associated with specific habitats, and their ranges may lie entirely within the assessment area. An example of a local endemic is *Castilleja christii*, a species that occurs only on one mountain summit in the Albion Range in south-central Idaho. *Penstemon lemhiensis*, an example of a regional endemic, occurs in four counties in southwest Montana and one county in adjacent east-central Idaho.

A primary focus of the vascular plant analysis was on taxa of conservation concern across their geographic range (table 5.9; data on the geography, trends, and threats to vascular plant species of special concern is on file, TS 1995). Such taxa include: (1) taxa currently listed as threatened or endangered under the federal Endangered Species Act; (2) taxa that are candidates (C1 or C2 candidates) or officially proposed for such listing; and (3) rare taxa with no current status that were recommended by the vascular plant expert panels for Federal listing or candidate status or for which there is a conservation concern (table 5.9). In some cases, species that were formerly C1 or C2 candidates but are now in Category 3 (no longer being considered for Federal listing) were also evaluated.

Rare Plant Communities—With increases in human influence on ecological processes, vegetation structure and function, and native plant communities, ecosystems across the United States have declined significantly. Langner and Flather (1994) expressed concern for recent declines in native biodiversity in the United States, and encouraged conservation of gene pools, species, communities, and ecosystems. Concerns such as these prompted the need to identify and assess the status of rare plant communities within the Basin.

Plant communities that are rare because of a unique set of abiotic features or because of land-altering human activities are especially vulnerable to change. For example, the bunchgrass grasslands of the Palouse region, once expansive in area, have been reduced to a few remnant stands in the wake of agricultural conversion. Low elevation cedar/hemlock old forests, on the other hand, may never have occupied a large proportion of the landscape, yet have been disproportionately affected due to the extraction of the large volumes of timber available in these highly productive areas. The potential for restoration of rare plant communities may be prioritized and perhaps expedited by knowing which communities are globally rare and the reason for their rarity.

Results of our vascular plant community assessments are presented fully in Croft and others (in prep.). Scant information exists on many plant communities. Typically, they occupy small areas on the land, which precludes many types of statistical analyses at a broad spatial scale. Few of these communities are mapped.

Plant Species of Concern to Tribes—A list of 205 vascular plant taxa deemed by the ICBEMP to be particularly significant to American Indian tribes in the Basin was compiled (table 5.10). This list of species is not a complete list of all plants used and valued by the American Indian tribes in the assessment area, but rather a set of representative species and species of greater cultural significance.

The plant species of tribal concern are listed here by scientific name. However, plants named by a plant taxonomist would not necessarily be recognized in the same way by a tribal member. An example is *Lomatium nudicaule*. In the spring, when the first sprouts appear, this plant is called *pt'ishpt'ish* in Warm Springs Sahaptin which refers to its edible first leaves.

Table 5.9— Plant species analyzed individually in the Terrestrial Ecology chapter, their U.S. Fish and Wildlife Service candidate status and their geographic distribution category: re= regional endemic, le=local endemic, sc=scattered, pe=peripheral, dj=disjunct; *=taxa of conservation concern to expert panels, E=endangered, T=threatened, PE=proposed endangered, C1=Category 1 candidate, C2=Category 2 candidate.

Scientific Name	USFWS Status	Distribution Category
Texosporum sancti-jacobi	C2	re
Abronia ammophila	C2	le
Achnatherum wallowaensis	*	re
Agrostis rossiae	C2	le
Allium aaseae	C1	le
Allium dictuon	C1	le
Amsinckia carinata	C1	le
Anntenaria arcuata	C2	sc
Anntenaria aromatica	C2	sc
Arabis falcifructa	C2	re
Arabis fecunda	C2	re
Arabis suffrutescens var. *horizontalis*	C2	le
Artemisia campestris var. *wormskioldii*	C1	re
Artemisia ludoviciana ssp. *estesii*	C2	le
Aster jessicae	C1	re
Aster mollis	C2	re
Astragalus anserinus	C2	re
Astragalus applegatei	E	le
Astragalus atratus var. *inseptus*	C2	le
Astragalus collinus var. *laurentii*	C2	le
Astragalus columbianus	C1	le
Astragalus diaphanus var.*diaphanus*	C2	re
Astragalus diaphanus var. *diurnus*	C2	le
Astragalus howellii	C2	le
Astragalus mulfordiae	C1	re
Astragalus onciformis	*	re
Astragalus paysonii	C2	re
Astragalus peckii	PE	re
Astragalus pulsiferae var. *suksdorfii*	C2	dj
Astragalus scaphoides	*	re
Astragalus siunatus	C2	le
Astragalus soliatarius	C2	re
Astragalus sterilis	C2	re
Astragalus tegetarioides	C2	re
Astragalus tyghensis	C2	le
Astragalus vexillflexus var. *nubilus*	C2	le
Astragalus yoder-williamsii	C2	re
Balsamorhiza rosea	*	le
Botrychium ascendens	C2	sc
Botrychium crenulatum	C2	sc
Botrychium lunaria	*	pe
Botrychium paradoxum	C2	sc
Botrychium pedunculosum	C2	sc
Botrychium pumicola	C2	le
Calchortus longebarbatus var. *longebarbatus*	C2	re

Table 5.9 (continued).

Scientific Name	USFWS Status	Distribution Category
Calchortus longebarbatus var. *peckii*	C2	le
Calchortus nitidus	C1	re
Camissonia pygmaea	*	le
Carex lenticularia var. *dolia*	C2	pe
Carex parrayana ssp. *idahoa*	*	re
Castilleja chlorotica	C2	re
Castilleja christii	C1	le
Castilleja cryptantha	C2	le
Castilleja fraterna	C2	le
Castilleja pilosa var. *steenensis*	C2	le
Castilleja rubida	C2	le
Chaenactis cusickii	C2	re
Chrysothamnus parryi ssp. *montanus*	FC2	le
Claytonia lanceolata var. *flava*	*	pe
Claytonia umbellata	*	le
Collomia mazama	C2	re
Collomia renacta	C2	sc
Cymopterus acaulis var. greeleyorum	*	le
Cymopterus davisii	C2	le
Cymopterus douglassii	C2	re
Cymopterus nivalis	C2	sc
Cypripedium fasiculatum	C2	sc
Delphinium viridescens	C1	le
Descurainia torulosa	C2	re
Douglasia idahoensis	C2	re
Draba trichocarpa	C1	le
Erigeron basalticus	C1	le
Erigeron lackschewitzii	C2	le
Erigeron latus	C2	re
Erigeron salmonensis	C2	re
Eriogonum chrysops	C1	le
Eriogonum crosbyae	C2	le
Eriogonum cusickii	C2	re
Eriogonum lewisii	C2	re
Eriogonum meledonum	C2	le
Eriogonum novonudum	*	re
Eriogonum prociduum	C2	re
Erythronium grandiflorum var. nudipetalum	*	le
Gratiola heterosepala	*	pe
Grindelia howellii	C2	re
Hackelia cronquistii	C1	re
Hackelia venusta	C1	le
Happlopappus insecticruris	C1	le
Happlopappus liatriformis	C2	re
Happlopappus radiatus	C1	re
Happlopappus uniflorus var. *howellii*	*	re
Howellia aquatilis	T	sc
Iliamna longisepala	*	re
Ivesia rhypara var.*rhypara*	C2	re

Table 5.9 (continued).

Scientific Name	USFWS Status	Distribution Category
Ivesia rhypara var.*shellyi*	C2	le
Lathyrus grimesii	C2	le
Lepidium davisii	C2	re
Lepidium papilliferum	C2	re
Leptodactylon glabrum	C2	le
Leptodactylon pungens ssp. *hazeliae*	C2	le
Lesquerella carinata var. *carinata*	C2	re
Lesquerella carinata var.*languida*	*	le
Lesquerella humilis	C2	le
Lesquerella paysonii	C2	re
Lesquerella sp. nov. *("pulchella")*	*	re
Limnanthes floccosa ssp. *bellingeriana*	C2	re
Lomatium erthrocarpum	C1	le
Lomatium greenmanii	C1	le
Lomatium sp. nov. *("Ochocensis")*	*	le
Lomatium suksdorfii	C2	re
Lomatium tuberosum	C2	le
Luina serpentina	C1	le
Lupinus biddlei	C2	re
Lupinus cusickii	C2	le
Meconella oregana	C2	sc
Mentzelia mollis	C2	re
Mentzelia packardiae	C2	re
Mimulus clivicola	C2	re
Mimulus evanscens	*	re
Mimulus hymenophylla	C2	le
Mimulus jungermannioides	C2	re
Mimulus patulus	C2	le
Mimulus pygmaeus	C2	re
Mimulus washingtonensis var.*washingtonensis*	C2	re
Mirabilis biglovii var. *retrosa*	*	dj
Mirabilis macfarlanei	E	le
Musineon lineare	*	dj
Oenothera psammophila	C1	le
Oryzopsis contracta	C2	sc
Oryzopsis hendersonii	*	re
Oxytropis campestris var. *columbiana*	*	re
Oxytropis pygmaeum	C2	re
Parnassia kotzebuei var. *pumila*	*	le
Penstemon "nikei"	*	le
Penstemon barrettiae	C2	re
Penstemon compactus	C2	re
Penstemon glaucinus	C2	re
Penstemon idahoensis	C2	le
Penstemon lemhiensis	C2	re
Penstemon peckii	C2	le
Perideridia erthrohiza	C2	le

Table 5.9 (continued).

Scientific Name	USFWS Status	Distribution Category
Petrophytum cinerascens	C1	le
Phacelia inconspicua	C2	sc
Phacelia lenta	C2	le
Phacelia lutea var. *calva*	*	re
Phacelia lutea var. *mackenzeorum*	*	re
Phacelia minutissima	C2	sc
Phlox idahonsis	C1	le
Physaria didymocarpa var. *lyrata*	C2	le
Physaria integrifolia var. *monitcola*	C2	re
Pleuropogon oregonus	C1	re
Polemonium pectinatum	C1	re
Potentilla cottamii	C2	re
Primula alcalina	C2	le
Ranunculus reconditus	C1	le
Rorippa coulmbiae	C2	sc
Rubus bartonianus	C2	le
Rubus nigerrimus	C1	le
Saxifraga bryophora var. *tobiasiae*	C2	le
Senecio ertterae	C1	le
Sidalcea oregana var. *calva*	C1	le
Silene seelyi	C2	le
Silene spaldingii	C2	re
Sisyrinchium sarmentosum	*	le
Stanleya confertifolia	*	sc
Stephanomeria malheurensis	E	le
Sullivantia hapemanii var. *hapemanii*	C2	dj
Tauschia hooveri	C2	le
Thelypodium eucosmum	C2	re
Thelypodium howellii ssp. *howellii*	*	le
Thelypodium howellii ssp. *spectabilis*	C1	le
Thelypodium repandum	C2	le
Tofieldia glutinosa ssp. *absona*	C2	le
Trifolium douglasii	*	re
Trifolium leibergii	C2	le
Trifolium owyheense	C2	re
Trifolium thompsonii	C1	le

Table 5.10— A list of 205 plant taxa found by the Science Integration Team to be of particular interest to American Indian tribes within the Basin.

Abies amablis
Abies concolor
Abies grandis
Abies lasiocarpa
Abies spp.
Acer circinatum
Acer glabrum
Agastache occidentalis
Agrostis exarata
Agrostis scabra
Allium acuminatum
Allium douglasii
Allium macrum
Allium madidum
Allium tolmiei
Alnus incana tenuifolia
Alnus spp.
Alopecurus aequalis
Amaranthus graecizans (blitoides)
Amelanchier alnifolia
Ampocynum androsaemi folium
Ampocynum cannabinum
Apocynum androsaemifolium
Apocynum cannabinum
Arctostaphylos nevadensis
Arctostaphylos patula
Arctostaphylos uva-ursi
Artemisia tridentata
Atriplex confertifola
Balsamorhiza careyana
Balsamorhiza hookeri
Balsamorhiza sagitatta
Beckmannia syzigachne
Berberis aquifolium
Berberis nervosa
Betula microphylla
Brodiaea douglassi
Brodiaea howellii
Brodiaea hyacinthina
Calochortus macrocarpus
Cameassia quamash
Carex sp.
Celtis douglasii (occidentalis)
Cercocarpus ledfolius
Chenopodium fremontii
Chrysothamnus bloomeri
Chrysothamnus nauseosus
Cirsium foliosum
Cirsium scariosum
Claytonia lanceolata
Conium maculatom
Cornis stolonifera (pubescens)
Corylus cornuta
Crateagus columbiana
Crateagus douglasii
Daucus pusillus
Descurainia pinnata var. *Filipes*
Descurainia sophia
Elymus canadensis
Elymus cinereus
Equisetum hyemale
Eriogonum umbellatum var. *stellatumi*
Erythronium grandiflorum var. *nudipetalum*
Fragaria vesca
Fragaria virginiana
Fritillaria pudica
Gilia aggregata
Helianthus annuus
Helianthus cusickii
Heracleum lanatum
Holodiscus discolor
Iris missouriensis
Juncus balticus
Juniperus occidentalis
Larix occidentalis
Lepidium perfoliatum
Lewisia rediviva
Ligusticum canbyi
Lilium columbianum
Lilium parvum
Lomatium californicum
Lomatium canbyi
Lomatium cous
Lomatium dissectum var. *dissectum*
Lomatium farinosum
Lomatium gormanii
Lomatium grayi
Lomatium hambleniae
Lomatium hendersonii
Lomatium leptocarpum
Lomatium macrocarpum
Lomatium minus
Lomatium nevadense
Lomatium nudicaule
Lomatium piperi
Lomatium salmoniflorum
Lomatium triternatum
Lonicera involucrata
Lygodesmia spinosa
Madia glomerata

Table 5.10 (continued).

Mentha arvensis
Mentha canadensis
Mentha piperita
Mentha spicata
Mentzelia albicaulis
Mentzelia congesta
Mentzelia laevicaulis
Microseris sp.
Microseris troximoides
Monardella odoratissima
Nicotiana attenuata
Nuphar polysepalum
Oenothera pallida
Opuntia fragalis
Opuntia polyacantha
Oryzopsis hymenoides
Osmorhiza occidentalis
Pedasites frigidus var. *palmatus*
Penstemon speciosus
Perideridia bolanderi
Perideridia gairdneri
Perideridia oregona
Philadelphus lewisii
Phragmites australis
Phragmites communis
Picea engelmanii
Pinus abicaulis
Pinus contorta
Pinus lambertiana
Pinus murrayana
Pinus ponderosa
Plectritis sp.
Polygonum douglasii
Populus tremuloides
Prunus emarginata
Prunus subcordata
Prunus virginiana
Pseudotsuga menziesii
Pseudotsuga mucronata
Purshia tridentata
Quercus garryana
Rhus glabra
Ribes aureum
Ribes bracteosum
Ribes cereum
Ribes inerme
Ribes lacustre
Ribes oxyacanthoides
Ribes sanguineum
Ribes velutinum
Rorippa curvisiliqua
Rosa californica
Rosa nutkana
Rosa spp.
Rosa woodsii
Rubus ideaus
Rubus laciniatus
Rubus macropetalus
Rubus nivalis
Rubus parviflorus
Rubus spectabilis
Rubus ursinus
Rumex paucifolius
Rumex salicifolius
Sagitarria cuneata
Salix amygdaloides
Salix lasiandra
Sambucus cerulea
Sambucus racemosa ssp. *pubens* var. *melanocarpa*
Sarcobatus vermiculatus
Scirpus acutus (lacustris)
Scirpus validus
Shepherdia canadensis
Sisymbrium altissimum
Sium suave
Sparganium eurycarpum
Sphenosciadium capitellatum
Sphepherdia argentea
Sphepherdia canadensis
Suaeda depressa
Suaeda dynessa
Suaeda intermedia
Tauschia hooveri
Thuja plicata
Trifolium macrocephalum
Trifolium tridentatum
Triteleia grandiflora
Triteleia hyancinthina
Tsuga mertensiana
Typha latifolia
Urtica sp.
Vaccinium alaskaense
Vaccinium caespitosum
Vaccinium deliciosum
Vaccinium membranaceum
Vaccinium occidentali
Vaccinium ovalifolium
Vaccinium parvifolium
Vaccinium scoparium
Valeriana edulis
Veratrum spp.
Wyethia amplexicaulis
Wyethia mollis
Xerophyllum tenax
Zigadenus venenosus

Mature plants with a stout edible stem are referred to as *xamsi*, while other plants with a narrow spindly stem are called *ashwaniya* which means "slave to *xamsi*" (from a story) and are not eaten. These are not, strickly speaking, names for stages of growth; rather, these are individual names for recognizably different plants (Helliwell 1995).

Vascular plant taxonomy is further complicated by local differences in what one tribal group prefers relative to another and also by differences within a taxon across its range. For instance, *Lomatium piperi* and *L. gormanii* are two closely related species often mistaken for one another. However, in central Washington, members of the Yakama Tribe readily distinguish between the two. *L. piperi* is recognized as edible whereas *L. gormanii* is eschewed as "groundhog food." In contrast, in southern Oregon *L. gormanii* is considered quite palatable.[18]

Management of culturally significant plants involves maintaining species viability as well as harvestability and long-term sustained use. For the most part, vascular plants of tribal interest are not rare species. Most are at least locally abundant. One conservation objective may be to ensure that large, healthy, accessible populations will be sustained over the long term.

***Ex Situ* and *In Situ* Conservation of Rare Plants**—*Ex situ* or "off-site" conservation includes a range of activities more or less distinct from *in situ* or "on-site" activities. Off-site and on-site activities often overlap. *Ex situ* activities include seed storage, maintaining living collections in botanical gardens, or various research activities.

[18] Personal communication. 1995. L. Housley, U.S. Department of Interior, Bureau of Land Management, Lakeview Resource Area, P.O. Box 151, Lakeview, Oregon 97630.

Ex situ plant conservation is not an alternative to *in situ* plant conservation, but both are part of a larger, comprehensive conservation effort (McMahan 1990). The Botanic Gardens Conservation Strategy, jointly produced by the World Conservation Union (IUCN), Botanic Garden Conservation International (BGCI: formerly Botanic Garden Conservation Secretariat, or BGCS), and the Worldwide Fund for Nature (WWF), stated: "*In situ* and *ex situ* are the opposite ends of a spectrum and there is no absolute distinction between them." The document goes on to call for a "seamless blend" of *in situ* and *ex situ* conservation as the most effective way to conserve plant species and ecosystems. (Additional information is available in contract reports on file; see appendix 5B for titles.)

Invertebrates

Terrestrial invertebrates are the greatest source of biological diversity within the Basin. Invertebrates are critical components of many ecosystem functions and can make excellent bioindicators of soil and vegetation health. Invertebrates are sensitive indicators of change, and can be used to index changes in the environment at small, spatial and very short, temporal scales.

There are no strictly terrestrial invertebrates that are federally listed as endangered or threatened in the assessment area. One aquatic invertebrate species is listed as threatened and four are listed as endangered (table 5.8). No invertebrates are listed as C1 candidates. Thirty-eight invertebrates (many are aquatic and are not discussed here) are listed as C2 candidates (TS 1995). In the Basin, none of the Forest Service regions lists any terrestrial invertebrate species on their regional sensitive species lists, although individual National Forest lists might vary. The BLM regional offices list 25 (TS 1995). A number of rare or endemic invertebrates exist in the Basin, and some may bear further watching (table 5.11).

Table 5.11— Rare and endemic invertebrate species[1] [L = need attention (potential for listing)[2]; C = currently listed; W = recommended to watch[3]].

Class/Order	Genus and Species	USFWS Category 1 or 2 Status	USDA-FS/USDI-BLM Sensitive
Gastropoda	**Snails**		
	Allongona lombardii	L	L
	Allongona ptychophora solida	L	L
	Anguispira nimapuna	L	L
	Cryptomastix n. sp. 1	L	L
	Cryptomastix n. sp. 2	L	L
	Cryptomastix populi	L	L
	Cryptomastix harfordiana	L	L
	Cryptomastix hendersoni	L	L
	Cryptomastix magnidentata	L	L
	Cryptomatix mullani blandi	L	L
	Cryptomastix mullani clappi	L	L
	Cryptomastix mullani latilbris	L	L
	Cryptomastix mullani tuckeri	L	L
	Cryptomastix n. sp. 1	L	L
	Cryptomastix n. sp. 2	L	L
	Cryptomastix n. sp. 3	L	L
	Cryptomastix n. sp. 4	L	L
	Cryptomastix sanburni	L	L
	Discus marmorensis	L	L
	Megomphix lutarius	L	C
	Monadenia fidelis n. subsp. 1	L	L
	Monadenia n. sp. 1	L	L
	Ogaridiscus subrupicola	L	L
	Oreohelix alpina	L	L
	Oreohelix amariradix	L	L
	Oreohelix carinifera	L	L
	Oreohelix elrodi	L	L
	Oreohelix hammeri	L	L
	Oreohelix haydeni hesperia	L	L
	Oreohelix haydeni perplexa	L	L
	Oreohelix idahoensis idahoensis	C	L
	Oreohelix intersum	L	L
	Oreohelix junii	L	L
	Oreohelix n. sp. 1	L	L
	Oreohelix n. sp. 2	L	L
	Oreohelix n. sp. 3	L	L
	Oreohelix n. sp. 4	L	L
	Oreohelix n. sp. 5	L	L
	Oreohelix n. sp. 6	L	L
	Oreohelix n. sp. 7	L	L

Table 5.11 (continued).

Class/Order	Genus and Species	USFWS Category 1 or 2 Status	USDA-FS/USDI-BLM Sensitive
	Oreohelix n. sp. 8	L	L
	Oreohelix n. sp. 9	W	W
	Oreohelix n. sp. 10	L	L
	Oreohelix n. sp. 11	L	L
	Oreohelix n. sp. 12	L	L
	Oreohelix n. sp. 13	L	L
	Oreohelix n. sp. 14	L	L
	Oreohelix n. sp. 15	L	L
	Oreohelix n. sp. 16	L	L
	Oreohelix n. sp. 17	L	L
	Oreohelix n. sp. 18	L	L
	Oreohelix n. sp. 19	L	L
	Oreohelix n. sp. 20	L	L
	Oreohelix n. sp. 21	L	L
	Oreohelix n. sp. 22	L	L
	Oreohelix n. sp. 23	L	L
	Oreohelix n. sp. 24	L	L
	Oreohelix n. sp. 25	L	L
	Oreohelix n. sp. 26	L	L
	Oreohelix n. sp. 27	W	W
	Oreohelix n. sp. 28	L	L
	Oreohelix n. sp. 29	L	L
	Oreohelix n. sp. 30	L	L
	Oreohelix n. sp. 31	L	L
	Oreohelix strigosa delicata	L	C
	Oreohelix strigosa goniogyra	C	L
	Oreohelix strigosa n. subsp. 1	L	L
	Oreohelix tenuistriata	L	L
	Oreohelix variabilis	L	L
	Oreohelix variabilis n. subsp. 1	L	L
	Oreohelix vortex	C	L
	Oreohelix waltoni	C	L
	Pristiloma arcticum crateris	L	L
	Pristiloma idahoense	L	L
	Pristiloma wasnocnoc	L	L
	Vespericola columbiana depressa	L	L
	Vespericola n. sp. 1	L	L
	Vespericola sierranus	L	L
	Slugs	L	L
	Hemphillia camelus	L	L
	Hemphillia danielsi	L	L
	Hemphillia malonei	L	L
	Hemphillia mycophaga	L	L
	Prophysaon humile	L	L

Table 5.11 (continued).

Class/Order	Genus and Species	USFWS Category 1 or 2 Status	USDA-FS/USDI-BLM Sensitive
	Udosarx lyrata lyrata	L	L
	Udosarx lyrata russelli	L	L
Insecta/Coleoptera	*Cicindela columbica*	L	
	Ctenicera barii		W
	Scaphinotus mannii	L	
Insecta, Hemiptera:Heteroptera	*Micracanthia fennica*		W
	Ambrysus mormon		W
	Boreostolus americanus		W
	Chorosoma sp. nov		W
	Hebrus buenui		W
Insecta, Hymenoptera	*Andrena aculeata*		
	Andrena winnemuccana		
	Ashmeadiella sculleni		
	Hesperapis kayella n. sp.		
	Hylaeus lunicraterius		
	Macropis steironema opaca		
	Megachile umatillensis		
	Nomadopsis barri		
	Osmia ashmeadii		
	Osmia cascadica n. sp		
	Perdita accepta		
	Perdita crassihirta		
	Perdita similis pascoensis		
	Perdita barri		
	Perdita salicis cuxantha		
	Perdita salicis sublaeta		
	Perdita wyomingensis sculleni		
	Perdita wyomingensis wyomingensis		
	Proteriades n. sp. *near plagiostoma*		
	Proteriades orthognathus		
	Synhalonia douglasiana		
	Synhalonia frater lata		
Insecta/Lepidoptera	*Parnassius clodius shepardi*	L	L
Oligochaeta	*Driloleirus americanus*		L
	Drilochaera chenowithensis		
	Argilophilus hammondi		

[1] These species are currently not listed by any public entity as needing protection. It is the judgment of species or functional group experts that these species be considered for possible measures by federal or state agencies to protect these species.

[2] For reasons specified in the contract reports, these species are thought to need specific attention.

[3] These species are either rare or endemics. There is no information to indicate that special measures are needed at this time to protect them or their habitats; however, because of reasons listed in the contract reports it is prudent to validate their status occasionally. Species with no indicators (L, C or W) are not known to need special protection.

Unique or Representative Habitats

Given the importance of habitat for conservation of invertebrates, unique or representative habitats key to the conservation of the Basin's invertebrate fauna of the assessment area are listed below. These habitats represent a partial list biased toward the taxa investigated in this assessment. Further work will need to address all invertebrates.

- Forested Habitats
  - Montane old conifer forest
  - Old ponderosa pine
  - Oregon white oak woodland
  - Douglas maple
  - Canyon bottom willow swamp
  - Forested/shaded talus
  - Natural riparian woodland in shrub-steppe zone
- Grasslands
  - Mountain meadow
  - Parks in ponderosa pine forest
  - Grassland oak savanna
  - Undisturbed meadow steppe (edge of Cascade Mountains)
  - Undisturbed meadow steppe (Palouse hills)
  - Undisturbed shrub-steppe at pine forest edge
  - Undisturbed shrub-steppe in Columbia River basin
  - Sand dune steppe
- Wetlands
  - Sphagnum bog
  - Low-elevation marshy pond in forest
  - Fen-type bog in Okanagon highlands
  - Hot spring
- Other unforested habitats
  - Alkaline lake shore
  - Cave

Functional Roles of Invertebrates[19]

The following sections discuss groups of invertebrates that perform similar ecological functions. The functions discussed include detritivory and nutrient cycling, wood decomposition, the herbivory functions of snails and slugs, predation, pollination, and grassland and forestland herbivory.

Detritivory and Nutrient Cycling—Contemporary studies indicate that soil resembles a living entity. It "lives" and "breathes" through a complex mix of interacting organisms ranging from viruses and bacteria, fungi, nematodes, and arthropods to ground squirrels, marmots, and badgers. Microbial biomass alone can reach 10,000 kilograms/hectare in productive, inland, western forest soils. Activities of all these organisms are responsible for developing the critical properties that underlie basic soil fertility, health, and productivity. Biologically driven properties resulting from such complex interactions require up to several hundreds of years to develop. No quick fixes are available if extensive damages occur.

Productive ecosystems tend to retain nutrients. Over time, nutrients are metabolized to forms that are less available for plants and animals such as phytates, lignins, tannins, and humic and fulvic acids. For nutrients to once again become available to plants and animals, they must be mineralized by the interaction of decomposers and their predators. These populations and their interactions are important to an ecosystem's stability, including its predator and prey interactions, mutualisms, and diseases.

As total ecosystem productivity increases, biodiversity within the soil food web also increases. The greater number of interactions between decomposers, their predators, and the

[19]Portions of this section rely heavily on information from Harvey and others (1994). Additional information comes from contract reports by Ingham (1995), Frest and Johannes (1995), and Schowalter (1994) (see appendix 5B). Insights on the implications of management practices were gained from information provided by the invertebrate expert panels.

predators of those predators, the fewer the losses of nutrients from that system. In undisturbed ecosystems ("undisturbed" defined hereafter as sites with little disturbance from European settlement) the processes of immobilization and mineralization are tightly coupled to plant growth. Following disturbance, this coupling is lost or reduced; nutrients are no longer retained within the area available to the plants' roots, which reduces the productivity of the ecosystem and causes problems for systems into which nutrients move, especially aquatic portions of landscapes. For this reason, the soil food web has been suggested as a prime indicator of ecosystem health. Measurement of disrupted soil processes; decreased bacterial or fungal activity; inappropriate change in the ratio of fungal to bacterial biomass; decreased number or diversity of protozoa; and altered nematode numbers, nematode community structures, or maturity indices can indicate problems long before the natural vegetation appears to be affected.

Earthworms—A group of invertebrates that play important roles in maintaining soil productivity is the earthworms. Earthworms require organic matter in various stages of decay and in various locations. Three broad functional groups of earthworms have been described by Bouche (1977): epigeic, endogeic, and anecic. Epigeic earthworms reside in leaf litter and under the bark of decaying logs. In a forested site, epigeic earthworms would be expected to have functional roles in organic matter comminution (chewing), in nutrient cycling, in soil structural modification, in the transfer of organic matter to the soil, and as a food source for other animals.

Endogeic earthworms live in the mineral soil and consume organic matter within the soil or at the soil-litter interface. The endogeic earthworm species occur in a wide range of habitats: forest and savannah, grassland and shrubland (including exotic grass pasture and seral stages following cessation of agriculture), and cultivated land. Endogeic species are the least known of all earthworms even though they constitute the majority. Factors that influence populations of endogeic earthworm species in the Basin are unknown. Only by assuming that they are comparable to other earthworms can one say that soil moisture, soil temperature, organic matter quantity and quality, and soil pH are probably the most important factors influencing presence, distribution, and abundance of populations (Lee 1985).

Anecic earthworms are those that inhabit a permanent or semi-permanent deep vertical burrow and emerge at night to consume relatively fresh plant detritus on the surface. Anecic earthworms are unstudied in natural vegetation in the assessment area. Their unique contributions may include the transfer of relatively fresh plant litter from the surface to deep levels of the soil and the creation of deep vertical burrows which assist water infiltration. Anecic species also likely provide food resources to endogeic worms by depositing fecal organic matter into the soil where endogeics can reach it.

The Basin is inhabited by at least three native earthworm species belonging to three genera. *Driloleirus americanus* was considered for inclusion in the IUCN Invertebrate Red Data Book because its habitat was threatened and its range was not known to be very large. Available information suggests that it may be a narrow endemic using a threatened habitat (grassland sites with productive soil). The other two native species, *Drilochaera chenowithensis* and *Argilophilus hammondi*, may be somewhat tolerant of habitat conversion to agricultural uses.

Other Soil Organisms—The other organisms in the soil including bacteria, fungi, protozoa, nematodes, and microarthropods play critical roles in maintaining soil health and fertility (Coleman and others 1992). These roles include: (1) decomposition of plant material by bacteria and fungi; (2) immobilization of nutrients in soil by bacteria and fungi in their biomass and in their secondary metabolites such as waste or defensive products; (3) soil aggregate structure improvement, which increases water-holding capacity, clay surface interactions with nutrients, and plant root architecture; (4) alteration of the soil pH; (5) mineral-

ization of nutrients by protozoan, nematode, and microarthropod predation of bacteria and fungi; and (6) control of disease-causing organisms through competition for resources and space, control of soil micronutrient status, and alteration of root growth.

Wood decomposition—Invertebrates also play key roles in wood decomposition. Secondary bark beetles (also primary, or tree-killing, bark beetles) penetrate the bark of freshly dead trees and inoculate wood with, and provide access to, saprophytic microorganisms. They also provide attractive aerosols, habitats, and resources for other invertebrates such as fungivores and termites, thereby accelerating wood decomposition (Schowalter and others 1992, Stephen and others 1993).

Herbivory functions of snails and slugs—Herbivory functions of snails and slugs help mediate nutrient and energy retention and transfer. Over 150 species of land snails and slugs are found in the Basin. Most are found in moist forest environments and in areas around springs, bogs, and marshes. Basalt and limestone talus slopes are also important habitats for some species.

The land snails and slugs within the Basin are mostly herbivores. A few consume animal matter and some are carnivorous on other land snails. Primary food for the herbivores includes deciduous tree leaves (green and fallen), understory vegetation, large fungi, and inner bark layers. Many mammals, reptiles, amphibians, and some birds prey on land snails and slugs. Various insects prey on snails or parasitize them. Some land snails are intermediate hosts for parasites of vertebrates. Snail shells are used as domiciles, shelters, or egg laying sites for a variety of arthropod taxa.

Taxa Associated with Litter, Coarse Woody Material, and Soil—Most of the invertebrate species associated with litter, coarse woody material, and soil have characteristics that allow them to recolonize disturbed areas and reestablish their functional roles in the ecosystem. Although several species perform the same specific ecological functions, some are less able or unable to survive in disturbed areas.

Frest and Johannes (1995) identified 95 terrestrial mollusks (87 land snails and 8 slugs) as species for which additional conservation attention may be warranted. Areas of high mollusk diversity are concentrated in specific, relatively small portions of the Basin. In particular, many species are confined to calcareous substrates including units such as the Paleozoic Madison, Lodgepole, Mission Canyon, Amsden, Phosphoria, and the Triassic Martin Bridge. Total outcrop areas of these units make up a small part of the total assessment area. Even within the outcrop area of these units, many species, particularly the 95 terrestrial mollusk species of concern, are limited to a small fraction of the total outcrop area. Specific drainages and small geographic areas are particularly significant to mollusk biodiversity. Preeminent areas of mollusk biodiversity are portions of the Columbia Gorge, Hells Canyon, the lower Salmon River, and the Clearwater, Clark Fork, and Bitterroot drainages. For some species, other sites also are very significant, such as a few localities with schist or limestone substrate in western and southeastern Idaho and in western Montana. Similarly significant areas for diversity of land snails are springs in the Upper Klamath Lake drainage, the Columbia Gorge, southeastern Idaho, and specific portions of the Oregon Interior Basins, western Wyoming and the northern quarter of the Basin.

Predation—The terrestrial invertebrate predators within the Basin are a diverse group of arthropods, primarily arachnids and insects that occur in every major habitat. This section covers the spiders (Arachnida:Araneae) and the major insect groups, principally the beetles (Coleoptera), ants (Hymenoptera:Formicidae), social wasps (Hymenoptera:Vespidae) (McIver and others 1994), true bugs (Heteroptera) (Lattin 1995), and lacewings (Neuroptera) (Johnson 1995). Any assessment of such a large, diverse group of species is likely to be superficial for at least two reasons: (1) an assessment even of a group such as the spiders would require information on well over 1,000 species, the majority of which are poorly known, and (2) the available information on each species is widely dispersed and would require an

enormous commitment of time to collect. Hence, this section provides information on the diversity of terrestrial invertebrate predators, their ecological functions, and factors that are thought to affect their abundance and distribution.

A total of 112 families contained in 15 orders and 3 classes of the phylum Arthropoda have species that are predominantly predaceous. Within these families, between 3,540 and 6,640 predaceous species are known to occur in the assessment area. The wide range in this estimate is due to uncertainty because of unknown geographic distributions of many species, incomplete examination of the literature, and incomplete examination of museum records. Although a thorough examination of literature and museum records would improve the accuracy of this estimate considerably, it is beyond the scope of the current project.

Despite the uncertainty of the number of species, arthropod predators clearly occur in great diversity throughout the Basin in every major habitat type. They prey upon virtually every conceivable type of arthropod species. Some major taxa such as the spiders, true bugs and beetles include species that are distributed throughout the Basin, whereas others, particularly the scorpions and pseudoscorpions, tend to occur mostly in dryland and moist microhabitat types, respectively.

In terms of abundance, predaceous spiders and ants dominate the terrestrial arthropod fauna associated with vegetation in the Basin. Beetles, ants and spiders are more prevalent on the ground. Beetles are represented by over 1,300 species, spiders by at least 980 species, and predaceous Hymenoptera by at least 500 species. Other major predaceous arthropod orders are the true bugs (Heteroptera) and the true flies (Diptera).

In managed forest ecosystems, predation is thought to be responsible in large part for regulating arthropod populations including pest populations under endemic conditions (Mason and others 1983). A preliminary evaluation of the HUSSI database (initiated by Hopkins and made available by Torgersen and McKnight, in press) suggests that predation is an ecological process that is a fundamental part of any healthy, natural or managed ecosystem.

Maintaining invertebrate predation processes over the long-term, while maintaining arthropod population fluctuations within some desirable range presents a challenge to managers. In some cases, maintaining predatory function may be as simple as maintaining structures within the landscape that predators are known to require, such as *Camponotus modoc* use of down wood.[20] Down wood, snags, specific habitat features (such as hydrological functions of bogs and springs), forbs, shrubs, and trees of various species and sizes are features to which predaceous arthropods are correlated, much like vertebrates. But unlike the vertebrates, virtually nothing is known about how particular human management practices influence the species composition, abundance, and distribution of predatory arthropods within a given area and the effects of management on ecological function and ecosystem processes. A landscape composed of a balanced mosaic of habitat types will likely have a balanced set of ecological functions.

Arthropod predators and pest insects—Predation has long been regarded as a potent force in suppressing forest insect pest populations. Predators have been implicated as primary suppressive agents of several pest species including *Dendroctonus* species, *Ips* species, pine tip moths, and the two principal defoliator species of western coniferous forests, western spruce budworm (*Choristoneura occidentalis*) (Campbell and others 1983, Torgersen and others 1990) and Douglas-fir tussock moth (*Orgyia pseudotsugata*) (Torgersen and others 1983).

Studies have revealed that birds and ants are primary predators of western spruce budworms (Torgersen and others 1990). In whole-tree exclosure experiments, insectivory predation by several species of passerine birds was identified as the most influential in the upper one-third of the

[20] Personal communication. 1995. Torolf R. Torgersen. USDA Forest Service, Pacific Northwest Research Station, Forestry and Range Sciences Lab, LaGrande, Oregon 97850.

canopy, and predation by ants (primarily) was more effective in the lower one-third. Pupal stocking studies have also implicated thatch ants as causing significant mortality of western spruce budworm. Spiders also might play a role in suppressing budworm populations, particularly when caterpillars are in the earlier stages of development. A key point established by these studies is that a diverse ensemble of predators, including birds, ants, spiders, and other arthropods, prey on western spruce budworm. Management techniques that enhance the role of these predators throughout the budworm population cycle will be likely to pay off in terms of decreased economic loss of green trees. An example illustrating the intricacy of predation effects is the central importance of down wood. Because *Camponotus modoc* nests only in large diameter down wood, maintenance of adequate large-diameter wood will favor larger populations of this important spruce budworm predator. Further, since *Camponotus modoc* is also the primary prey of pileated woodpeckers (*Dryocopus pileatus*), and since these woodpeckers excavate cavities used by a variety of insectivorous birds, management of down wood can provide substantial benefit by encouraging the maintenance of larger populations of budworm predators, principally ants and birds.[21]

Many studies involving stocking experiments (for example, Mason and Paul 1988) and key-factor analysis (for example, Mason and Torgersen 1987) have implicated predation as a primary cause of declines in Douglas-fir tussock moth populations. Primary predators that contribute to mortality include the jumping spider (*Metaphidippus aeneolus*), philodromid hunting spiders, web-spinning spiders, heteropteran predators, predaceous ants, and birds (for example, Mason and Paul 1988). Although predation may contribute well over one-half of the total mortality of tussock moth larvae and pupae during outbreak conditions, even this level of suppression might be inadequate to deflect the outbreak population trajectory (Mason and Wickman 1988). Hence, predation is typically thought to be most influential on tussock moth populations during non-outbreak (or endemic) phases of the moth's population cycle. Management activities that increase the rate of predation during these endemic conditions are, therefore, most likely to either defer or decrease subsequent population levels during the outbreak phase.

The HUSSI database also helped us identify some of the major predators of several insect pest species including pine tip moths, tussock moths, budworms, sawflies, tent caterpillars, and bark beetles. A total of 71 predator species have been observed to attack these pest insect species, 33 for *Dendroctonus* species alone. These numbers are likely underestimates of the actual number of predators that attack pest insects.

Additional attention may be warranted for 13 species of arthropod predators, including eight beetles and five bugs. Other species likely warrant attention but our knowledge of them is inadequate to either identify them or document their scarcity or sensitivity to disturbance. In addition, McIver and others (1994) provided additional detailed information on 14 other "exemplar" species that were chosen to represent the taxonomic diversity and ecological functions of invertebrate predators. These exemplar species include five species of beetles, two species of ants, one species of social wasp, and six species of spiders.

Critical Factors Affecting Arthropod Predators—Probably the only way to manage most arthropod species effectively is to manage their habitat. Among inherent environmental features, the architecture of the physical environment upon which predators depend for hunting and nesting is of primary importance. Plant architecture (that is, size, number, and arrangement of leaves, needles, and branches) is known to influence presence of canopy spiders (for example, Gunnarsson 1988). Plant species composition has been shown to influence abundance of spiders as well. Physical structures, such as down logs, can provide nesting, foraging, or hiding habitat for major predator species such as ants (including *Formica* spp. and *Camponotus modoc*),[22] beetles, and spiders. Many

[21]See footnote 20.

[22]See footnote 20.

predator species are associated with specific habitat types suggesting that special attention be paid to management of these features.

The second category of factors that can influence conservation of arthropod predators is disturbance. In the most basic sense, any disturbance that affects habitat will affect the species that depend on that habitat. For example, short fire-return intervals in cheatgrass-dominated rangelands in southern Idaho will very likely eliminate dominant predator species such as the thatch ant, *Formica obscuripes*. Thatch ants have the following ecological functions. Thatch ant nests provide habitat for over 100 species of other arthropods, serve as overwintering and foraging habitats for small mammals, and concentrate nutrients on a local scale. In addition, thatch ant workers care for several species of aphids and other Homoptera, are predators and scavengers of other insects, and the workers and pupae are prey for other vertebrate insectivores. Where they occur, thatch ants are probably responsible for the majority of secondary production through conversion of honeydew and prey proteins into ant protein. Although thatch ant colonies can survive fire by maintaining the queen and brood below ground, post-fire survival is challenged by a lack of resources since the sagebrush-feeding Homoptera that the ants depend on for honeydew energy are typically eliminated. Hence, thatch ant colonies are generally reduced by fire to less than 20 percent of their original size. Fire events every few years will likely drive these challenged colonies to extinction.

A general trend in the northern Great Basin is the removal of sagebrush and other shrubs upon which Homoptera feed and the subsequent loss of the thatch ant. Vegetation communities and ecosystems with short fire-return intervals (typically cheatgrass-dominated) will tend to favor "weedy" ant species with different ecological functions. In general, because many of our ecosystems have been modified significantly by fire suppression, grazing, and the introduction of exotic plant species, use of prescribed burning may not meet the objective of returning the land to its previous condition. Hence, it is suggested that prescribed burning be used with caution and with native species in mind.

Forest silvicultural practices can have profound effects on the composition of predator species in a given area. In coniferous forests of western Oregon, clearcutting causes a complete replacement of forest-dwelling, litter spiders with species that are adapted to sunny, open places (McIver and others 1992). Selective cutting, the more typical silvicultural practice in eastside forests, is not likely to have such an effect, but more work needs to be done to determine the connection between silviculture, predator species composition, and the benefits that predatory species provide to the ecosystem. Structural diversity, including varying ages of conifers, angiosperms, and standing and down dead wood, are important components in maintaining the microhabitats, moisture regimes, light regimes, food plants, and prey base for arthropod predators.

Several species of tiger beetles (Cicindelidae: Coleoptera) occur as top invertebrate predators in sand dune steppe habitats along the Snake, Salmon, and other rivers of Idaho. The tiger beetles are threatened by recreation (especially off-road vehicle use), grazing and trampling by livestock in a few places, and dune stabilization efforts (including removal of exotic grasses and change of dune vegetation structure). The Idaho State Office of BLM has developed a Habitat Conservation Assessment and Conservation Strategy for these species.[23]

Pollination—About 67 percent of all flowering plant species benefit from insects that visit their flowers (Axelrod 1960). In the absence of insect pollinators, these plants would reproduce at substantially lower rates or not at all. Bees (Hymenoptera), butterflies and moths (Lepidoptera), flies (Diptera), and some beetles (Coleoptera) are the main insect taxa that visit flowers.

[23]Personal communication. 1995. Allan E. Thomas, Fish and Wildlife Biologist. U.S. Department of Interior, Bureau of Land Management, Idaho State Office, 3380 Americana Terrace, Boise, Idaho 83706.

The primary insect pollinators of plants in the Basin are native bees. Bees are the only organisms, with a few minor exceptions, that depend exclusively on pollen and nectar for food throughout their lives. Among flower visitors, bees are the most reliable and efficient group at transferring pollen among flowers. The most obvious exception is at higher elevations where flies assume increased importance (del Moral and Standley 1979) apparently because of their greater ability to cope with high altitudes and cold temperatures.

Based on 8,350 specimen records documented in unpublished and published reports on file at the Bee Laboratory in Logan, Utah, 647 species of bees are presently known to occur in the Basin. However, the actual number of bee species in the Basin is believed to be substantially higher because little collecting has been conducted in this region. Based on other areas in the western United States that have been sampled more extensively, Tepedino and Griswold (1995) estimated that the actual number of bee species in the Basin is much closer to 1,000. Little biological or ecological information is known about most of these species.

The primary ecological function of native bees is as pollinators of flowering plants. Without bee-facilitated pollination, few if any seeds or fruits would be produced by these plants. In addition, bees can influence the genetic variability of the seeds produced by the plants that they visit; they can affect the rate of inbreeding in plants with self-compatible flowers by their movement patterns within and between plants. The products of pollination, fruits and seeds, are important not only to the plants that produce them but also to the numerous birds, mammals, and insects that use them as food for all or part of the year.

Many bee species are specialized to some degree and collect pollen from a restricted group of plants. The degree of specialization on plants ranges from fairly broad groups of plants (such as pollinating composites) to only particular plant genera. Generalist bees (such as Halictinae and Bombinae), visit a variety of flowers on individual foraging trips.

Ground-nesting bees, particularly those that breed in large aggregations of thousands of nests, move large amounts of soil while digging their main burrows and side branches. In so doing, they help to recycle soil layers and nutrients.

Grassland herbivory—In grasslands, several invertebrate groups function primarily as grazers and are important links in food webs. Most invertebrate herbivores that inhabit grasslands feed on various herbs, shrubs, and trees and they are seldom considered pests. However, some taxa, such as some species of grasshoppers, are of economic importance when populations reach outbreak levels and consume significant amounts of vegetation. In addition to being important consumers of vegetation (annual primary production), grassland herbivores provide important food resources for a wide variety of wildlife and are an especially critical resource for nesting birds and their broods in the spring.

Many arthropod species function as grassland herbivores. Three groups of grassland herbivore species will be considered in this section: grasshoppers (Acrididae; see also Kemp 1994), moths and butterflies (Lepidoptera; see also Hammond 1995), and true bugs (Hemiptera:Heteroptera; see also Lattin 1995).

Approximately 100 species of grasshoppers inhabit the grasslands of the assessment area. Most populations fluctuate in numbers in direct response to available food resources. Unfortunately, we know much more about how to control populations of grasshoppers in grasslands than we do about the specific ecological roles of these species. Furthermore, what little we do know about the ecology of grassland grasshoppers comes from grasslands other than (and in a number of cases very different from) those within the Basin.

Recently, considerable progress has been made in understanding the rich species diversity of moths and butterflies (Lepidoptera) within western coniferous forest ecosystems. Parsons and others (1991) reported 492 species of moths and butterflies collected from the H.J. Andrews Experimen-

tal Forest in western Oregon. Similarly, Grimble and others (1993) found 438 species of moths and butterflies on the Umatilla and Wallowa-Whitman National Forests in eastern Oregon. In both of these areas, 90 percent of the species feed on angiosperms and only 10 percent use conifers as a food source. Less is known about the diversity of moths and butterflies in western grasslands, but 302 species have been recorded from the semi-desert grasslands of Harney County in southeastern Oregon.

About 307 species, 163 genera, and 30 families of true bugs occur in the assessment area.[24] We have reasonable knowledge of the general biogeographical distribution of the true bug fauna of the region based on collections at Oregon State University, Washington State University, the University of Idaho, the University of British Columbia, and the California Academy of Sciences and from the personal experiences and reprint library of J.D. Lattin, Oregon State University.

All of the grassland herbivores discussed above act as primary plant consumers; however, their degree of plant specificity varies between groups. Most butterflies feed exclusively upon a single type of plant. Grasshoppers display varying degrees of host plant specificity. However, the grasshopper species that frequently occur in high densities and that are detrimental to agricultural production are generalists that graze on a variety of grasses, forbs, and cereals. For true bugs, host specificity depends on the bug group and the plant group involved. Bug species that feed on grasses tend to have lower host specificity than those that feed on trees.

Herbivory by insects can influence the rates of nutrient cycling of elements such as nitrogen and carbon. This function is of particular significance with pest species that consume large amounts of vegetation (for example, generalist grasshoppers in various range habitats and *Labops hesperius* in fields of crested wheatgrass).

[24] Personal communication. 1995. J. Lattin, Oregon State University. Corvallis, Oregon 97331. Personal communication of unpublished data.

Small vertebrates such as some passerine birds, rodents, shrews, and bats, are dependent on insects for a protein source when rearing their young in spring and early summer. For example, the nesting success of western sage grouse is tied to their dietary needs, primarily succulent forbs and insects. These primary predators then become food for secondary predators such as hawks, owls, coyotes, and bobcats.

Forest Herbivory—Several groups of invertebrates feed either as immatures or as adults on the forbs, shrubs, and trees of forests. In addition to being primary consumers, which are in turn eaten by various invertebrate and vertebrate predators, they directly or indirectly influence forest ecosystem processes in a variety of ways.

Forest herbivore insects have traditionally been viewed as pests that interfere with management objectives by damaging forest resources. Thus, management concerns and research emphases have concentrated on single species, principally tree defoliators and bark beetles, and only during high population densities (Huffaker and others 1984). This work has been successful in providing information on how these organisms affect other parts of the ecosystem, including forest succession, and has helped to identify the necessary tools for their control.

Within the current assessment, two other efforts have examined aspects of invertebrate forest herbivory. Hessburg and others (1995; see also Landscape Dynamics chapter, this document) assessed landscape susceptibility to major defoliator and bark beetle disturbance, and Kurtz and others (1994) modeled the role that specific bark beetle and defoliator species play in forest succession. While we address these topics in this chapter, we also refer the reader to these sources for more detailed assessments.

The taxonomic groups addressed in this section are moths and butterflies (Lepidoptera), bark beetles (Coleoptera:Scolytidae) and their associated mites (Acariformes), true bugs (Hemiptera: Heteroptera), sawflies (Diprionidae and

Tenthredinidae), and aphids (Aphiodidae). See Hammond (1995), Miller (1994), Ross (1995), Moser (1994), and Wagner and McMillin (1994) for further information about these forest herbivores.

All invertebrate forest herbivores have the potential to influence forest ecosystem processes and interactions in many ways by changing the following: (1) microclimate and water relations, (2) carbon and nutrient cycling or energy flow through the ecosystem, (3) plant succession or community structure, (4) food sources for other organisms, (5) wildlife habitat, and (6) pollination of plants in the forest ecosystem (Haack and Byler 1993, Schowalter 1993). The following discussion provides examples of such effects.

Reductions in percent tree-canopy cover or tree basal area in a forest stand from insect-caused defoliation or tree mortality can, in turn, influence interception of precipitation, evapotranspiration, light penetration, and wind speed (Speight and Wainhouse 1989). In addition, tree defoliation or tree mortality temporarily removes actively transpiring foliage from the forest canopy. This reduces the flow of water from the root zone to the tree canopy and therefore can lead to increased soil moisture. Warmer soil temperatures in the spring and summer in combination with increased soil moisture caused by defoliation by insects provide a generally more favorable microclimate for invertebrate activity. Therefore, environmental conditions may become more favorable for decomposition of organic matter in defoliated stands than in non-defoliated stands (Klock and Wickman 1978), especially during dry periods (Schowalter and Sabin 1991). Furthermore, the improved water balance as a result of decreased transpiration may enhance plant survival during drought periods in some environments (Schowalter 1993).

The importance of arthropods in contributing to biomass decomposition, carbon cycling, nutrient cycling, soil fertility, and energy flow in forest ecosystems has been recognized for several years. Forest invertebrate herbivory contributes to both short- and long-term nutrient cycling processes in forest ecosystems. Low levels of defoliation (for example, less than 7%) can return as much as 30 percent of foliage standing crop of potassium and 300 percent of foliage standing crop of sodium to the litter than would otherwise occur (Schowalter and others 1986). In addition, a considerable amount of mobile elements are returned indirectly to the soil by defoliation as a result of increased leaching from damaged foliage during rainfall. Insect remains and grass also contribute to litter and may decompose faster than do fallen leaves and needles. This may result in faster cycling of elements such as calcium, potassium, nitrogen, and phosphorus.

An additional role that herbivorous insects play in the forest ecosystem is as pruning or thinning agents which may stimulate plant growth and increase biomass turnover (for example, Velaquez-Martinez and others 1992). Pruning and thinning of plant parts can help stimulate plant growth by reducing competition for limited light. Although insects and pathogens typically remove less than 10 percent of foliage and shoots in non-outbreak years, removal of these plant parts apparently reduces plant metabolic demands and facilitates reallocation of plant resources.

Hard data are not available to indicate the importance of these insect-mediated effects on nutrient cycling and the long-term productivity of forest ecosystems. However, growth responses of trees to the addition of nutrients, in general, will occur only when growth at that site is nutrient-limited (Speight and Wainhouse 1989).

Tree growth and mortality is affected by insects and diseases, as they in turn influence microclimate, water relations, nutrient and carbon cycling, and direct loss of foliage. These effects on individual trees are ultimately manifested as changes in stand and ecosystem structure and function (Schowalter and others 1986). Selective herbivory by insects can favor tree species resulting in changes in stand age, plant composition, and tree density.

Trees killed by insects are used as wildlife habitat both as standing snags and down wood. In areas where cover is plentiful but forage is limited, severe defoliation caused by insects can have a positive influence on deer and elk use by increasing the amount of forage biomass within two to four years (Thomas 1979).

Forest herbivores are preyed upon by a variety of other arthropods and vertebrates. Arthropod predators of defoliators include spiders, ants, true bugs, nerve-winged insects, beetles, flies, and wasps. Of animals other than arthropods, birds probably consume the highest number of tree-feeding insects. There are at least 32 species of birds that feed on the western spruce budworm and Douglas-fir tussock moth in eastern Oregon and Washington ecosystems. In one study, mountain chickadee (*Parus gambeli*) and red-breasted nuthatch (*Sitta canadensis*) were the most common predator of western spruce budworm and Douglas-fir tussock moth (Torgersen 1994).

Butterflies are an example of a forest herbivore group that would make a good indicator of total ecosystem diversity (Hammond 1994). They are relatively conspicuous and easy to observe in the field, and their functional role is well known. Their abundance and diversity relates directly to the presence of their host plants as they are generally monophagous. Butterflies, in turn, support a rich diversity of generalist predators including arthropod predators and parasites, passerine birds, bats, rodents, and other small mammals. Other invertebrate herbivore groups may offer similar opportunities to act as indexes to important ecosystem functions or to total ecosystem diversity.

Implications of Management Practices on Invertebrates

Little information exists on the effects of management practices on invertebrates because the importance of the ecological functions performed by these organisms has not been recognized previously. In this section we discuss some general principles which may be used to help conserve invertebrates. After that we discuss some implications of management practices on various invertebrates including those associated with detritivory and nutrient cycling, anthropod predators, bees, grassland herbivores, and forest herbivores.

Three guiding principles may help to conserve invertebrates: (1) provision of a diversity of habitat composition and structures to maintain invertebrate biodiversity and ecosystem functions, (2) maintenance of soil structure and chemistry to sustain diversity and functions of the invertebrate food web in the soil, (3) eradication or prevention of the introduction of exotic organisms to maintain invertebrate biodiversity and ecosystem functions.

Habitat composition and structures—Alteration of the structure of the forest canopy layer from tree harvest, tree stand improvement activities, or wildfire, affects several functional groups of invertebrates. The altered forest stand may be more or less hospitable to various herbivores resulting in different amounts of nutrients in foliage falling to the litter or different rates of subsequent tree mortality. The changes may result in varying quality and quantity of prey available to predators including both invertebrate and vertebrate species. Changes in density or composition of the tree canopy can affect habitat for predators that help control population irruptions of pest species. Also, canopy changes cause microclimatic changes in the understory, and in coarse woody material and litter environments which may be detrimental for some species. For example, if the light/moisture regime is changed sufficiently, the understory angiosperm flora may change, resulting in affects upon pollinators, herbivores, and predators. These changes in forest stand structure may be inimical to species such as land snails whose lack of mobility may prevent them from seeking conditions in disjunct patches of forest habitat. In addition, coarse woody material may dry out more quickly, thereby affecting the internal environment within standing and down dead trees and altering suitability for decaying-wood dwelling invertebrates.

In the forest understory, management practices that disturb flowering plants and other ground vegetation or that compact or mix the soil may have distinct effects on several functional groups of organisms. In addition to the effects of management practices on organisms with limited dispersal capabilities or those that are in a non-mobile stage, habitat of many functional groups of invertebrates can be disrupted. Consequently plant and animal communities can change, sometimes resulting in detrimental effects to particular invertebrate species.

On the forest floor, the major structural element contributing to the invertebrate fauna is coarse woody material. This consists primarily of down tree boles and large branches. This material serves as habitat for prey for mammalian, avian, and invertebrate predators and as a carbon source for soil biota. Various species of arthropods, nematodes, fungi, annelids, and bacteria are responsible for the comminution and conversion of the wood to elements that are available to the soil. To maintain soil productivity, sufficient coarse woody material should be maintained through time. In grasslands, retaining native plant species is important as they may be key to maintaining large invertebrate communities of over 100 species representing several functional groups.

Soil structure and soil chemistry—Maintenance of forest soil chemistry and structure helps to sustain soil health and fertility. This is vital to retaining forest and range productivity and biodiversity. Chemical changes of soil from fire and structural changes of soil from compaction or mixing of soil layers are two results of management practices that are of concern. Fire, whether natural or human-caused, has the potential to consume the litter and coarse woody material that are the primary sources of carbon and other elements necessary for the soil food web. Erosion, resulting from loss of soil-binding materials, further depletes the capacity of the soil. Fire can volatilize nutrients found in the upper horizon of the soil and change water-retention characteristics. Structural changes to soil from either compaction or soil mixing can have long-lasting effects on successional patterns and duration. These effects are expected with multiple management entries into a forested area.

Exotic Organisms—The introduction or maintenance of exotic invertebrates and plants can adversely affect range and forest succession and reduce native invertebrate diversity. Sailer (1983) and Kim and McPheron (1993) reported that nearly 2,000 species of exotic insects and mites have become established in North America. Mattson and others (1994) listed all of the immigrant phytophagous (plant-eating) insect species known to have become established in North America on native and introduced woody plants (that is, trees and shrubs). More than 368 species of exotic phytophagous insects have become established in North American (north of Mexico) forests, parks, woodlots, shelterbelts, and orchards. The orders Homoptera, Coleoptera, Lepidoptera, and Hymenoptera account for most of the introductions. The majority of the species have come from the western Palearctic (Old World) and Asia.

Without their native enemies to restrain population growth, exotic organisms can occupy the niches of native species. The exotic species, because of their competitive nature, may become pests and may require eradication or suppression activities and concomitant risks and financial costs.

Implications for Invertebrates Associated with Detritivory and Nutrient Cycling—Groups of viruses, bacteria, protozoa, rotifers, nematods, microfungi, and algae, all help determine productivity of many parts of the ecosystem, especially soils, organic matter decomposition, and other aspects of the below-ground environment. Most are critical to maintaining diverse ecosystems and productive and sustainable renewable resources. In particular, knowledge of how land management activities affect various kinds of soil bacteria is important because some (desirable) bacteria species inhibit disease-causing organisms, whereas other (undesirable) bacteria species will cause disease.

Two areas of concern for invertebrates are the direct effects of fire on populations and the role of fire in forest or range succession and soil chemistry. In fire-adapted systems, direct effects on invertebrate populations are thought to be slight. However, in systems where large volumes of fuel (litter and coarse woody material) are present, higher intensity fires may pose hazards to slow-moving organisms such as land snails. Direct effects on invertebrates will be reduced if refugia of litter and coarse woody material are retained.

Fire removal of organic matter has opposite effects on forest and range succession. In the forest, loss of organic matter may change the ratio of fungi:bacteria to favor bacteria. This change in ratio favors grasses rather than woody vegetation, not necessarily the direction desirable in forestry. In grasslands, the consumption of organic matter and the subsequent change to a bacteria-dominated food web is beneficial to the maintenance of grasses. The effects on invertebrates by early-season fires in cheatgrass with its damage to native perennial grasses is unknown.

Coarse woody material provides habitat for prey of other organisms, serves as primary habitat for invertebrate predators, and serves as a carbon source for the soil food web. It is not known how much litter and coarse woody material and what sizes are necessary to continue ecosystem functions of associated invertebrates. It is assumed that the standards to provide prey for vertebrate species will suffice to continue the functions of invertebrate populations.

Compaction or mixing of soils is an issue that has implications for maintaining the soil food web. Compaction occurs from use of machinery on the land and from the effects of grazing by large herbivores. Compaction reduces soil pore size which results in loss of nutrient retention and increases the bacterial component of the soil-based food web. This may reverse succession in the forested environment, causing a negative impact on cyanobacteria, lichen, and mat-forming ectomycorrhizal fungi. With loss of the ectomycorrhizal fungi, tree productivity declines. Compaction also changes the community of nematodes, favoring bacteria and root-feeding species. Root-feeding nematodes can be highly detrimental to survival of tree and grass seedlings.

Compaction has a negative effect on all other groups of invertebrates but especially mollusks and earthworms, which may occupy specific habitats or which cannot disperse quickly. Overgrazing and the congregating of livestock near water sources can directly affect mollusks by trampling individuals and degrading their favored riparian habitats.

Tilling to reduce compaction and other means of physically mixing the duff and soil can potentially adversely affect many ecological functional groups of invertebrates. Disruption of the duff/litter layer has immediate effects on water and thermal relations, degrades habitat for many functional species groups that inhabit woody debris and litter, and alters forb and flowering plant communities. Excess mixing of soils affects the soil food web by breaking roots and fungal mats and by changing water and thermal conditions, thereby encouraging growth of bacteria populations.

The use of pesticides mostly negatively impacts mollusks. Further consideration should be made to determine the non-target effects on mollusks of using pesticides.

Implications for Arthropod Predators—The following practices may help to ensure the health of habitat-specific, forest predator populations: (1) cautious management of low elevation, old forests because they represent such a low percentage of habitat types and since the microhabitats they provide are favored by a number of predaceous species, (2) management of other forests to include retention of legacies of its former character so that there are source areas from which plants and animals may colonize the disturbed areas, (3) provision of uncut forest buffer zones for bogs and wetlands including lake-edge and stream-edge grasslands, and (4) maintenance of an uncut forest buffer zone around sand, gravel, canyon, waterfall, spring, and cave habitats because these habitats harbor unique predator species.

Overgrazing of shrub-steppe, prairie, savannah, or mountain meadows can eliminate arthropod predator species through conversion of perennial grasses to introduced annuals. Range managers could strive to maintain native plant populations as these habitats favor native arthropod predator species.

Recreation activities potentially damage arthropod predator habitat by trampling areas or by associated development of roads and facilities. Caves are probably the most critical habitat that is affected by recreation. Some of the more unusual arthropod fauna live within these caves. Excessive and uncontrolled use of caves by recreationists can cause habitat degradation in numerous ways.

Wildlife can, in some cases, damage important habitat. For instance, sphagnum bogs can become flooded by beavers. Where bogs are to be preserved, beaver removal could be considered. Exotic plants or arthropods that are introduced as biological controls of pest species may competitively displace native species that are important to beneficial predators or other functional groups.

Implications for Bees—Four major implications of management practices on bees pertain to effects on nesting habitat, flowering plant resources, exotic flora and fauna, and use of pesticides.

The nest sites of ground-nesting bees may be subject to a variety of disturbances. Land use activities such as grazing, mechanized activities, off-road vehicle use, and subsoiling can damage maturing progeny in the soil and disrupt current nesting activity. Sites in vertical or near-vertical embankments are subject to erosion, whereas sites in more level ground are vulnerable to compaction. Effects caused by constant or heavy use can vary greatly by site. Some degree of compaction on heavier soils may be tolerable and even beneficial to certain ground-nesting bee species. However, bees that inhabit light soils, particularly sandy soils, occur in higher densities and include more endemic species than in other types of soils, and are extremely sensitive to disturbance. Activities can also obliterate or change the subtle landmarks adjacent to nest-holes that bees use to find their nests when returning from foraging trips. Disturbance early or late in the year when bees and most plants are less active would reduce effects. In addition to seasonal mitigation, any reduction in the intensity and frequency of such disturbing activities will help to maintain adequate ground-nesting habitat and provide time for recovery and recolonization of sites.

Habitat availability for wood-nesting bee species can be adversely affected by any management practices that remove wood resources (such as, prescribed burning, intensive tree harvesting, and intensive vegetation management). Many of these practices can open up forest habitat for foraging and breeding by ground-nesting bees by increasing light penetration, and thus increasing flowering plant abundance. On rangeland and in open forests, fire occurring during active bee nesting and foraging seasons results in direct mortality of bees and decreases habitat for wood-nesters. Since closed forests have no significant use by bees, seasonality of fire is inconsequential; but seasonality of fire is of consequence in rangeland and open forests.

The easiest and most straightforward way to manage for bees of all degrees of specialization is to maintain or augment the diversity of flowering plant species. Carefully managing domestic grazing practices on public lands can help promote native plant diversity and, therefore, bee diversity in the assessment area. Careful rotations and exclusions of selected rangelands might enhance plant and bee diversity particularly in higher elevation and forested sites. Where annual grasses predominate, such as in many grazed areas, pollinators are reduced in numbers as a result of resource depletion. Any activity that reduces cheatgrass or other introduced annual grasses will likely benefit the diversity of native flowering plants and the abundance of pollinators. Grazing by sheep has a particularly strong effect on flowering plant diversity as sheep are forb eaters.

Herbicides are the most obvious immediate detriment to floristic diversity. Current management policies that limit the use of herbicides to spot applications can help maintain plant and bee diversity, whereas broad-scale use can reduce diversity of angiosperm and associated bee species.

Where plants with specialist bees are known to occur, grazing, burning, and other activities with similar effects on the flora can be timed to periods when these plants are not flowering. Silvicultural practices that leave clusters of trees are preferred methods as they will result in an increase in floral diversity while maintaining other habitat requirements.

Management activities aimed at providing for the bee fauna could encourage a move away from exotic plants such as crested wheatgrass, Russian forage kosha, and cheatgrass, and toward native plant species. Both the promotion of current exotics and the introduction of new exotic species could be discouraged. The intentional introduction of either non-native or native bees into areas they did not originally occupy to pollinate agricultural crops as well as accidental introductions could result in the competitive displacement of native bee species.

Chemical insecticides currently being used on grasshoppers are highly toxic to bees. Use of insecticides is currently restricted on Federal lands in the assessment area to controlling grasshoppers on rangelands adjacent to agricultural areas. While situations will always exist where insecticides are the only recourse, the judicious use of them may help to minimize adverse effects on bee diversity and abundance. Alternative control methods could be implemented whenever possible. When insecticide spraying is the only treatment available, unsprayed strips could be left to help retain beneficial fauna, and applications could be made on different tracts of land each year. Carbaryl baits are the preferred treatment for grasshoppers because such baits have a lower effect on leafcutter bees than do spray applications.

Implications for Grassland Herbivores— Three major issues related to managing grasslands for insect herbivores are the effects of management activities on plant community composition, the introduction of exotic flora and fauna, and the effects of insecticides.

Changes in plant community composition affect the herbivore community by changing the availability of their host plants and the abundance of generalist predators. Management activities that change vegetation structure, vegetation biomass, and plant species composition can affect presence and densities of insect herbivores in grasslands. A diverse insect fauna is best ensured by maintaining a structurally and taxonomically diverse floral community.

Season-long grazing tends to convert grassland plant communities to earlier seral stages that have increased likelihood of invasion by exotic species. Such conditions increase the probability of a less diverse grasshopper community that could easily be dominated by one of the generalist pest species. Season-long grazing also reduces the diversity of moths and butterflies in most areas because of the loss of food plants for larvae. Grassland vegetation structure and plant species composition can be manipulated to increase species diversity of grassland herbivores and to reduce the likelihood of irruptions of individual pest species. The intensity, duration, season, and spatial extent of grazing regimes are all factors that potentially can be restructured to favorably alter plant communities. Grazing can be used as a tool to maintain or restore diversity of grassland herbivores, if done carefully.

Fire has little direct effect on insect populations unless burns are timed to kill all individuals that would emerge that season. A greater effect is the way fire can shift plant community composition. If burning, especially in association with other disturbances, results in areas that are dominated by early successional forbs, outbreaks of some herbivorous invertebrate species may occur, at least in the short-term. A "cool" fire may have positive effects on moths and butterflies by opening up the

community to their preferred food plants. A "hot" fire could result in mortality of shallow-rooted plants which could decrease diversity of closely associated herbivores.

The second issue related to management for grassland herbivores is the invasion of exotic flora and fauna. Unfortunately, most native insects, with the exception of a few grasshopper species, are unable to feed on exotic plant species. The result is a reduction in the diversity of grassland insects, including predaceous as well as herbivorous species, leading to the specific favoring of one or a few insect species of the community. An example is the favoring of various species of grasshoppers, such as *Irbisia pacifica* and *Labops hesperius* in crested wheatgrass, and *Lygus* spp. in kochia.

The consequences of proposed introductions of exotic enemies (for example, scelionid egg parasites and fungal pathogens) to control native grasshoppers are unclear. Such actions may disrupt natural interactions in unanticipated ways. The effect of introducing exotic control agents on native biological control agents is largely unknown. Since only a small proportion of grasshopper species are pests, such practices could put non-target species at risk. Introduction of exotic control agents only after possible direct and indirect effects have been rigorously assessed would help maintain native control agents.

The third issue related to management for grassland herbivores is the role of insecticides. Broad spectrum insecticides, like malathion and carbaryl, can produce drastic reductions in both community composition and densities of grassland grasshoppers. Furthermore, populations of many non-target species often are affected negatively, including moths and butterflies, bees, beetles, and aphids. Bait applications of carbaryl are less harmful to flying, non-target insects than they are to non-flying insects, but may negatively affect ants. Many other arthropods that may be affected by spraying insecticides are predators of grasshoppers that provide a natural control. Once they are eliminated, acute problems may turn into chronic problems. Insecticides also may have secondary negative effects on insectivorous birds if most of the prey base is killed.

Implications for Forest Herbivores—Major issues related to forest herbivores include the effects of management on overstory and understory host plant availability. Management activities affect canopy and bole herbivores indirectly by altering their food source. Tree species composition, tree age and size, stand structure, and stand stress, influence the composition and relative abundance of forest invertebrate herbivores.

Forest management practices affect understory herbivores in several ways: (1) indirectly by altering the density of the overstory canopy which in turn influences the type and abundance of understory plants, (2) indirectly by manipulating the understory vegetation, and (3) by direct mortality caused by application of pesticides for overstory defoliators. Changes in the assemblage of understory herbivore species can affect plant community dynamics and the predators and parasites that use these species as prey or hosts.

Vertebrates

Vertebrate species occupy widely diverse habitats in the Basin and play various ecological roles. Five hundred forty-seven terrestrial vertebrate species were evaluated for this assessment, 47 of which are listed under the Endangered Species Act as endangered, threatened, or Category 2 candidates (C2). This section presents a summary of findings listed by vertebrate taxonomic class. Additional species information and databases with information on cover types and structures, environmental correlates, and ecological functions are on file (TS 1995).

Amphibians

Information on the distribution and abundance of amphibians in the Basin is quite limited. They are difficult to survey because localized populations may fluctuate widely over time and trends are difficult to determine. Distribution and abundance of many amphibian species are more closely associated with specific substrates (such as down wood) and microhabitat conditions (such as deep,

moist talus), than with general vegetation cover types and structural stages. Most amphibian species require water, either standing (including wet meadows, marshes, and ephemeral ponds) or flowing, for egg laying and larval development. A few species, such as the Larch Mountain salamander (*Plethodon larselli*), may lay eggs in moist habitats but are associated with down wood or talus as adults rather than aquatic environments. Frogs are primarily inhabitants of forested vegetation but some occur in shrub or grasslands. Riparian habitat is important for most adult forms. Dispersal occurs both in water along streams and within 400 meters of the stream.

Exotic species, such as bullfrogs and some fish introduced into high elevation lakes have been detrimental to many amphibian species. In some cases, these introductions may be responsible for the decline or elimination of species, such as the northern leopard frog (*Rana pipiens*), from some locations (Leonard and others 1993).

A number of amphibian species have declined or disappeared from portions of their ranges from undetermined factors or a combination of factors. These species include the southern race of the Columbian spotted frog[25] (*Rana luteiventris*), northern leopard frog (*Rana pipiens*), and western toad (*Bufo boreas*).

Key ecological functions provided by amphibians includes the storage and transfer of energy and nutrients from aquatic to terrestrial systems. Most species, especially the larval stages, provide high biomass in aquatic and some mesic terrestrial systems, provide prey for many terrestrial and aquatic species, and consume large amounts of plankton. Also, some amphibian species may control densities of other amphibian species. One example is the tiger salamander (*Ambystoma tigrinum)* which, by dint of its high biomass in some ponds, can out-compete other amphibians for food. Another example is the rough-skinned newt (*Taricha granulosa)*, which may preclude some amphibians from inhabiting the same ponds.

Very little is known about amphibian distribution or about the effects of livestock grazing and pesticide use on amphibian populations. Some species, such as tree frogs like *Pseudacris regilla,* are known to be tolerant of grazing whereas others, including the Cascade frog (*Rana cascadae)* and spotted frog, are intolerant. Irrigation can be beneficial or detrimental; irrigation canals or field flooding can provide adequate habitat for egg laying and larval development, but if water is shut off to these areas prior to hatching or metamorphosis, reproduction is lost.

Reptiles

Many species of reptiles may require specific topographic conditions, such as slope and aspect, and are not particularly associated with broad vegetation cover types and structural stages. Many species of reptiles are relatively long-lived and are not reproductively active until three years of age. Loss of individual animals, especially adult females, might have large effects on trends of some populations.

Some species currently listed by agencies as sensitive may be more common or more widely distributed than originally reported. Species of concern that appear to have declining trends but are still common or that are associated with substrates or environmental conditions that are not well distributed in the assessment area were identified. One example is the common garter snake (*Thamnophis sirtalis*) which is widespread in distribution, but appears to be declining in parts of the Basin including southeast Idaho and western Wyoming. Another example is the sharptail snake (*Contia tenuis*), which associates with large, old, rotting logs, and is restricted in range and spotty in distribution. The California mountain kingsnake (*Lampropeltis zonata*) has a patchy distribution and is absent in seemingly suitable habitat.

[25]Recent studies by Green and others (1996) suggest that the spotted frog (prev. *Rana pretiosa*) is really a complex of cryptic species, and that the populations east of the Cascades crest form at least one distinct species from those west of the Cascades crest. The species within the Basin is referred to here as the Columbian spotted frog, *Rana luteiventris.*

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Birds

Little information is available on the effects to ground-nesting birds of fire and fire suppression, season of burn, and changes in vegetation pattern resulting from burns and fire suppression. Although general trends have been reported, in the Basin species-specific effects on bird population density and trends from livestock grazing, changes in distribution and density of nest parasites (principally brown cowbird), changes in insect populations, and availability of free water are poorly known. Resource management, including fire suppression and timber management, and the resulting changes in the structure and distribution of vegetation communities has influenced the distribution and abundance of many avian species. For example, the amount of old, single-strata, interior ponderosa pine forests that have been maintained by frequent, low-intensity fires have declined by approximately 80 percent from historic conditions to present. Species associated with this community, such as white-headed woodpeckers (*Picoides albolarvatus*) and flammulated owls (*Otus flammeolus*), have declined in abundance and are considered sensitive by federal agencies. Spotted owls (*Strix occidentalis caurina*) and marbled murrelets (*Brachyramphus marmoratus*), associated with late-successional conifer forests in the Cascade Mountains, likely have also declined in abundance as a result of loss of habitat (Thomas and others 1993), although some mixed-conifer forest habitat for spotted owls may have increased in recent decades on the east slope of the Cascade Mountains as a result of fire suppression. Some non-forest communities and associated vegetation structures have also greatly changed as a result of human activities.

Species associated with native grasslands and shrublands [such as Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) and sage grouse *(Centrocercus urophasianus)*] have declined dramatically. Conversely, grand fir/white fir communities have increased 964 percent from historic to current; the largest increases have been observed in the stem exclusion closed canopy (1,629%), understory reinitiation (1,100%), young multi-strata (1,676%), and old multi-strata (533%) structural stages. Species associated with or adapted to these cover types and structural stages likely have benefited from their management.

In recent decades, management practices have also reduced some habitat attributes within various cover types and structural stages, primarily large, standing dead trees and large down woody material. The distribution and abundance of many species, including the cavity excavators and secondary cavity users, have been adversely affected.

Neotropical Migrant Birds[26]—Among 132 species of neotropical migratory birds (NTMB) that breed in the assessment area, 38 species have been adequately sampled in breeding bird surveys from which to detect statistically significant population trends over two time periods; 1968-1994 (26 years), and 1984-1994 (10 years). Fourteen species showed significant declines over the 26-year period, and 13 species showed significant declines over the 10-year period. Similarly, 13 and 12 species showed significant increases over those periods, respectively. Seven species [killdeer (*Charadrius vociferus*), olive-sided flycatcher (*Contopus borealis*), willow flycatcher (*Empidonax traillii*), red-winged blackbird (*Agelaius phoeniceus*), western meadowlark (*Sturnella neglecta*), Brewer's blackbird (*Euphagus cyanocephalus*), and Brewer's sparrow (*Spizella breweri*)] showed consistent long-term declines over both time periods. However, five of these seven species occur in low-elevation wetlands or open shrub habitats largely off FS- and BLM-administered lands, and thus are not likely to be heavily influenced by FS or BLM land management activities. The two remaining species are both flycatchers and are both likely influenced to some degree by FS and BLM land management.

Some 16 habitats (vegetation types) were included in the assessment of NTMB status and trends. Riparian vegetation is used by more species (64%

[26]This section is summarized from Saab and Rich (in press).

of all NTMB species) than any other habitat. Other habitats that are used by relatively high numbers of NTMB species include young coniferous forest (38%) and old/mature forest (35%). Among all species with significant 26-year population trends, nine habitats had more species with decreasing populations than species with increasing populations, whereas seven habitats had more increasers. Five of the 16 habitats analyzed with regard to NTMB trends were identified collectively as potentially needing higher conservation priority: riparian vegetation, old forest, shrub-steppe, native grasslands, and juniper woodland. Priority habitats were identified based on declines in populations of associated NTMB species and on the habitats' vulnerability to ongoing management activities. See appendix 5E for information on species that have undergone significant declines and increases over the 10- and 26-year time periods.

Mammals

Small Mammals—Small mammals evaluated in the assessment included those mammals other than bats, carnivores, or ungulates. Species that were considered are collectively found in all of the cover types in the assessment area. Several of the species are exotic to the study area including the Virginia opossum (*Didelphis virginiana*), red fox (*Vulpes vulpes;* a carnivore; native populations are also present), eastern cottontail (*Sylvilagus floridanus*), and nutria (*Myocastor coypus*). Some species, for example many species of ground squirrel in the genus *Spermophillus*, have benefited from changes in cover type like the loss of big sagebrush and the increase in agricultural crops. Habitat for these species may have improved, but they are considered agricultural pests and sometimes are poisoned or killed using other animal control methods. Some species, particularly pocket gophers (*Thomomys* spp.), porcupines (*Erethizon dorsatum*), and mountain beaver (*Aplodontia rufa*), appear to have benefited from conversion of closed-canopy forest to early successional stages. Some small mammals are primarily herbivores, some are omnivores, and others are carnivores and insectivores. Most are considered hosts for a variety of internal and external parasites and prey for a variety of predators. They may also be reservoirs for human disease, such as plague in some species, which is an important consideration in human-animal interactions.

Bats—Very limited information is available on bats of the Basin. Information is lacking on preferred habitats, effects of vegetation alterations, effects of pesticides, and abundance and distribution of bats within the Basin. Insect control was identified as a potential key ecological function for many bat species. Although published accounts refer to bats "controlling" insect populations, few studies are available that quantify effects on insect population abundance. It is known, however, that some species consume vast numbers of insects, including mosquitos and moths. Other ecological functions of bats include the transfer of nutrients to subterranean environments by many bat species and acting as an occasional carrier of rabies.

Human development has favored some species of bat by providing roost sites, hibernaculums, and nurseries. Buildings, bridges, and mines provide habitat for roosting. However, these human-made structures might provide only "sink" habitat for some species; they may entice some bats to roost and hibernate, but other local human activities such as animal control efforts and use of pesticides may cause a net deleterious effect on the bat populations. The effects of changes of distribution and abundance of vegetation communities (for example, interior ponderosa pine) on bats are not well understood. Many species use "deep-furrowed" bark provided by large ponderosa pine. This type of habitat has been reduced. Other conditions providing for bats include mature forests with high snag densities and healthy riparian and wetland areas that provide foraging habitat.

Recreation can potentially adversely affect bat populations, especially if cave nurseries or hibernacula are disturbed. In such cases, seasonal restrictions or cave closures have proven effective measures in avoiding such effects.

Much is being done to help promote conservation of and a positive image about bats to the public. For example, Idaho promotes the building and installing of bat boxes by school classes and offers environmental education, posters, and training courses on bats. Some activities are conducted in conjunction with Bat Conservation International. In Idaho and elsewhere in the Basin, winter cave closures and gating of caves and old mine entrances, which protect bat habitat and prevent disturbances during hibernation, are occuring, usually with cooperation of spelunking groups. Also in Idaho, major studies are being conducted to learn more about the habitat needs and population levels of the Townsend's big-eared bat and the spotted bat.

Carnivores—Many of the carnivores in the Basin are habitat generalists dependent more on availability of prey and lack of disturbance from humans. Examples of such carnivores in the assessment area are the gray wolf (*Canis lupus*), bear [grizzly (*Ursus arctos*) and black (*Ursus americanus*)], wolverine (*Gulo gulo*), and coyote (*Canis latrans*). Others, such as American marten (*Martes americana*) and Pacific fisher (*Martes pennanti*) are closely associated with late-succession conifer forests and riparian habitats or with interior forest environments (Gibilisco 1994). Still other species, such as river otter (*Lutra canadensis*) and mink (*Mustela vison*), occur near or in water and riparian areas. Mustelids (fisher and marten in particular) use large down logs for den sites. Mustelids also use forest landscapes with contiguous or near-contiguous mature or old forest stands.

Distribution and abundance of some carnivores have changed dramatically from historical conditions (Paquet and Hackman 1995). Several species, particularly grizzly bear, gray wolf, and mountain lion *(Felis concolor)*, were and are considered a threat to human safety and livestock production (Curnow 1969; U.S. Department of Interior, Fish and Wildlife Service 1993). Consequently, these species were pursued by government trappers and others from the mid-1800s through the mid-1900s. Methods such as trapping, poisoning, shooting, and the use of bounties were used to reduce the populations. Grizzly bear and gray wolf populations were essentially eliminated from most of the Basin; grizzly bears now remain only in isolated populations. Mountain lion populations were likely reduced in many areas but have increased recently as a result of increased prey populations. Some species such as coyotes, foxes, and skunks increased as a result of reduced competition and removal of their major predators.

The following information is adapted from a longer report commissioned on vertebrate carnivores.[27] Martin and others (1995) also provides information on the legal status and harvest summaries of carnivores in the assessment area.

Ten carnivore species were selected for additional analysis because of issues surrounding their conservation and population viability, and other societal concerns. These species are gray wolf, grizzly bear, black bear, mountain lion, lynx (*Lynx lynx*), wolverine, coyote, American marten, Pacific fisher, and river otter. Long-term conservation of representative carnivores in the Basin is problematic at best. Each species has unique conservation problems that will be difficult to solve.

Many of the large carnivores are habitat generalists and respond well to changes in vegetation. Gray wolves can respond to many vegetation conditions as long as populations of ungulate prey are available. Even though gray wolf, grizzly bear, and other species are protected either by the Endangered Species Act, as amended, or through state regulation, illegal killing and accidental human-caused mortality (misidentification, protection of life, or highway kill) still occur. Consequently, long-term conservation of many of the large carnivores will depend on the attitudes of the public.

Smaller carnivores generally do not garner such highly negative public attitudes, but nonetheless have their own conservation challenges and susceptibility to human activities. Species such as the

[27]Martin and others 1995.

marten and fisher select for late-successional forests which are becoming more limited. Wolverines may be affected by increasing human disturbance of subalpine environments and accidental mortality from trapping. Lynx select for early-seral stage, boreal forest habitats supporting high populations of snowshoe hare (*Lepus americanus*) and other small mammals, as well as landscapes also having older forest mosaics. Because they are at the southern portion of their range in the assessment area and therefore have low population densities, incidental mortality of lynx from trapping, illegal harvest, and road use may adversely affect populations, particularly during population lows. Lynx are very scarce in Idaho, and whether or not they are maintaining themselves along the Montana side of the Rocky Mountains and in northeastern Washington is disputed. The river otter is a habitat specialist dependent on riparian areas that are associated with clean rivers and streams with productive fish populations. Extensive degradation of water quality and riparian communities has reduced habitat for this species.

Conservation themes that simultaneously benefit several species of carnivores include:

- conservation of late-successional forests,
- preservation of large or inaccessible blocks of habitat (with low human disturbance),
- protection or restoration of low elevation riparian and forested habitats to link or connect source populations,
- maintenance of adequate prey populations and their specific habitat requirements, and
- reduction in illegal and accidental killing including accidental take of non-target species during legal hunting, legal trapping, or predator control programs.

Development and use of roads is a primary factor that influences distribution and abundance of most carnivores. Increased access to remote areas results in higher carnivore mortality from hunting, including potential misidentification of species (grizzly bears for black bears, gray wolves for coyotes), and illegal killing (U.S. Department of Interior, Fish and Wildlife Service 1993). Roads also act as significant barriers to movement for some species although the effects of roads on animal movements are not well documented for species other than gray wolf or in ways that helps improve understanding of carnivore population dynamics. Access management of roads in forested, non-forested, and riparian environments is critical to conservation of carnivores.

Many of the carnivore species are very wide-ranging and their conservation likely will require the cooperation of all land managers including private landowners. Close and effective cooperation with Canada is also imperative since many of the species range across the border. Canada contains more suitable habitat and larger populations of some species (lynx, grizzly bear, and gray wolf).

Many area- or site-specific management quandries and problems associated with carnivores simply cannot be resolved at the broad scale. As with other species groups, site-specific consultation with local experts and analysis of local conditions need to be conducted. Management of carnivores should be considered in the full context of their ecosystems while addressing such local issues as restoration of ecological processes and control of the adverse effects of poaching.

Ungulates—Livestock grazing on BLM- and FS-administered lands is an important issue that affects the management of wild ungulate populations. Livestock grazing can be compatible if appropriately managed (that is, when both grazing season and grazing intensity are considered). Two approaches to grazing considered in this assessment emerged from literature reviews and panel discussions: (1) maintaining adequate forage is the key to ungulate management, and (2) cover, especially on winter ranges, is important to offset the poor nutritional quality of forage in winter. The common factor with both views is the vulnerability of wild ungulates. As well, roads play a major role in affecting ungulate vulnerability during all seasons of the year, not just during hunting season.

Ungulates provide an important prey base for most of the large carnivores and provide carrion for many scavengers. Bison *(Bos bison)*, as an example from the Greater Yellowstone Ecosystem portion of the Basin, provide carrion for many vertebrate scavengers and invertebrates as well. Elk (*Cervus elaphus nelsonii*) and moose (*Alces alces*) also provide carrion in this way. The invertebrates that inhabit the carcasses provide a source of food for insectivores, such as bluebirds. Deer and elk are also considered important species for subsistence by most of the American Indian tribes within the assessment area. Woodland caribou probably were never abundant south of Canada, and were never legally hunted. They are endangered with an active protection, reintroduction, and recovery program underway.

The following is abstracted, in part, from a contract report on selected ungulates in the assessment area.[28]

Ungulates were identified for additional analysis to address management concerns, social (recreational hunting) and other public issues, tribal concerns, and economic importance in the Basin. Three ungulate species, moose, black-tailed deer (*Odocoileus hemionus columbianus*), and bison, were not included in the analysis because of limited distribution or rarity of occurrence within the assessment area. Issues and associated environmental correlates were identified, and habitat models for the remaining species [elk, mule and white-tailed deer (*Odocoileus hemionus* and *Odocoileus virginianus*), California and Rocky Mountain bighorn sheep (*Ovis canadensis californiana* and *Ovis canadensis canadensis*), mountain goat (*Oreamnos americanus*), American pronghorn *(Antilocapra americana)*, and woodland caribou (*Rangifer tarandus caribou*)] were reviewed.

All or most of the Basin is occupied by one or more ungulate species. Ungulates are important both for social reasons (recreational hunting and viewing) and for economic returns to local communities through expenditures during hunting and tourism seasons. For example, approximately 450,000 hunters pursue elk annually within the Basin, which results in an economic effect of about $225,300,000 and 3,467 jobs (Teisl and Southwick 1995). Although the permit numbers may be limited for some of the other ungulate species, for example, mountain goat or bighorn sheep, at least some individuals or corporations are willing to pay from $50,000 to over $300,000 for the opportunity to harvest a single bighorn sheep. Other than hunting, viewing ungulates is important to many people. In some areas, congregations of ungulates on winter ranges provide the public the opportunity to see many individuals.

Many ungulate species are important to American Indians for subsistence. Twenty-two tribal areas of interest were identified in the Basin. Elk and/or deer occur in all of these areas and are hunted by tribal members. Bighorn sheep have been the main source of subsistence for Shoshone-Bannock-Paiute Indians in Idaho, although elk, deer (both mule and white-tailed), pronghorn, and mountain goats also have been important.[29]

Similar to states and rural communities, hunting wild ungulates on tribal reservations can provide economic returns to tribes and stimulate active management for these species. Traditional hunting areas for the tribes also include considerable public lands, and in some instances, result in competition for the annual harvest with the general public hunting seasons.

In some instances, competition for forage between domestic livestock and wild ungulates, and use of agricultural crops by wild ungulates present a different economic issue. Reported damage to haystacks, alfalfa fields, and fruit orchards often results in damage claims to states. States expend funds to fence haystacks and orchards to prevent deer or elk entrance, and special hunts are held to reduce ungulate population numbers. Another

[28]Lyon and others 1995.

[29]Personal communication. 1995. Allan E. Thomas, Fish and Wildlife Biologist. U.S. Department of Interior, Bureau of Land Management, Idaho State Office, 3380 American Terrace, Boise, Idaho 83706.

social issue is disease transmission from domestic sheep to wild sheep. This has resulted in severe reductions of wild sheep populations in the Basin.

Ungulates of the Basin are important ecologically because of their influence on vegetation. For example, large numbers of elk in southwestern Montana and at least that portion of the Greater Yellowstone Ecosystem that lies within the Basin have severely reduced riparian willow cover along many streams and rivers by excessive grazing. Large ungulates also provide carrion and prey for many of the large carnivore species such as gray wolf, mountain lion, and bears (both black and grizzly). Carrion is also important to many scavengers such as wolverines, ravens (*Corvus corax*), and magpies (*Pica pica*).

Commodity use of public lands, such as mining, livestock grazing, and timber harvest, affect habitat for many of the ungulate species. Land management often alters vegetation composition and structure and can be beneficial to ungulates if their habitat requirements are considered. However, some human demands, such as recreation and residential development on winter ranges might conflict with management for ungulates.

Threatened, Endangered and Candidate Species

There are 47 terrestrial vertebrate taxa (species or subspecies) listed as endangered, threatened, or as Category 2 candidates (C2) under the Endangered Species Act, as amended (table 5.12). No vertebrates are listed as Category 1 candidate (C1) or proposed by USFWS as threatened or endangered (table 5.8).

For this assessment, U.S. Fish and Wildlife Service provided species status reports on selected threatened, endangered, and candidate species. Those reports are summarized here.

Endangered Vertebrate Species—

Peregrine Falcon (*Falco peregrinus*)—Populations experienced dramatic declines between 1946 and 1975 as a result of pesticide use, primarily DDT and its metabolites DDE and dieldrin. These chemicals accumulated in peregrine falcons and their prey. Mechanisms of the chemicals induced eggshell thinning which caused reproductive failure and nearly caused extirpation (Pagel 1995). The Pacific States Recovery Plan was approved in 1982 and has aided recovery.

Current population survey information within the assessment area indicates slow increase in population densities. Since 1979, 47 new nests have been located in the assessment area. Reproductive success has been fair to good, with higher rates of productivity reported now in Idaho than in previous years, where numbers of young per known nest site averaged 1.15 (N = 190 nests) over the last 11 nesting seasons (Pagel 1995). In Idaho, the species has recovered sufficiently that it is proposed for down-listing to threatened status.

Eggshell thinning continues to be a problem in some areas, particularly Oregon. Pagel (1995) reported that eggshells were thinner by approximately 11 percent, 12 percent and 16 percent in the Yellowstone, Idaho, and Oregon sites within the Basin, respectively, as compared with the average thickness of natural, unaffected eggshells. Levels of eggshell thinning exceeding 17 percent were found in peregrine falcon populations that are currently declining or have been extirpated (Peakall and Kiff 1988).

The population of peregrine falcons of the Basin has been artificially augmented since 1980. Approximately 1,062 birds have been artificially raised at hack sites in the Basin. However, two primary threats remain: contaminants and disturbance of natural nest sites. And at least in Idaho, another potential concern is avian predation of young, especially by great horned owls.

Whooping crane (*Grus americana*)—This migratory species winters outside the Basin (southeast Texas coast) and breeds in Wood Buffalo National Park in Alberta, Canada, and Grays Lake National Wildlife Refuge in Idaho. A third, non-migratory flock is being established in Florida. Natural occurrence in the assessment area is currently

Table 5.12— Threatened (T), endangered (E), and candidate (C1 and C2) vertebrate species of the Basin.

Scientific Name	Common Name	USFWS Status
Amphibians		
Ascaphus truei	Tailed frog	C2
Bufo boreas	Western toad	C2
Plethodon larselli	Larch Mountain Salamander	C2
Rana aurora	Red-legged frog	C2
Rana cascadae	Cascades frog	C2
Rana luteiventris	Spotted frog	C2
Reptiles		
Clemmys marmorata	Western pond turtle	C2
Sceloporus graciosus graciosus	Sagebrush lizard	C2
Birds		
Accipiter gentilis	Northern goshawk	C2
Agelaius tricolor	Tricolored blackbird	C2
Athene cunicularia	Burrowing owl	C2
Brachyramphus marmoratus	Marbled murrelet	T
Buteo regalis	Ferruginous hawk	C2
Centrocercus urophasianus	Sage grouse	C2
Chlidonias niger	Black tern	C2
Contopus borealis	Olive-sided flycatcher	C2
Cygnus buccinator	Trumpeter swan	C2
Empidonax traillii	Willow flycatcher	C2
Falco peregrinus	Peregrine falcon	E
Grus americana	Whooping crane	E
Haliaeetus leucocephalus	Bald eagle	T
Histrionicus histrionicus	Harlequin duck	C2
Ixobrychus exilis hesperis	Western least bittern	C2
Lanius ludovicianus	Loggerhead shrike	C2
Plegadis chihi	White-faced ibis	C2
Strix occidentalis caurina	Northern spotted owl	T
Tympanuchus phasianellus columbianus	Columbian sharp-tailed grouse	C2
Mammals		
Brachylagus idahoensis	Pygmy rabbit	C2
Canis lupus	Gray wolf	E
Euderma maculatum	Spotted bat	C2
Gulo gulo	Wolverine	C2
Lynx lynx	Lynx	C2
Martes pennanti	Fisher	C2

Table 5.12 (continued).

Scientific Name	Common Name	USFWS Status
Microtus pennsylvanicus kincaidi	Potholes meadow vole	C2
Myotis ciliolabrum	Western small-footed myotis	C2
Myotis evotis	Long-eared myotis	C2
Myotis thysanodes	Fringed myotis	C2
Myotis volans	Long-legged myotis	C2
Myotis yumanensis	Yuma myotis	C2
Ovis canadensis californiana	California bighorn sheep	C2
Plecotus townsendii pallescens	Pale western big-eared bat	C2
Sorex preblei	Preble's shrew	C2
Spermophilus brunneus endemicus	Idaho ground squirrel	C2
Spermophilus brunneus brunneus	Idaho ground squirrel	C2
Spermophilus washingtoni	Washington ground squirrel	C2
Ursus arctos	grizzly bear	T

limited to the Grays Lake site. This population winters at Bosque del Apache National Wildlife Refuge in New Mexico. Only three birds use the Grays Lake site. Primary habitat is shallow, wet meadows and their adjacent uplands with minimum human disturbance. Cross-fostering with sandhill cranes is being used to augment the population at Grays Lake National Wildlife Refuge. This population has been declining as a result of poor or improper imprinting on foster parents to the point where the Grays Lake site has been removed as critical habitat and the birds designated as "experimental nonessential" (U.S. Government 1996b).

Whooping cranes likely were never common in the Basin and were nearly extirpated for plumage in the early 1900s. Continued threats to recovery are loss of wetlands, illegal shooting, collisions with powerlines, and disease.

Gray wolf (*Canis lupus*)—Wolves were nearly exterminated from the Basin between the mid 1880s and early 1900s (Fritts and others 1994, Lauffer and Jenkins 1989). Individuals were killed by shooting, poisoning, and trapping. Prior to Euro-American settlement of the western United States, bison, elk, bighorn sheep, deer (mule and white-tailed), and moose were the primary prey of wolves. During and following settlement, domestic livestock were introduced in large numbers, and native ungulates were killed for food and hides. This resulted in drastic declines in the native prey base, reduction in natural habitats, and increases in human-wolf encounters.

Public attitudes toward wolves have slowly changed since the 1970s with increasing interest in wildlife, conservation, and the environment. As a result of public agency management, wild ungulate populations, especially elk and deer, have increased. As a result of changing attitudes towards predators such as wolves in Canada, reductions in human-caused mortality allowed wolves to recolonize northwest Montana in the 1970s and 1980s and Washington and Idaho in the 1990s. Reintroduction of wolves in Yellowstone National Park and in the Central Idaho Wilderness (Central Idaho Gray Wolf Recovery Area) were made in winters of 1994-95 and 1995-96. All reintroductions appear successful with very minor impacts to humans. Reintroductions were also made in the Sawtooth Mountains of Idaho in 1995 and 1996. The Central Idaho Recovery Area and the Northern Rocky Mountain Recovery Plan (U.S. Department of Interior, Fish and Wildlife Service 1987) are two other ongoing efforts to recover the population in the assessment area.

Wolves can successfully respond to most changes in vegetative cover types and structures. Their primary needs are available ungulate prey, available den sites, and freedom from human persecution (Fritts and others 1994). The major threats to recovering gray wolf populations are continued persecution and illegal killing.

Woodland caribou (*Rangifer tarandus caribou*)—A small population of approximately 60 of woodland caribou remains in the Selkirk Mountains of northeastern Washington and northern Idaho. The range of this herd extends into southern British Columbia. The population decline, which began in the mid-1950s, resulted primarily from illegal killing. The recovery program for this population began in 1987 with an augmentation of 24 animals, followed by introductions in 1988 and 1990 of 24 and 12 animals, respectively. A fourth introduction is currently underway.

Early winter habitat has been described as low elevation, late-succession cedar/hemlock forests. Later in winter, animals move to high-elevation, wind-blown slopes of late-succession spruce/fir forests where they seek fallen arboreal lichens.

Threats to the population include habitat alteration as a result of timber harvest or wildfire; a restricted range which, when coupled with predation, has greatly increased risk to long-term viability; and low population numbers. In Idaho, chief threats are timber harvest, illegal killing, and highway road-kill during migration. Disturbance by winter recreation is also a threat.

Threatened Vertebrate Species—

Bald eagle (*Haliaeetus leucocephalus*)—The bald eagle was listed by USFWS as threatened in Oregon and Washington and endangered in Montana, Idaho, Wyoming, and Utah (within the Basin) in 1978. The endangered status was proposed for down-listing to threatened in 1994 and was down-listed in 1995. Major declines in the nesting population in the Basin began in the early 1900s and continued through the 1960s. Causes were direct killing, direct and secondary losses as a result of chemical contaminants (DDT and DDE), disturbance during nesting and loss of nesting habitat.

Nest territories are typically associated with large bodies of fish-producing water. Bald eagles use the same territory in successive years. Although multiple nests may be constructed within one territory, bald eagles show a strong fidelity to the same nest. In the Basin, nest stands consist largely of coniferous trees with large branches to hold the nest, though cottonwood trees are also used, as in the South Fork area of the Snake River, Idaho.

The Pacific Northwest accounts for 25 percent of the wintering bald eagles in the contiguous 48 states. Most wintering habitat is associated with prey sources of fish, waterfowl, or carrion. An existing recovery plan for Pacific bald eagle (U.S. Department of Interior, Fish and Wildlife Service 1996) has been instrumental in mobilizing conservation activities for the species in the assessment area.

Grizzly bear (*Ursus arctos*)—Historically, the grizzly bear was present over most of the Basin. The population was reduced from over 50,000 to less than 1,000 bears between 1800 and 1975 (U.S. Department of Interior, Fish and Wildlife Service 1993). The reduction was a result of human expansion into and development of the western United States. The primary causes of the decline were trapping, unregulated hunting, and killing while protecting human life. The grizzly bear was listed as threatened in 1975. A recovery plan was approved in 1982 that identified six recovery areas to be managed for grizzly bears (Cabinet-Yaak, North Cascades, Selkirks, Bitterroots, Northern Continental Divide, and Yellowstone Grizzly Bear Recovery Areas, sometimes also referred to as Ecosystems). All six of these are totally or partially within the Basin. Population estimates for the six zones range from 600 to 1,100 bears with 95 percent in the Northern Continental Divide and Yellowstone Grizzly Bear Ecosystems.

Human-induced mortality is the primary threat to grizzly bear recovery. Management actions or lack of actions that are threats include increasing access with road and trail construction and lack of sanitation management in some recovery areas. Food and garbage associated with residential development on the forest/urban interface, developed campgrounds, and other recreation activities can result in bears becoming conditioned to human foods. In many cases, such conflict causes bears to be destroyed. Lack of interchange of bears between populations may also be a long-term threat to many of the populations.

Northern spotted owl (*Strix occidentalis caurina*)—The northern spotted owl nests in late-successional forests on the east slopes of the Cascade Mountains. The majority of nest sites are in late-succession Douglas-fir or mixed conifer vegetation. In some cases nest sites are in younger vegetation but with structural components that are found in older stands. Most of the low and mid-elevation forest habitat is fragmented as a result of natural factors (for example, soils, fire, and unforested high elevations), and timber harvest.

Marbled murrelet (*Brachyramphus marmoratus*)—No known nesting of murrelets has been recorded within the Basin. Reports of individuals have been recorded near the crest of the Cascade Mountains. The species is expected to be present within 55 miles of marine environments and is thus barely within the assessment area just east of the crest of the Cascade range in Washington. Loss of nesting habitat is the major threat to marbled murrelets within the Basin.

Species of Tribal Interest

Vertebrates of interest to the American Indian tribes within the Basin were analyzed by comparing historical vegetation cover types and structural stages with the current condition. Environmental correlates other than vegetation were not considered in this analysis. The Science Integration Team identified 71 terrestrial vertebrates as species of special tribal interest (TS 1995). Species were not listed by specific tribe; therefore, all species were analyzed for all tribal areas regardless of whether or not the species range overlapped a specific tribal area. Decreasing trends in suitable environments were exhibited by 63 percent of the species and increasing trends by 37 percent. Of those that decreased, 50 percent decreased more than 20 percent and of those that had increasing trends, 52 percent increased more than 20 percent (TS 1995) (also see tables and appendices for information on trends of suitable environment).

Areas Containing Populations of Large, Wide-Ranging Carnivores

The overall distribution of most of the large carnivores (secondary predators, or tertiary consumers) has declined and individual populations have decreased since European settlement in the Basin and other parts of the western United States. Large carnivores of the Basin include six species: grizzly bear, American black bear, gray wolf, mountain lion, lynx, and wolverine (a mid-size carnivore also considered here). All of these are large-bodied and have large home ranges.

Many parts of the Basin continue to support populations of black bear and mountain lion but few areas still contain grizzly bear and gray wolf. Information on distribution and density of wolverine in the assessment area is lacking, although some studies have been conducted in the Sawtooth Mountains of Idaho. Four areas, the Yellowstone, North Cascades, Cabinet-Yaak, and Selkirks Grizzly Bear Recovery Areas, each contain all of the six species but have low numbers of either grizzly bear, wolf, and/or wolverine. Only the Northern Continental Divide Grizzly Bear Recovery Area (which includes Glacier National Park, the Bob Marshall Wilderness, and the North Fork of the Flathead River) and possibly parts of the Cabinet Mountains contain populations of all six species that are well distributed and abundant enough to allow studies to investigate the relations among the above species. Historically, much of the Basin, especially the forested parts, supported populations of all of these large predators.

Mountain lions remain well distributed within the forested habitats in the Basin. Human encounters with mountain lions have increased over the past few years, possibly as a result of increased numbers of mountain lions or of increased human activity in mountain lion habitat. Black bears are also well distributed in the forested ecosystems within the Basin. All states continue to offer sport hunting of black bears and most, if not all, offer permits for mountain lions.

Within suitable vegetation cover types in the Basin, lynx and wolverine are widely distributed although their total numbers and local density have been reduced significantly. Within the Basin, lynx are on the southern extension of their range (Koehler and Aubry 1994). Their distribution in the assessment area may have retracted northward (Koehler and Aubry 1994). The largest concentration of lynx in the contiguous 48 states has been identified in north-central Washington (Brittell and others 1989). Smaller, isolated populations remain across northern Washington but in some cases in very low numbers as compared with historical levels. Most of these individuals are connected to populations and habitat in British Columbia. Lynx are also present in Idaho and Montana and are still trapped (two permits per year) in Montana. Wolverine are reported over much of the Basin, but are found in very low densities except in parts of the Rocky Mountains (Banci 1994).

The northern Rocky Mountains (Glacier National Park and adjacent wilderness areas) and Yellowstone National Park have succeeded in maintaining grizzly bear populations because of associations with protected recovery areas and protection against trapping, poisoning, and killing during settlement of the western United States. Although gray wolves were nearly extirpated from all of the lower 48 states, recolonization of the Northern Rocky Mountains began when the Canadian government relaxed their predator control programs for wolves allowing wolf populations to expand and disperse southward from Canada (Fritts and others 1994). Changes in human attitudes toward wolves and the reintroduction of wolves increase the chances that some of the dispersing animals will survive.

Grizzly bears are present in five of the six currently designated Grizzly Bear Recovery Areas (the Bitterroot Recovery Area is the exception). The North Continental Divide and Yellowstone Recovery Areas have grizzly bear populations that are of sufficient size to study relations and interactions with other species such as predators and scavengers. The Yellowstone Recovery Area may not have populations of gray wolves (reintroduced in 1995) or lynx of sufficient size to investigate interactions between species. The Cabinet-Yaak Recovery Area may have sufficient populations, although the grizzly bear population is still being augmented, of all six predators to warrant studies of their interactions but no such research is currently being conducted.

There are ongoing studies in northern Montana on grizzly bears, gray wolves, and mountain lions. Some preliminary anecdotal information from these studies relates to how these three species interact. Four cases of wolves killing mountain lions but not consuming them have been reported. There has been one report of several wolves pursuing a grizzly bear sow with cub and possibly killing and consuming the cub. Other reports are of wolves killing coyotes.[30]

In previous studies, mountain lions tended to remain with their kill, primarily ungulates, for more than one week until they eventually completely consumed the animal. In northern Montana, however, mountain lions tend to abandon their prey following the kill and a single meal. Such observations suggest that other scavengers, such as magpies and ravens, have a continuous source of carrion when such carnivores are present.[31]

There is speculation[32] that mountain lions began to occupy low elevation areas where wolves were

[30]Personal communication. 1995. Daniel Pletcher. University of Montana, School of Forestry, Bozeman, Montana 59717.

[31]Lyon and others 1995.

[32]See footnote 31.

eliminated and took advantage of prey sources. With recovery of wolves and their occupation of low elevation valleys, mountain lions will likely recede to their more traditional, rougher terrain habitat.

Paquet (1992) indicated that where prey resources are not limiting, that is where healthy populations of deer, moose, and elk are present, little competition for food occurs among large carnivores. Paquet (1992) found that where coyotes and wolves occupied the same area and elk, white-tailed deer, and moose were present, coyotes tended to prey primarily on deer and occasionally on young elk, and wolves selected elk and white-tailed deer and, secondarily, moose. Coyotes also tended to follow wolves to scavenge wolf kills. Periodically, wolves killed coyotes, but did not search them out. Similar differences in prey preference have been noted in northern Montana[33] where mountain lions prey more on elk, wolves on deer, and grizzly bears on moose calves. Wolverines are primarily scavengers (Banci 1994) and benefit from ungulate kills made by other predators. Recent (1995) information from Yellowstone National Park[34] on reintroduced wolves indicates that grizzly bears are displacing wolves from carcasses.

Large carnivores can also influence their environment in other ways. Grizzly bear digs in alpine meadows currently are being investigated relative to nutrient cycling. Preliminary results indicate higher levels of nitrogen in digs as compared to similar areas with no recent digs. Some plants, especially glacial lily, are more robust and vigorous within digs.

Distribution and abundance of most of the large-bodied carnivores in the assessment area have decreased since settlement by Europeans. Very few studies have evaluated effects of changes in distribution and abundance of these large animals on other species or the environment. This change, in turn, has likely influenced the distribution and abundance of scavenger species of vertebrates throughout the assessment area. There is very little information that suggests populations of prey, particularly ungulates, have increased as a result of reduction of predator abundance and distribution. Many ungulate populations, such as deer and elk, have dramatically increased since decline of predators, but this is largely a result of habitat enhancement, or regulation of hunting. Other potential effects of the long-term decrease in large carnivores might include reduced competition with other smaller predators, such as coyotes, raccoons, and skunks, which allows those species to increase in distribution and abundance.

Ultimately, the distribution and health of large carnivore populations of the Basin can be thought of as an index of the status and distribution of wild areas in the western United States. These species are sensitive indicators of the degree of human-caused change of wild lands. From a human perspective, they also play critical roles in American Indian tribal lore and religion and are living embodiments of places that are felt to be still truly wild.

Implications of Management Activities on Terrestrial Vertebrates

Distribution and abundance of species can be influenced by many factors. Some of the factors are well understood (for example, reductions in cover type or structure affects almost all species to some degree). The northern spotted owl provided the classic example. Reductions in late-succession, conifer forests west of the Cascade Mountains resulted in the listing of the species as threatened under the Endangered Species Act. Other examples include the broad-scale use of pesticides for vegetation or insect control resulting in downward trends in species such as peregrine falcons and bald eagles. Throughout the expert panels on vertebrates, threats to species or groups were identified. The following section describes threats to each taxonomic group.

[33]Personal communication. 1995. John Weaver, carnivore panelist, Missoula, Montana 59807.

[34]See footnote 33.

Amphibians—Most of the amphibians present in the Basin have life cycles that include aquatic conditions as well as terrestrial conditions. The larval stage of most salamanders and frogs occurs in an aquatic environment.

Loss of wetlands has the biggest adverse effect on amphibians. The direct loss of habitat through development for residences or agriculture has had major adverse effects. Leonard and others (1993) estimated that between one-third and one-half of the wetlands in Oregon and Washington have been drained or filled.

Introduction of exotic species has increased predation in many areas and resulted in lower population numbers or elimination of some species in waters where the predators are present. Many high-elevation lakes have been stocked with spiny-rayed fish, primarily trout, over the past 50 years. In lakes with breeding amphibians, the high biomass of young provided abundant food for fish, but as a result, many amphibian species declined. The introduction of bullfrogs in some low elevation ponds has also increased predation on larval and adult stages of many amphibian species. Introduction of carp in some areas removed aquatic vegetation and in turn limited both egg-laying habitat and habitat for plankton and small insects used as food.

Some species, such as the Great Basin spadefoot (*Spea intermontana*) and tiger salamander (*Ambystoma tigrinum*), have a wide tolerance for water quality including dissolved oxygen content and temperature. Other species, like the Idaho giant salamander (*Dicamptodon aterrimus*), have a lower range of tolerance. Increased sedimentation resulting from land management practices, whether agricultural or forestry, can fill crevices and interstitial spaces or other niches and affect eggs and larval stages directly and indirectly by reducing aquatic insect production and thus, limiting food.

Irrigation can be both beneficial and detrimental. Large dams and irrigation reservoirs can result in drawdowns that cause egg masses to dry. Irrigated areas may provide suitable conditions for egg laying but many dry up before the eggs hatch, resulting in loss of production for some species. For other species, irrigating fields increases their habitat; the tiger salamander and Great Basin spadefoot are examples.

Roads can have direct effects on individual amphibians through mortality, especially during dispersal. Roads can also result in increased sedimentation of aquatic systems which influences both food and reproduction.

Herbicides and other pesticides also have both direct and indirect adverse effects on amphibians. Much information is available on this topic. Livestock management is another area that may adversely affect species by altering water quality (run-off from feed lots), changing native vegetation, trampling, and altering native methods. The last threat relates to collection and use of various amphibians for "pets," for science industries, and, in some cases, for fish bait. Many states have passed statutes to prevent these practices.

Reptiles—Large dams have resulted in the loss of considerable habitat for reptiles, especially along the Snake River. In addition to loss of riparian and aquatic habitat, for some species, most of the pool filling occurs in winter when many species are communally hibernating. The result is loss of many individuals and perhaps even local extirpation of some species, such as the longnose leopard lizard (*Gambelia wislizenii*) and striped whipsnake (*Masticophis taeniatus*), from parts of their range, although the leopard lizard may not be in any particular trouble on Idaho BLM land. Operations of large dams and associated regulated rivers can also result in drawdowns at times critical for some species such as garter snakes.

Conversion of native vegetation to agricultural use, livestock grazing, draining of wetlands, and use of pesticides in the Basin has resulted in degradation of environments or loss of habitats for some reptile species. Livestock grazing and associated activities have altered plant species composition and introduced many exotics, resulting in habitat degradation and loss for the sagebrush lizard

(*Sceloporus graciosus graciosus*) and western terrestrial garter snake (*Thamnophis elegans*). Loss of wetlands has directly reduced populations of painted turtle and western pond turtle.

In some of the "desert" areas or sand dunes, off-road vehicle use has become a major threat to reptiles. Roads and off-road vehicles result in direct mortality and in indirect losses by fragmenting habitats. Populations of longnose leopard lizards have been affected by roads and road use in parts of their range. Roads fragment some reptile habitats and can become barriers to movements of some species, particularly burrowing (fossorial) species such as the longnose leopard lizard, striped whipsnake, and gopher snake (*Pituophis catenifer*). Gopher snakes migrate seasonally between habitats and are frequently killed on roads. Many species warm themselves on roads and are run over. In addition to direct mortality, road construction and mining activities for gravel and other materials for road surfaces can destroy habitats and hibernacula for species such as the western fence lizard (*Sceloporus occidentalis*) and western rattlesnake (*Crotalus viridis*).

In the past, some species such as the western pond turtle *(Clemmys marmorata)* were captured for food and trade. Most states now provide some protection. Capture for pets may be a problem with some species, such as the horned lizards and Mojave black-collared lizards (*Crotaphytus bicinctores*). Some of these species including common garter snakes and horned lizards were abundant in the past and are still common, but their numbers and distribution have declined.

Fire suppression has induced conifer encroachment on certain shrub habitats and has contributed to loss of habitat for reptiles. Additionally, fire suppression and intensive grazing has altered the vegetation structure of some of the shrub habitats. If intensive fire occurs in these habitats under current conditions, the shrubs over large areas may be lost and the area converted to grassland; this would reduce habitats for some species closely associated with shrub habitats, including the Mojave black-collared lizard.

Mammals and Birds—The diversity of species and habitat uses between these two groups is such that actions that are threats to one species may be beneficial to others. For example, some of the ground squirrels may have benefited from conversion of native arid shrub and grassland vegetation to agricultural lands while at the same time the pygmy rabbit (*Brachylagus idahoensis*), which inhabited the same areas, has been reduced to isolated populations and extirpated in parts of its range.

In forested environments, species that more heavily depend on late-succession forests decline as that structure declines, and species tied to early-succession cover types likely benefit. Threats to species that require late-forest succession and associated structural components such as large snags and down, woody material include the reduction or loss of these components, changes in wood decay rates, and declines in insect (primarily ant) populations (Bull and others 1995). The demand for wood products has reduced these components in parts of the assessment area. Anecdotal information on declines in numbers of bats in local areas is related to reduction in the number of large snags.

Fire suppression and intensive forest management has altered much of the forested areas in the Basin area. Associated with this harvest is increased access into areas of previously low human use. These largely inaccessible areas were refuges for some species, like the wolverine and grizzly bear, that are sensitive to human disturbance. Road construction and travel has created barriers for some species. It has also resulted in indirect mortality of some species, increased disturbance during critical periods of life cycles; and increased mortality during recreational hunting and trapping.

Livestock grazing can be a threat to some species, beneficial to some, and neutral to others. The degree or intensity of grazing, both in removal of vegetation and in soil compaction, determines the effect on most species. Species such as ground squirrels, moles, and some shrews are adversely affected by soil compaction and trampling of runways by livestock.

Agricultural practices other than livestock grazing have similar effects. Some species, such as some of the voles *(Microtis* spp.), benefit from an increase in agricultural development but are adversely affected by increased tilling. Use of pesticides and other control measures associated with agricultural production is detrimental to most species either directly or indirectly through reduction of forage or animal prey. Many of the bat species are suspected to be adversely effected by pesticide use for control of forest insects. In some cases non-target species such as nocturid moths are killed; these are important prey for some bats. Some species, such as gophers, ground squirrels, and jackrabbits that increase as a result of agriculture, are considered pests.

Animal damage control through livestock, forest management, or agricultural practices can be a threat to many species. Control of predators, such as coyotes, occasionally may result in mortality of some non-target species including wolves. There have been cases of poisoning for gophers or other small mammals that have resulted in secondary poisoning of scavengers feeding on carcasses. Predator control resulted in extirpation of gray wolves from the Basin by the mid-1940s. The northern portion of the assessment area is being recolonized by wolves both naturally and through reintroduction programs, but human attitudes toward wolves in some areas remain negative and illegal killing still occurs. Numbers of grizzly bear have been significantly reduced but they have not been extirpated in remote areas. Recovery of these species is difficult because of public attitudes and illegal killing.

Recreation activities can present threats to some of the species. Activities can be and are compatible in many areas if the needs of certain species are addressed and managed. Development of large resorts for alpine or cross-country skiing can result in loss of alpine habitat or disturbance of species during winter. Snowmobiles provide access into areas that historically were free of human disturbance during winter. Some species, such as wolverines in high cirque basins, may be easily disturbed and displaced from food sources by snowmobilers. Access into high elevation, deep snow areas by snowmobiles compacts the snow and allows other predators, such as mountain lions and coyotes, into areas where historically they were not present. In some cases this can increase competition on limited prey. Wintering concentrations of ungulates can be disturbed by skiers, snowmobilers, or snowshoers. During summer, this level of disturbance may not be a problem but, in winter, quality food is limited, and movements by large animals require use of calories that cannot be replaced. Under certain weather conditions, additional movements may result in higher-than-normal winter mortality or loss of fawns and calves. Much of this disturbance by recreationists is unintentional.

Summer recreation use, especially in the backcountry, can result in habituation of some wildlife species typically repelled by human presence. In some areas, both black and grizzly bears become conditioned to foods left unattended in camps or garbage left in campsites. Typically, conflicts between humans and bears result in destroying the individual bear.

Recreational hunting is also considered a threat to some species. During black bear seasons, misidentification can result in killing of grizzly bear. Also, most states allow coyotes to be killed during any time of the year, and occasionally gray wolves are killed because of misidentification. Legal seasons for hunting mountain goats may present problems in some areas where hunting limits are too liberal.

Roads, especially interstate highways or other multi-laned, high-traffic-volume roads may present barriers to several species and might directly cause mortality. At least two gray wolves have been killed by vehicles in the last five years. In some cases, large highway systems are fenced, preventing movement of some species. Because of fencing, some ungulate wintering ranges are inaccessible to many animals. The animals, therefore, winter in areas that do not provide sufficient resources.

Loss of wetlands through filling for development or draining for agriculture has reduced habitat for most species of waterfowl, many shorebirds, amphibians, and some mammals such as muskrats.

Trends in Vegetation Cover Types and Structural Stages

In previous sections we have presented results on taxonomic groups and species functional groups. In this section we explore terrestrial ecology of the Basin from the standpoint of habitat–principally, trends in vegetation cover types and structural stages. We discuss shifts in habitat area for vertebrate species; implications of broad-scale vegetation changes for species using native grasslands, native shrublands, and old forests; and implications of habitat fragmentation. We then discuss modeling of mid-scale habitat patch trends, focusing on mid- and old-structure stages of forests. Detailed results of modeling of historic and current vegetation conditions are presented in the Landscape Dynamics chapter of this report. We use the term vegetation community here to refer to vegetation cover types and structural stages.

Shifts in Habitat Area for Vertebrate Species

Four hundred and sixty-three vertebrate species were analyzed for changes in habitat area over time across the Basin (TS 1995). Primary habitat for 63 percent of these species had increased or had not changed in area from estimated historical values across the Basin, while habitat for 38 percent of the species had decreased more than 10 percent from the historical area (fig. 5.3; also see TS 1995). The decline in estimated habitat area was greater for birds (44%) and reptiles (41%), than for amphibians (26%) and mammals (25%).

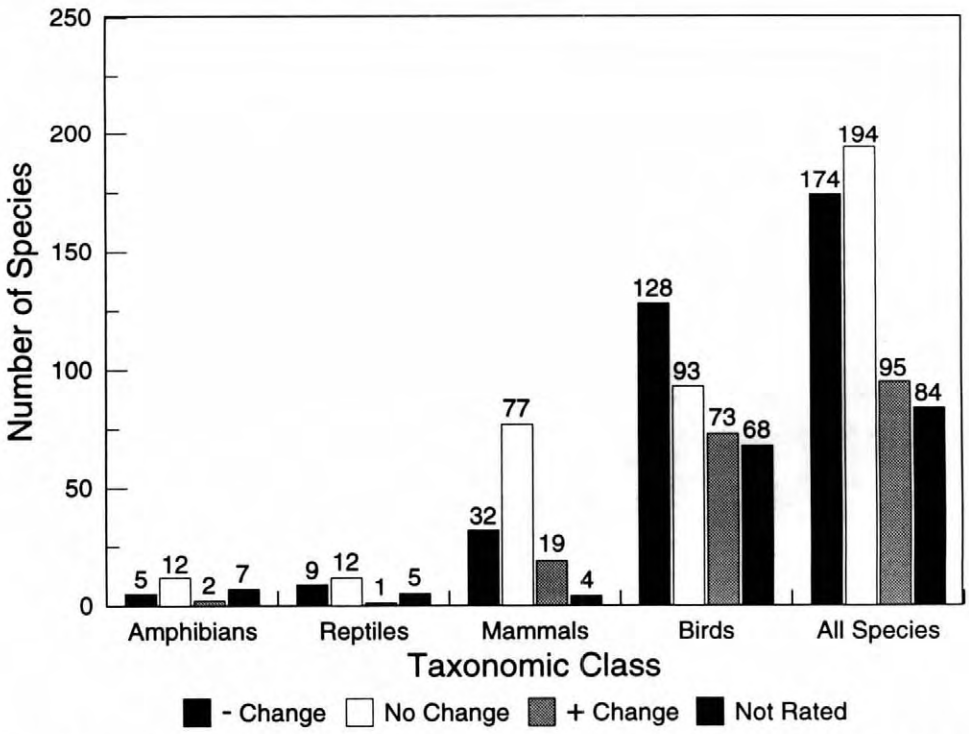


Figure 5.3— Trends in primary habitat change for vertebrates in the Basin since the early 1800s. "No change" was defined by ±10% change in area from the historic area, "negative change" was a >10% decrease in area, and "positive change" was a >10% increase in area. Primary habitat was estimated as the sum area of cover type/structural stage map polygons in Ecological Reporting Units (ERUs)in which the species range intersected ≥10% of the ERU. Species occurrence that was peripheral, occasional, accidental, or with restricted ranges was not rated.

However, estimates of numbers of vertebrate species affected do not tell the full story; further evaluations of species closely associated with specific habitats or environmental conditions revealed additional patterns. Species closely associated with agricultural areas; exotic rangeland vegetation (for example, cheatgrass); stand initiation and young phases of forest development, especially montane cover types such as grand fir and Douglas-fir; and juniper-sagebrush woodlands generally showed gains in habitat area. Species showing habitat losses over the historical period were closely associated with ponderosa pine cover types (especially single-story old-forest stands); other single- or multi-story old-forest structural stages of forest development; native grasslands and shrublands, especially native bunchgrass, sagebrush and other shrub-steppe habitats; riparian cottonwood-willow, and herbaceous and shrub wetland habitats; and large-snag, defective-tree, or log microhabitats.

Declines in riparian, wetland, old forest macrohabitats, and woody debris microhabitat accounted for the decreasing habitat incurred by the bird species tallied. About 45 percent of birds in the assessment area are associated with wetlands and riparian habitats, which declined in quantity (by conversion to other uses such as agriculture) and quality (through degradation from some management practices) over the historical period. A relatively large number of bird species (14%), compared with other vertebrate taxonomic classes, were associated with late-successional forest conditions, especially old forest (3.5%).

In contrast, most mammals were forest or range generalists (58%), which explains why for nearly 60 percent of the mammal species there was little estimated change in habitat area. Losses in mammal habitat appeared to be associated with conversion of rangelands to agriculture and loss of some old-forest macrohabitat and woody debris microhabitat.

Reptiles are mostly associated with rangelands (about 75%) and appeared to have lost habitat largely from the conversion of rangelands to agriculture, and conversion of native shrublands to exotic grasses. Although amphibians are primarily associated with aquatic and riparian habitats (52%), many species are not affected by the scale of disturbance from management practices as they affect terrestrial habitats, are fairly general in use of adjacent terrestrial habitats, or are affected by other factors.

Although percent change in current period habitat area for given species from historical area can be great, the absolute area affected might be very small and relatively insignificant within an individual landscape or Ecological Reporting Unit (ERU). The most dynamic ERUs, in terms of the number of species showing large shifts in habitat area as a percentage of the ERU area, were the Columbia Plateau, Northern Cascades, Northern Glaciated Mountains, Southern Cascades, and Upper Clark Fork ERUs (fig. 5.4; also see TS 1995). About 16 percent of the species in these ERUs were estimated to have lost habitat across greater than 10 percent of the ERU area, whereas similar increases in habitat were estimated for 15 to 20 percent of the species. With the exception of the Columbia Plateau, which is largely non-forest, habitat changes in these ERUs were driven primarily by changes in forest composition and structure. Changes of habitat area in the Columbia Plateau were largely from loss of rangeland habitats and gains in agricultural habitats.

Caution should be used in interpreting estimated habitat changes within ERUs, however, because changes for each species in each ERU were not individually evaluated by panel experts. Therefore, ERU-specific habitat trends should be considered working hypotheses. The Basin-wide model trends for each species are more reliable, but they do not provide ERU-specific results.

Implications of Broad-Scale Vegetation Changes for Species Using Native Grasslands

Nineteen percent (133 plant species) of the listed plant species and groups in the SER database are found in grassland structural stages of rangeland cover types (TS 1995) as well as in other structural

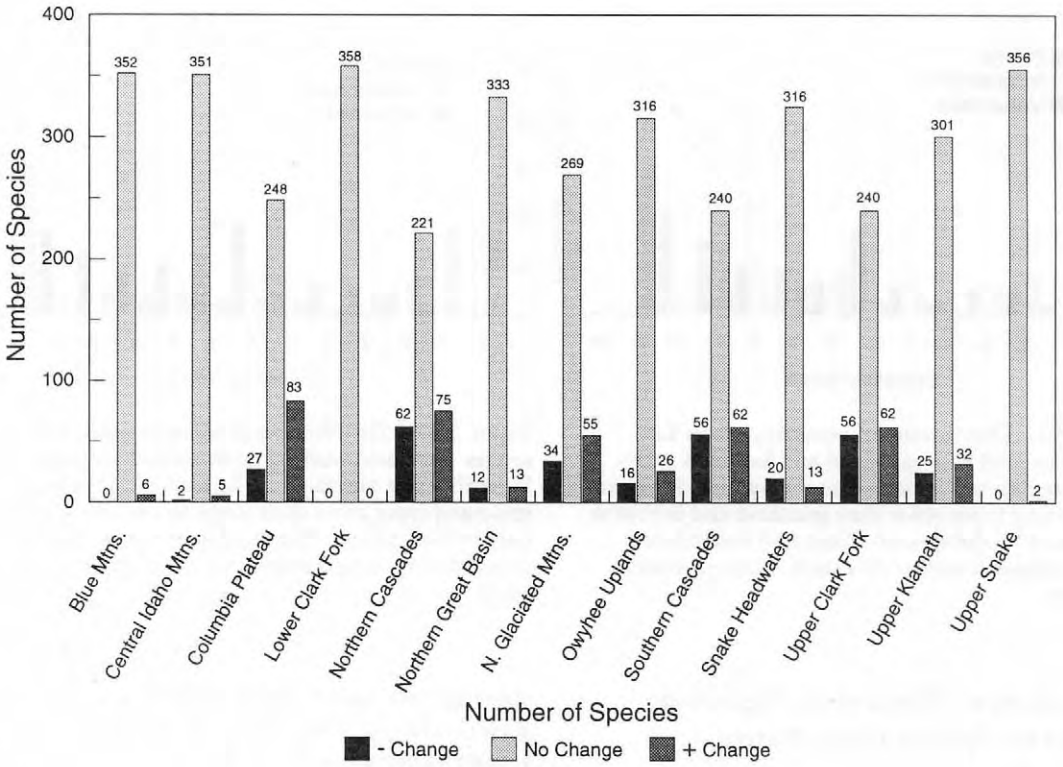


Figure 5.4— Trends in primary habitat change for vertebrates in ecological reporting units (ERUs) within the Basin since the early 1800s. No change was assessed as ±10% difference in habitat area over time relative to total ERU area, negative change was a >10% decrease relative to ERU area, and positive change was a >10% increase relative to ERU area. Primary habitat was estimated as the sum area of cover type/structural stage map polygons in ERU in which the species range intersected ≥10% of the ERU.

stages. [Plants in the database included only federally listed, candidate, or proposed listed species or groups, and are a relatively small subset (less than 10%) of the complete vascular flora.] Nearly 35 percent of species included in the assessment show low flexibility in their use of other structural stages, with versatility scores less than or equal to 2 (fig. 5.5). Versatility scores were calculated as the number of other structural stages used as primary habitat by the species, as listed in the SER database. Scores should be compared only within the vegetative communities, and not compared among vegetative communities.

Of the invertebrate species, 23 percent used herbaceous cover types among other cover types (TS 1995). Of those species, about one-third showed low versatility in using other than grassland/herb cover types and structural stages (fig. 5.5), whereas more than half showed fairly robust versatility by using more than nine other structural stages of other cover types. It is unknown if the entire entomofauna of the Basin would also display these trends. Only a small selection of invertebrate species representing different cover types and ecosystem functions were listed in the database.

Forty-seven percent of the vertebrate species used grassland/herb cover types (TS 1995). Most of those species showed relatively high versatility in habitat use (that is, few were linked solely to grassland/herb types). Low versatility was found in the nine percent of species that used less than or equal to other structural stages of range or forest cover types (fig. 5.5).

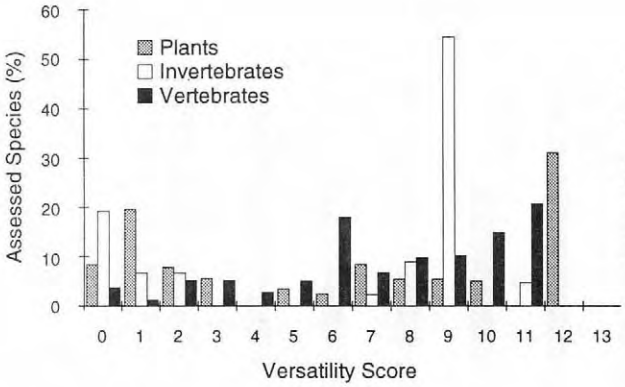


Figure 5.5— Distribution of versatility scores for species associated with grassland and herbland structure. Versatility was measured as the number of vegetation structural types other than grassland and herbland that are used by the species. Plant and invertebrate species considered were only a small subset of much larger biota.

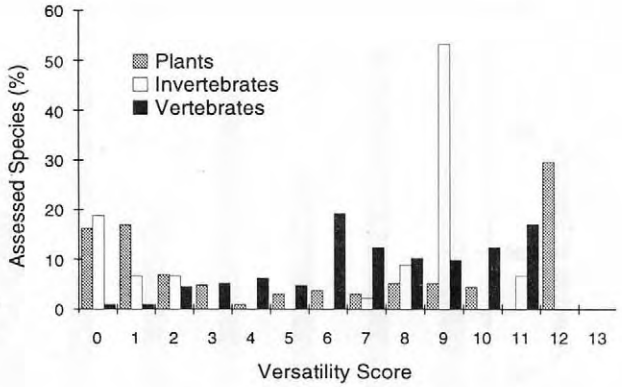


Figure 5.6— Distribution of versatility scores for species associated with range shrubland structure. Versatility was measured as the number of vegetation structural types other than range shrubland that are used by the species. Plant and invertebrate species considered were only a small subset of much larger biota.

Implications of Broad-scale Vegetation Changes for Species Using Native Shrublands

Twenty-three percent of the plant species or groups included in the SER database are found in rangeland shrub cover types or structural stages (TS 1995). Of those species or groups, 43 percent showed low versatility (scores less than or equal to 2) in using other habitats and consequent high impacts from habitat loss (fig. 5.6). However, 33 percent of those species using shrubland showed flexibility in habitat relationships with a high score of versatility (12).

Analysis of invertebrates in shrublands yielded results nearly identical to that for invertebrates in grasslands (TS 1995; fig. 5.6). This is explained by the fact that, as denoted in our SER database, invertebrate species are either rangeland generalists or species whose habitat relationships were not sufficiently well known to allow us to detect different use of grasslands or shrublands.

A relatively large percentage of the vertebrates (57%) use range shrublands (TS 1995), but few of those species were restricted in habitat use to shrublands (fig. 5.6). Only 5.5 percent of those species showed low flexibility (versatility score less than or equal to 2) in using other habitats, with over 80 percent showing use of greater than or equal to 6 other range or forest structural stages.

Implications of Broad-scale Vegetation Changes for Species Using Old Forests

About 15 percent (105) of the 686 vascular and nonvascular plant species or groups listed in the SER database are found in old forest habitats (TS 1995). However, vascular and nonvascular plant species or groups that use old forest have relatively high versatility with respect to the types of forest and range structural stages used. All species or groups are found in at least four structural stages other than old forest, and nearly 40 percent of the species use at least 12 other structural stages of various forest or rangeland vegetation types (fig. 5.7).

Among the 206 invertebrate taxa listed in the SER database and included in this analysis, 32 percent used old forest structural stages of early- and late-seral forests (TS 1995). Of those 66 species, 22

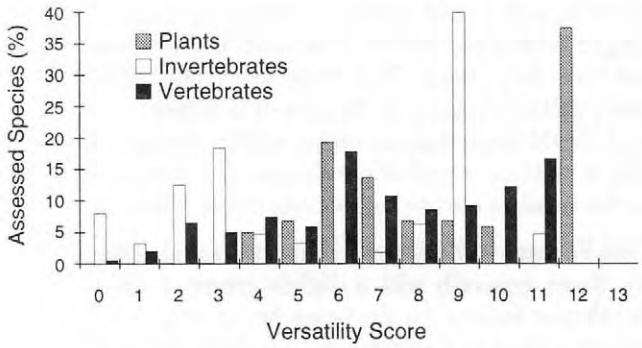


Figure 5.7— Distribution of versatility scores for species associated with old-forest structure. Versatility was measured as number of vegetation structural types other than old forest that are used by the species. Plant and invertebrate species considered were only a small subset of much larger biota.

percent used less than or equal to two other structural stages, showing relatively low versatility with respect to structural stages used (fig. 5.7).

About 60 percent (267 species) of all vertebrate species (467) in the Basin use old forests, along with other stages of forest development (TS 1995). Two percent (6 species) of those species had versatility scores less than or equal to one, and another 6 percent (17 species) used no more than two other structural stages (fig. 5.7). A separate expert panel analysis also found that 2 percent of all vertebrates were closely associated with the old forests to the exclusion of other stages, and an additional 13 percent were closely associated with mid- and late-seral stages of forest development.

Discussion of Rankings and Habitat Fragmentation

Trends in habitat area, as analyzed above, are not meant to necessarily imply trends in population sizes for individual species. Although it is true that appropriate habitat is essential for species to persist, populations respond to more than just habitat. Thus, this analysis should be considered only as a first approximation or a working hypothesis of potential trends of populations; species-specific trends might need further and more detailed analysis.

Broad-scale pattern analysis in the landscape assessment indicated that some of the relatively less abundant habitats have become spatially fragmented (see Landscape Dynamics chapter), thus compounding the potentially deleterious effects of overall habitat loss on regional viability of associated species. Native grasslands and sage-shrub habitats have become the most fragmented vegetation types in the Basin, largely from agricultural development. Lower montane ponderosa pine forests also showed substantial decreases in abundance and patch sizes, thus increasing fragmentation. Among the vertebrate "decreaser" species using old forests were the primary cavity-excavating woodpeckers, which provide cavities and inner-tree access for a wide variety of other fungi, plant, and animal species.

Vertebrate species with large home ranges often are adversely affected by loss and fragmentation of habitats (Lehmkuhl and Ruggiero 1991). Among the species closely associated with mid- and late-seral forest, species with large home ranges will be most affected by the loss and fragmentation of late-seral forests. About 50 percent of those species associated with mid- and late-seral forests have very small home ranges [less than 5 hectares (ha)] and may be less affected locally by fragmentation than would species with larger home ranges (greater than or equal to 5 ha). Thirty-two percent of the mid- to late-seral species have medium to large home ranges (greater than 1 km^2) and likely would be affected by habitat fragmentation locally and regionally. Effects of habitat fragmentation on viability of smaller-ranging species, however, may be accelerated if local habitat fragments become too small to support local, mostly isolated, genetically diverse populations of these species.

When considering the entire Basin, some forests have remained relatively intact, have increased in area, or have become more homogeneous or less fragmented as compared with conditions in early historic times (see Landscape Dynamics chapter). Montane forests have become slightly more homogeneous since early historic times. Upland juniper woodlands have increased in total area, increased

in average patch size, and decreased in isolation (distance between) patches. At least some species associated with montane forests and upland juniper woodlands will likely have increased their distribution.

Modeling of Mid-scale Habitat Patch Trends

Forest Mid-to-Old Structural Stages—Mid-to-old habitat (as identified by running the habitat patch model) within lower montane forests declined for vertebrates in all home range classes in nearly all ERUs (table 5.13). Species habitat area decreased with increasing home range area from an 11 percent decrease (median decline from historic level among ERUs) for species with small home ranges (less than or equal to 50 ha) to 21 percent decrease for species with the largest home ranges. The trend in a decreasing habitat area with larger home-range size among ERUs was driven by differences, between the Southern Cascades and the Upper Klamath ERUs, in habitat change among home-range size categories. Habitat for small home-range species in the Upper Klamath declined about 8 percent, whereas habitat for the largest home-range species declined 35 percent. The Southern Cascades ERU was the only ERU that showed an increase in lower-montane habitat from the historical period. Overall, lower-montane mid-old forest habitat not only declined, but forest fragmentation accentuated habitat loss for species with large home ranges.

In contrast to lower-montane forest habitat, montane mid-to-old forest habitat increased an average of 5 percent among all home range size classes for the whole Basin (table 5.13), but with high variability among ERUs. The area of effective habitat differed little among home-range classes, which suggests a uniform increase in montane forest habitat across landscapes. Major increases (greater than 70%) in montane mid-to-old forest habitat occurred in the Lower Clark Fork and Upper Snake ERUs, with other large increases (15 to 60%) occurring in the Blue Mountains, Central Idaho Mountains, and Columbia Plateau. In contrast, mid-to-old montane habitat decreases ranged from 3 percent to 24 percent in the Southern Cascades, Upper Clark Fork, and Upper Klamath ERUs. Changes in the area of subalpine mid-to-old forest habitat varied widely among ERUs, with an overall slight decline of 4 percent in the smallest home range classes (table 5.13).

Old Forest— Old forest habitat decreased across the Basin, generally with a slightly greater decrease in effective habitat for the larger home range species groups in montane and subalpine community types (table 5.14). Lower-montane old-forest structure declined among ERUs an average 26 percent for species with home ranges up to 300 hectares. The decline in habitat was much less for old-forest species with the largest home ranges (301-650 ha), which would indicate that forest fragmentation occurred at a scale smaller than 300 hectares. However, not all ERUs followed this trend. In some ERUs, (for example, Upper Klamath and Northern Cascades ERUs) habitat area changed similarly across home-range categories. In the Southern Cascades ERU, habitat area increased with increasing home-range size classes, whereas in the Northern Glaciated Mountains ERU no clear trend of habitat area across the home-range size classes emerged.

Montane and subalpine old-forest habitats declined consistently across the Basin. Habitat for species in the 301- to 650-hectare home-range group showed slightly greater decreases than for smaller home ranges, suggesting greater large-scale fragmentation effects. A prominent exception was the large increase (greater than 200%) in subalpine old-forest habitat in the Southern Cascades ERU, especially for species in the 650-hectare home-range size group.

General Species Trends

Much of the above discussions has focused on species response to habitats affected by management activities, particularly timber management and livestock grazing (also see Landscape Dynamics chapter). Here, we summarize some general

patterns among taxa and selected ecological subsystems, ecological processes, and other management activities. Although the following discussions pertain to the entire Basin, the information also can be separated by vegetative community and physiographic province.

This section summarizes information found mostly in the SER database and listed as key environmental correlates or KECs (appendix 5F). It is important to remember that, at this time, this information is very incomplete for plants and invertebrates. Because of the large scope of the current assessment, information on KECs for plant species and plant groups was gathered only for those species currently listed as C1 or C2 candidate, or for species and groups which the plant expert panels and contractors deemed deserving of additional conservation focus, that is, as potential C1 or C2 candidates. Thus, the plant information cited below is restricted to rare plants only. The information on invertebrates is also an incomplete representation of all invertebrates in the Basin. The database contains only example species of a much larger invertebrate fauna (see table 5.3). For plants and invertebrates, then, having species listed with key ecological correlates does not imply that those are the only such species with those correlates. Listings below of species must be viewed merely as examples until a more complete database can be compiled. It is a starting point for considering species in a much broader context.

No listing of recently extinct or extirpated taxa is available for plants, invertebrates, or vertebrates in the Basin. None of the information gathered for this assessment indicated that any vertebrate species has become extinct throughout their range in the Basin in recent decades. However, it is possible that undescribed, locally endemic species or subspecies might have vanished before they could be studied. The lack of evidence for Basin-wide extinction does not imply that extirpation at a local scale has not occurred. Local extirpations of some plant, invertebrate, and vertebrate species have occurred, caused either by natural disturbance or by human settlement and land use.

The status of isolated populations of some of the smaller-bodied, less vagile species may be precarious, and this deserves empirical study. Two possible examples are: the locally endemic potholes meadow vole (*Microtus pennsylvanicus kincaidi*), found only in one tiny location in central Washington at the edge of the otherwise extensive range of the parent species *M. pennsylvanicus*; and the locally endemic White Salmon pocket gopher (*Thomomys talpoides limosus*, which is also a federally listed C2 candidate taxon), also found at the edge of the range of its parent species, *T. talpoides*, in the Columbia Gorge (map 5.1a, 5.1b). These examples illustrate that sometimes the periphery of ranges provides conditions for differentiation of taxonomic lineages, in that distinct subspecies have evolved at these two species' ranges within the Basin. Thus, the periphery of species' ranges deserve conservation attention if the intent of management is to provide for evolutionary potential of the species. Other examples of potentially precarious, locally distributed organisms include locally isolated populations of species with disjunct ranges (maps 5.2a, and 5.2b, show some of the less widely-vagile amphibians and reptiles that have disjunct local populations within the Basin).

Species Associated with Forest Canopy Conditions

Hundreds, if not thousands, of species inhabit the forest canopy subsystem. However, a smaller set of species were identified that particularly correlate with canopy factors such as the density of live tree crowns and canopy closure (from queries to the SER database). Seven example invertebrates correlate with either open or closed canopies or tree crowns (three species of *Choristoneura*, *Malacosoma disstria*, *Scolytus ventralis*, *Pterostichus protractus*, and *Enoclerus sphegeus*). (These are examples only of invertebrate species associated with forest canopy conditions.) Among vertebrates, at least one amphibian (Coeur d'Alene salamander

Table 5.13— Past and current habitat area for vertebrates closely associated with mid- to late-seral (old forest) structural stages of forest development in the Basin. Species were grouped by home range area. Area was determined by the HABSCAPES pattern analysis procedure (Mellen and others 1995a).

Community Group	Ecological Reporting Unit	Habitat Area and Percentage Change by Home Range Area											
		≤ 50 hectares			51-300 hectares			301-650 hectares			651-1300 hectares		
		Past	Current	% Change	Past	Current	% Change	Past	Current	% Change	Past	Current	% Change
Lower Montane	Blue Mountains	1,903	1,607	-16%	2,605	2,207	-15%	2,683	2,177	-19%	2,860	2,217	-22%
	Central Idaho Mtns.	822	725	-12%	757	654	-14%	682	656	-4%	795	633	-20%
	Columbia Plateau	2,854	2,579	-10%	3,492	2,982	-15%	3,694	3,108	-16%	4,068	3,798	-7%
	Lower Clark Fork	0	805	na	0	805	na	0	805	na	0	805	na
	Northern Cascades	1,836	1,279	-30%	1,827	1,274	-30%	1,825	1,274	-30%	1,875	1,227	-35%
	Northern Glaciated Mtns.	901	812	-10%	925	791	-15%	921	792	-14%	1,034	809	-22%
	Southern Cascades	2,491	3,173	27%	2,876	3,156	10%	2,887	3,138	9%	2,863	3,115	9%
	Upper Clark Fork	672	533	-21%	665	529	-20%	663	552	-17%	710	569	-20%
	Upper Klamath	2,497	2,291	-8%	2,672	2,221	-17%	2,960	2,196	-26%	3,582	2,345	-35%
	Total	13,976	13,803		15,821	14,619		16,316	14,697		17,786	15,517	
	Median			-10.9%			-15.0%			-16.3%			-21.1%
Montane	Blue Mountains	1,987	2,363	19%	1,818	2,230	23%	1,859	2,154	16%	1,933	2,228	15%
	Central Idaho Mtns.	1,563	1,808	16%	1,546	1,851	20%	1,610	1,914	19%	1,742	2,126	22%
	Columbia Plateau	404	646	60%	455	630	39%	459	726	58%	500	685	37%
	Lower Clark Fork	1,124	3,255	190%	997	3,213	222%	1,217	3,038	150%	197	2,868	1356%
	Northern Cascades	2,311	2,439	6%	2,348	2,413	3%	2,346	2,385	2%	2,375	2,436	3%
	Northern Glaciated Mtns.	2,358	2,392	1%	2,372	2,363	0%	2,348	2,354	0%	2,403	2,479	3%
	Owyhee Uplands	33	20	-39%	0	0	0%	0	0	0%	0	0	0%
	Snake Headwaters	1,754	1,796	2%	1,666	1,746	5%	1,595	1,720	8%	1,833	1,896	3%
	Southern Cascades	2,407	2,182	-9%	2,404	2,168	-10%	2,404	2,162	-10%	2,404	2,142	-11%
	Upper Clark Fork	1,787	1,546	-14%	1,874	1,700	-9%	1,823	1,744	-4%	2,116	2,048	-3%
	Upper Klamath	2,152	1,985	-8%	2,566	1,972	-23%	2,145	1,972	-8%	3,093	2,353	-24%
	Upper Snake	521	1,239	138%	715	1,234	73%	715	1,243	74%	958	1,907	99%
	Total	**18,402**	**21,672**		**18,760**	**21,519**		**18,523**	**21,411**		**19,554**	**23,168**	
	Median			**4.0%**			**4.8%**			**7.8%**			**3.5%**

Table 5.13 (continued).

Community Group	Ecological Reporting Unit	Habitat Area and Percentage Change by Home Range Area											
		≤ 50 hectares			51-300 hectares			301-650 hectares			651-1300 hectares		
		Past	Current	% Change	Past	Current	% Change	Past	Current	% Change	Past	Current	% Change
Subalpine	Blue Mountains	1,003	569	-43%	998	496	-50%	1,071	484	-55%	1,033	549	-47%
	Central Idaho Mtns.	1,465	1,506	3%	1,463	1,518	4%	1,527	1,539	1%	1,742	1,720	-1%
	Columbia Plateau	14	14	0%	14	14	0%	14	14	0%	14	14	0%
	Lower Clark Fork	109	62	-43%	67	62	-7%	42	62	48%	5	43	760%
	Northern Cascades	1,674	1,609	-4%	1,691	1,632	-3%	1,682	1,627	-3%	1,714	1,698	-1%
	Northern Glaciated Mtns.	528	566	7%	520	546	5%	530	532	0%	532	554	4%
	Snake Headwaters	1,625	1,750	8%	1,578	1,834	16%	1,573	1,807	15%	1,920	2,196	14%
	Southern Cascades	3,537	2,939	-17%	3,533	2,930	-17%	3,537	2,934	-17%	3,537	2,942	-17%
	Upper Clark Fork	500	819	64%	497	817	64%	462	851	84%	440	983	123%
	Upper Klamath	1,284	1,228	-4%	1,284	1,228	-4%	1,284	1,228	-4%	1,284	1,228	-4%
	Total	**11,739**	**11,062**		**11,643**	**11,077**		**11,721**	**11,078**		**12,220**	**11,926**	
	Median			**-3.9%**			**-3.5%**			**0.4%**			**-1.0%**
All Mid-Late Forest	Blue Mountains	4,894	4,539	-7%	5,421	4,934	-9%	5,614	4,815	-14%	5,825	4,993	-14%
	Central Idaho Mtns.	3,851	4,039	5%	3,766	4,022	7%	3,820	4,110	8%	4,278	4,478	5%
	Columbia Plateau	3,272	3,240	-1%	3,961	3,626	-8%	4,168	3,848	-8%	4,582	4,497	-2%
	Lower Clark Fork	1,233	4,122	234%	1,063	4,080	284%	1,259	3,904	210%	202	3,716	1739%
	Northern Cascades	5,821	5,327	-8%	5,866	5,319	-9%	5,852	5,286	-10%	5,964	5,361	-10%
	Northern Glaciated Mtns.	3,786	3,770	0%	3,817	3,700	-3%	3,799	3,677	-3%	3,968	3,842	-3%
	Owyhee Uplands	33	20	-39%	0	0	0%	0	0	0%	0	0	0%
	Snake Headwaters	3,379	3,546	5%	3,244	3,580	10%	3,169	3,527	11%	3,753	4,092	9%
	Southern Cascades	8,434	8,295	-2%	8,814	8,255	-6%	8,829	8,234	-7%	8,804	8,198	-7%
	Upper Clark Fork	2,959	2,898	-2%	3,036	3,046	0%	2,948	3,147	7%	3,266	3,600	10%
	Upper Klamath	5,933	5,504	-7%	6,522	5,421	-17%	6,389	5,396	-16%	7,959	5,926	-26%
	Upper Snake	521	1,239	138%	715	1,234	73%	715	1,243	74%	958	1,907	99%
	Total	**44,117**	**46,537**		**46,225**	**47,215**		**46,560**	**47,186**		**49,560**	**50,610**	
	Median			**-0.4%**			**-4.4%**			**-3.5%**			**-3.2%**

Table 5.14— Past and current habitat area for vertebrates closely associated with old forest structural stages of forest development in the Basin. Species were grouped by home range area. Area was determined by the HABSCAPES pattern analysis procedure (Mellen and others 1995a).

Community	Ecological Reporting Unit	Habitat Area and Percentage Change by Home Range Area								
		≤ 50 hectares			51-300 hectares			301-650 hectares		
		Past	Current	% Change	Past	Current	% Change	Past	Current	% Change
Lower Montane	Blue Mountains	362	310	-14	601	610	2	647	604	-7
	Central Idaho Mtns.	921	508	-45	751	422	-44	728	596	-18
	Columbia Plateau	1,815	1,952	8	3,183	2,361	-26	3,168	3,291	4
	Lower Clark Fork	0	0	0	0	0	0	0	0	0
	Northern Cascades	769	254	-67	861	302	-65	943	270	-71
	Northern Glaciated Mtns.	290	164	-44	194	656	238	180	676	277
	Southern Cascades	864	1,108	28	1,378	1,528	11	1,835	1,881	3
	Upper Clark Fork	0	5	na	0	0	0	0	0	0
	Upper Klamath	794	585	-26	756	515	-32	656	408	-38
	Total	**5,814**	**4,885**		**7,724**	**6,394**		**8,156**	**7,725**	
	Median			**-26.4**			**-25.8**			**-6.6**
Montane	Blue Mountains	512	171	-67	482	233	-52	549	195	-64
	Central Idaho Mtns.	496	436	-12	649	411	-37	690	634	-8
	Columbia Plateau	394	406	3	394	277	-30	394	631	60
	Lower Clark Fork	18	176	878	0	0	0	0	0	0
	Northern Cascades	667	367	-45	731	455	-38	808	499	-38
	Northern Glaciated Mtns.	438	99	-77	565	121	-79	1,478	67	-95
	Owyhee Uplands	0	0	0	0	0	0	0	0	0
	Snake Headwaters	1,377	723	-47	2,050	796	-61	3,032	1,129	-63
	Southern Cascades	494	16	-97	581	0	-100	636	0	-100
	Upper Clark Fork	859	160	-81	1,135	318	-72	1,229	137	-89
	Upper Klamath	2,051	1,975	-4	2,051	1,935	-6	1,996	1,922	-4
	Upper Snake	137	51	-63	135	0	-100	0	0	0
	Total	**7,442**	**4,580**		**8,773**	**4,545**		**10,812**	**5,214**	
	Median			**-47.5**			**-56.5**			**-62.8**

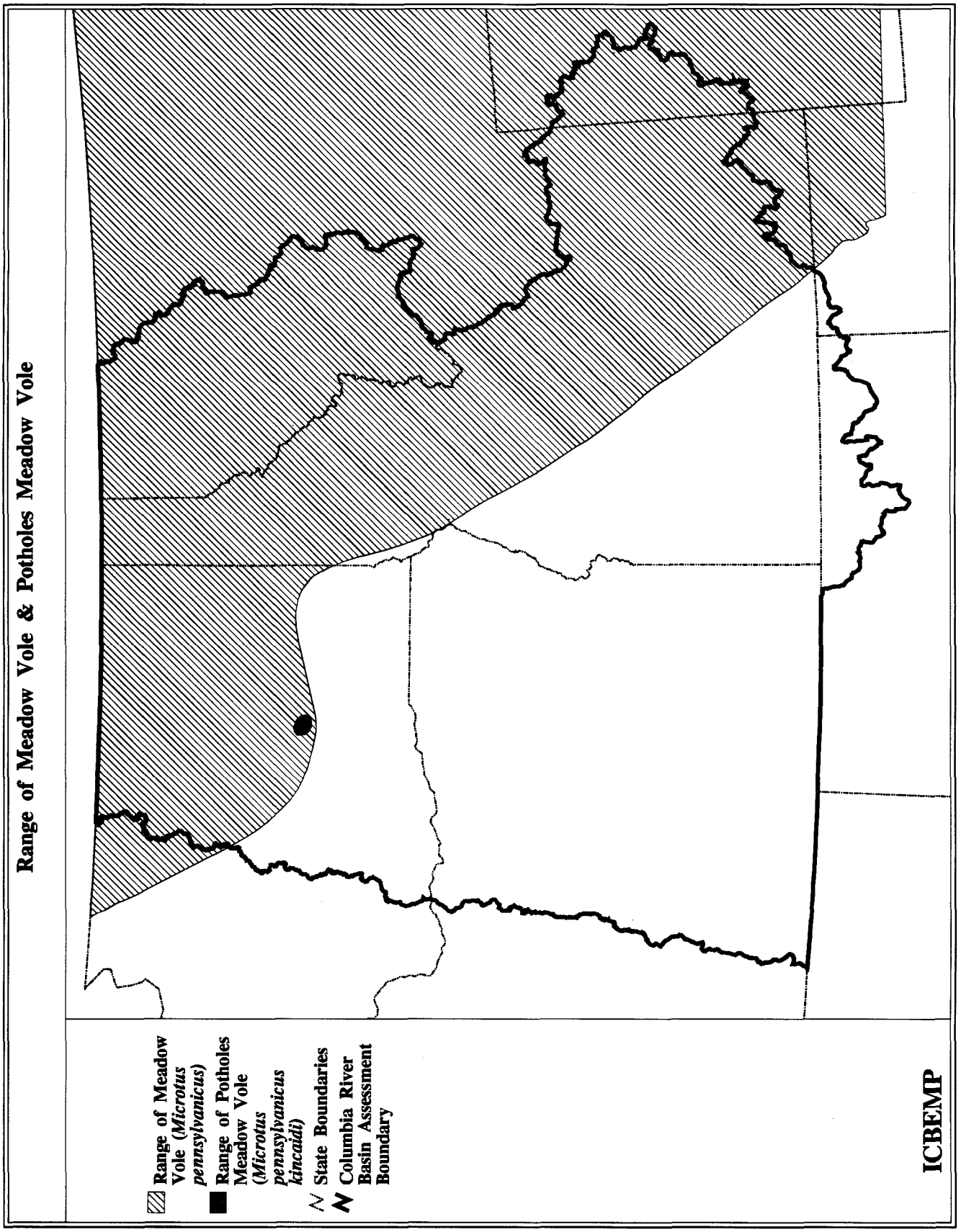
Table 5.14 (continued).

Community	Ecological Reporting Unit	Habitat Area and Percentage Change by Home Range Area								
		≤ 50 hectares			51-300 hectares			301-650 hectares		
		Past	Current	% Change	Past	Current	% Change	Past	Current	% Change
Subalpine	Blue Mountains	709	23	-97	654		-100	678	0	-100
	Central Idaho Mtns.	206	139	-32	109	82	-25	152	0	-100
	Columbia Plateau	0	0	0	0	0	0	0	0	0
	Lower Clark Fork	0	0	0	0	0	0	0	0	0
	Northern Cascades	535	282	-47	599	297	-50	633	280	-56
	Northern Glaciated Mtns.	154	60	-61	192	20	-90	0	0	0
	Snake Headwaters	616	517	-16	951	782	-18	823	862	5
	Southern Cascades	298	923	210	498	1,110	123	130	1,965	1411
	Upper Clark Fork	105	75	-28	87	0	-100	87	0	-100
	Upper Klamath	821	424	-48	811	404	-50	807	424	-47
	Total	**3,444**	**2,443**		**3,900**	**2,694**		**3,310**	**3,530**	
	Median			**-39.9**			**-50.3**			**-55.9**
All Old Forest	Blue Mountains	1,582	503	-68	1,737	843	-51	1,875	800	-57
	Central Idaho Mtns.	1,623	1,084	-33	1,508	916	-39	1,570	1,230	-22
	Columbia Plateau	2,208	2,358	7	3,576	2,638	-26	3,562	3,922	10
	Lower Clark Fork	18	176	878	0	0	0	0	0	0
	Northern Glaciated Mtns.	883	322	-63	951	797	-16	1,658	743	-55
	Northern Cascades	1,972	904	-54	2,191	1,053	-52	2,385	1,048	-56
	Owyhee Uplands	0	0	0	0	0	0	0	0	0
	Snake Headwaters	1,993	1,241	-38	3,001	1,578	-47	3,855	1,990	-48
	Southern Cascades	1,655	2,048	24	2,457	2,638	7	2,600	3,845	48
	Upper Clark Fork	963	240	-75	1,222	318	-74	1,316	137	-90
	Upper Klamath	3,666	2,984	-19	3,618	2,854	-21	3,459	2,754	-20
	Upper Snake	137	51	-63	135	0	-100	0	0	0
	Total	**16,699**	**11,909**		**20,396**	**13,634**		**22,278**	**16,469**	
	Median			**-43.6**			**-43.8**			**-42.9**

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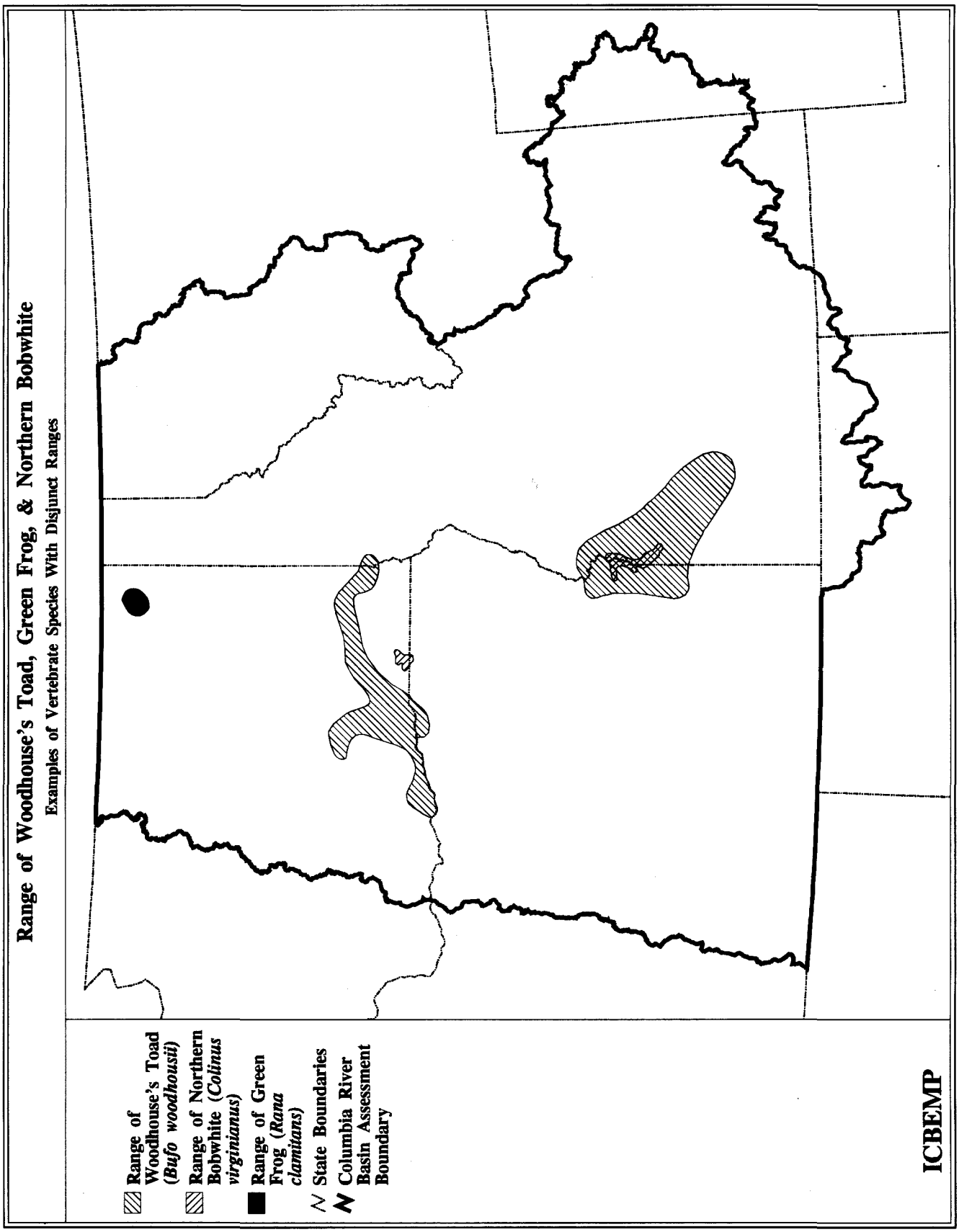
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Map 5.1a— Ranges of two locally endemic subspecies on the edges of their parent species' ranges. Potholes meadow vole *(Microtus pennsylvanicus kincaidi)* and its parent species, meadow vole (*M. pennsylvanicus*).

Map 5.1b— Ranges of two locally endemic subspecies on the edges of their parent species' ranges. White Salmon pocket gopher (*Thomomys talpoides limosus*) and its parent species, northern pocket gopher (*Thomomys talpoides*).



Map 5.2a—Examples of vertebrate species with disjunct ranges within and adjacent to the Basin: Woodhouse's toad, green frog and Northern bobwhite.

Map 5.2b—Examples of vertebrate species with disjunct ranges within and adjacent to the Basin: California mountain kingsnake, ground snake, longnose snake, and wild turkey.

Plethodon idahoensis), no reptiles, 12 birds (including 5 raptors, 4 primary cavity excavators, and others), and 3 mammals (American marten, heather vole *Phenacomys intermedius*, and woodland caribou) show particular correlations to canopy condition.

Other species show correlations with other forest stand characteristics, including tree bark structure, tree diameter (dbh), stem density, and flora. Certainly, many species can be included in these lists, but the species listed above provide a beginning point for identifying good indicators of changes in canopy conditions.

Species Associated with Mistletoe Brooms

A set of species show correlations with mistletoe brooms in tree crowns, including at least one invertebrate, the gossamer-winged butterfly *Mitowra johnsoni* (Lycaenidae). Among vertebrates, the marbled murrelet, spruce grouse (*Dendragapus canadensis*), Cooper's hawk (*Accipiter cooperii*), long-eared owl (*Asio otus*), and American fisher (*Martes pennanti*) all use mistletoe brooms for a variety of purposes.

Species Associated with Dead Parts of Live Trees

Among species associated with dead tree branches are the bark beetle *Scolytus ventralis* (Scolytidae), 6 species of woodpeckers, and 2 owls [great gray owl (*Strix nebulosa*) and, though it occurs erratically within the Basin, northern hawk owl (*Surnia ulula*)].

Species Associated with Trees With Exfoliating Bark

Some six vertebrates specialize on trees with exfoliating (peeling) bark: the white-headed woodpecker (*Picoides albolarvatus*), the brown creeper (*Certhia americana*), and four bats [silver-haired bat (*Lasionycteris noctivagans*), California myotis (*Myotis californicus*), little brown myotis (*Myotis lucifugus*), and Yuma myotis (*Myotis yumanensis*)], although some of these species also use other substrates as roost or nest sites.

Species Associated with Snags, Including Cavity-users

Another forest component is the presence of dead standing trees or snags. Primary cavity-excavator birds include some 17 species (3 chickadees, 3 nuthatches, and the rest woodpeckers). Beyond these 17 species are an additional 29 species of vertebrates that closely associate with snag substrates. These include 3 amphibians, 3 raptors, 7 bats, and 3 carnivores, which use a variety of specific snag characteristics for a wide variety of purposes. At least another 14 species are obligate secondary cavity-users (see discussion below under the section Interspecies Relations).

Species Associated with Down Wood

Among the listed, candidate, or potential candidate species of plants, 46 fungi species, the decayed wood bryophyte group, and five lichen groups were identified in the database as associated with down wood. At least 11 invertebrate species were identified as examples of the several thousand species associated with down wood. Two examples are the checkered beetle, *Enoclerus sphegeus* (Cleridae), which uses both fresh down wood and also intact but older down wood; and the leafcutting bee *Osmia bruneri* (Megachilidae), which uses snags and stumps, but also uses down wood stems with abandoned beetle burrows. Additionally, 82 species of amphibians, reptiles, birds, and mammals show correlations with down wood.

Interestingly, our investigations uncovered a small set of species that seem, in part, to specialize on bark piles at the base of snags. These include at least the invertebrate *Pseudogarypus hesperus* (Psendogarypidae: Chernilldal), and two amphibians, the northwestern salamander *Ambystoma gracile* (which also uses down logs), and the Larch Mountain salamander *Plethodon larselli* (which uses bark piles especially in the driest season in sites that also have moist talus and low soil content).

Species Associated with Litter And Duff

Some example species listed in the SER database that are closely associated with litter and duff conditions include six species of fungi, the humus/duff bryophyte group, one lichen species and two lichen groups (nitrogen-fixing soil lichens, and rotten log and tree base lichens). The carib beetle *Pterostichus protractus* (Carabidae) associates with fallen woody material and litter, as well as with bases of herbaceous plants, rocks, and snags. Among vertebrates, at least four shrews, the shrew-mole, and three songbirds show close associations with litter and duff.

Species Associated with Fire Processes and Insect Outbreaks

Plant species show various responses to fire suppression, frequency, intensity, and seasonality (table 5.15). Response to fire by fungus, lichen, and bryophyte species generally is not known, and response by vertebrate species is not easily depicted.

Among the many invertebrates that respond in various ways to fire, three examples are the lace bug *Acalypta cooleyi* (Tingidae), which is adversely affected by prescribed (and unprescribed) range fires that burn mosses; bark beetles including *Dendroctonus pseudotsugae* (Scolytidae), which are positively correlated with forest fire intensity and that associate with forest stands with severe drought (but not with forest stands with few to no fire-injured Douglas-fir trees greater than 30 cm dbh within a 10-km radius); and the thatch ant *Formica obscuripes* (Formicidae), which is positively correlated with fire frequency.

Among the vertebrates, western tanager (*Piranga ludoviciana*) and purple martin (*Progne subis*) respond positively to recent burns (tanagers more in cottonwood riparian forest, and martins in locations near water). Red-headed woodpecker *Melanerpes erythrocephalus* (rare in the Basin) and orange-crowned warbler (*Vermivora celata*) respond more to older burns, the woodpecker in cottonwood/oak forests and open woodlands, and the warbler more in brushland, riparian, and fire-generated shrubby montane sites with deciduous trees in the understory. Lewis' (*Melanerpes lewis*), black-backed (*Picoides arcticus*), and three-toed (*Picoides tridactylus*) woodpeckers, along with mountain and western bluebirds (*Sialia currucoides* and *Sialia mexicana*), associate with sites where fires have killed the forest overstory.

Black-backed and three-toed woodpeckers associate with mid- to high-elevation forests following irruptions of insect populations such as bark beetles. In the eastern portion of the Basin, the uncommon Tennessee warbler (*Vermivora peregrina*) increases after outbreaks of spruce budworm.

Species associated with Recreation Activities, Roads, and Trails

As with all other management activities, ground and soil disturbances associated with recreational areas, roads, and trails, can have positive, neutral, and negative effects on distribution or abundance of species. Among vertebrates, black-tailed deer may be negatively affected by the presence of cross-country skiers, destination resorts, logging activities, off-road vehicle activity, roads, and subdivisions. Other species also adversely affected by such disturbance activities include tailed frog (*Ascaphus truei*), western toad (*Bufo boreas*), Woodhouse's toad (*Bufo woodhousii*), Great Basin spadefoot, Coeur d'Alene salamander, sage grouse, and mountain goat.

Vertebrates benefiting from disturbance activities are species associated with building structures, including swallows and some of the bats (such as pallid bat *Antrozous pallidus*); gravel road and shoreline substrates, benefiting species such as killdeer; agricultural areas, benefiting species such as horned lark *(Eremophila alpestris)* and rosy finches (*Leucosticte* spp.); and human presence and habitations, benefiting species such as house sparrow (*Passer domesticus*), opossum, house mouse (*Mus musculus)*, and black rat (*Rattus rattus*).

Table 5.15— Plant species associated with various aspects of fire dynamics (excluding fungi). BG = bryophyte group, L = lichen, LG = lichen group, P = vascular plant, PG = vascular plant group (source: SER database).

Class	Name	Class	Name
Fire Suppression Activities			
Positive Effect			
LG	Pioneer Soil Stabilizer Lichens	LG	Tree Crusts
P	*Collomia renacta*		
Negative Effect			
BG	Aquatic Submerged Bryophyte	BG	Decayed Wood Bryophyte
BG	Epiphytic Bryophyte	BG	Humus Duff Bryophyte
BG	Rock Wet Bryophyte	BG	Soil Dry Bryophyte
L	Oceanic Fruticose	L	*Texosporium sancti-jacobi*
LG	Charred Snag Lichens	LG	Forage Lichens
LG	Fruticose Tree Lichens	LG	Leaf Lichens
LG	Moss and Detritus Binders Lichens	LG	N-fixing epiphytes lichens
LG	N-fixing riparian lichens	LG	N-fixing soil lichens
LG	Oceanic forage lichens	LG	Oceanic leaf lichens
LG	Oceanic tree crust lichens	LG	Pin Lichens
LG	Riparian Lichens	LG	Rotten Log and Tree Base Lichens
LG	Soil lichens	P	*Allium dictuon*
P	*Amsinckia carinata*	P	*Arabis falcifructa*
P	*Arabis fecunda*	P	*Arabis suffrutescens* var. *horizontalis*
P	*Aster jessicae*	P	*Astragalus anserinus*
P	*Astragalus atratus* var. *inseptus*	P	*Astragalus mulfordiae*
P	*Astragalus oniciformis*	P	*Astragalus paysonii*
P	*Astragalus peckii*	P	*Astragalus solitarius*
P	*Astragalus sterilis*	P	*Astragalus tegetarioides*
P	*Astragalus tyghensis*	P	*Astragalus yoder-williamsii*
P	*Botrychium ascendens*	P	*Botrychium crenulatum*
P	*Botrychium paradoxum*	P	*Botrychium pedunculosum*
P	*Botrychium pumicola*	P	*Calochortus longebarbatus* var. *longebarbatus*
P	*Calochortus longebarbatus* var. *peckii*	P	*Calochortus nitidus*
P	*Castilleja chorotica*	P	*Castilleja christii*
P	*Chaenactis cusickii*	P	*Collomia mazama*
P	*Cypripedium fasciculatum*	P	*Douglasia idahoensis*
P	*Erigeron latus*	P	*Eriogonum novonudum*
P	*Grindelia howellii*	P	*Hackelia cronquistii*
P	*Haplopappus liatriformis*	P	*Haplopappus radiatus*
P	*Ivesia rhypara* var. *rhypara*	P	*Lepidium davisii*
P	*Lepidium papilliferum*	P	*Lesquerella carinata* var. *languida*
P	*Lesquerella paysonii*	P	*Lesquerella* sp. nov. ("*pulchella*")
P	*Lomatium erythrocarpum*	P	*Mentzelia mollis*

Table 5.15 (continued).

Class	Name	Class	Name
P	*Mimulus clivicola*	P	*Mirabilis biglovii* var. *retrosa*
P	*Mirabilis macfarlanei*	P	*Orysopis herdersonii*
P	*Penstemon glaucinus*	P	*Penstemon lemhiensis*
P	*Penstemon peckii*	P	*Phacelia inconspicua*
P	*Phacelia lutea* var. *calva*	P	*Phacelia lutea* var. *mackenzeorum*
P	*Phacelia minutissima*	P	*Phlox idahonis*
P	*Rubus bartonianus*	P	*Silene spaldingii*
P	*Stanleya confertiflora*	P	*Thelypodium eucosmum*
P	*Trifolium thompsonii*	PG	*Botrychium* Marsh Spp Group
PG	*Botrychium* Meadow Spp Group	PG	*Carex* Calcareous Peatlands Group
PG	*Carex* Dry Forest Group	PG	*Carex* Dry Meadow Low Moderate Elev Group
PG	*Carex* Ephemeral Meadow Subalpine Group	PG	*Carex* Mesic Forest Group
PG	*Carex* Mesic Meadow Low Moderate Elev Group	PG	*Carex* Mesic Meadow Subalpine Group
PG	*Carex* Noncalcareous Peatlands Group	PG	*Carex* Sagebrush Steppe Dry Group
PG	*Carex* Sagebrush Steppe Wetland Riparian Group	PG	*Carex* Wet Meadow Low Moderate Elevation Group
PG	*Carex* Wet Meadow Subalpine Group		
Fire Frequency			
Positive Effect			
BG	Rock Wet Bryophyte	BG	Soil dry Bryophyte
LG	Charred Snag Lichens	LG	Pioneer Soil Stabilizers Lichens
P	*Astragalus paysonii*	P	*Botrychuim ascendens*
P	*Botrychium crenulatum*	P	*Botrychium lineare*
P	*Botrychium paradoxum*	P	*Botrychium pedunculosm*
P	*Botrychium pumicola*	P	*Cypripedium fasciculatum*
P	*Grindelia howellii*	P	*Lesquerella sp. Nov ("pulchella")*
P	*Mimulus clivicola*	P	*Penstemon glaucinus*
P	*Penstemon lemhiensis*	P	*Silene spaldingii*
P	*Trifolium thompsonii*	PG	*Botrychium* Marsh spp group
PG	*Botrychium* Meadow spp group	PG	*Carex* Dry Meadow Low Moderate Elev Group
PG	*Carex* Ephemeral Meadow Low Moderate Elev Group	PG	*Carex* Ephemeral Meadow Subalpine Alpine Group
PG	*Carex* Mesic Forest Group	PG	*Carex* Mesic Meadow Low Moderate Elev Group
PG	*Carex* Mesic Meadow Subalpine Alpine Group	PG	*Carex* Sagebrush Steppe Dry Group
PG	*Carex* Wet Meadow Subalpine Alpine Group		
Negative Effect			
BG	Aquatic Submerged Bryophyte	BG	Decayed Wood Bryophyte
BG	Epiphytic Bryophyte	BG	Humus Duff Bryophyte

Table 5.15 (continued).

Class	Name	Class	Name
BG	Rock Other Bryophyte	L	Oceanic Fruticose
L	*Texosporium sancti-jacobi*	LG	Fencepost Lichens
LG	Forage Lichens	LG	Fruticose Tree Lichens
LG	Leaf Lichens	LG	Moss and Ditritus Binders Lichens
LG	N-Fixing Riparian Lichens	LG	N-Fixing Soil Lichens
LG	Oceanic Forage Lichens	LG	Oceanic Tree Crust Lichens
LG	Pin Lichens	LG	Soil Lichens
LG	Tree Crusts	P	*Aster jessicae*
P	*Astragalus anserinus*	P	*Astragalus atratus* var. *inseptus*
P	*Astragalus mulfordiae*	P	*Astragalus pulsiferae* var. *suksdorfii*
P	*Astragalus sinuatus*	P	*Astragalus solitarius*
P	*Astragalus sterilis*	P	*Botrychium cenulatum*
P	*Calochortus nitedus*	P	*Chaenactis cusickii*
P	*Collomia renacta*	P	*Cypripedium fasciculatum*
P	*Erigeron latus*	P	*Eriogonum novonudum*
P	*Hackelia cronquistii*	P	*Haplopappus radiatus*
P	*Howellia aquatilis*	P	*Lepidium davisii*
P	*Lepidium papilliferum*	P	*Lupinus cusickii*
P	*Mirabilis biglovii* var. *retrosa*	P	*Phancelia lutea* var. *mackenzeorum*
P	*Stanleya confertiflora*	P	*Thelypodium eucosmum*
P	*Thelypodium howellii* ssp. *spectabilis*		
Fire Intensity—Overstory Lethal			
Positive Effect			
LG	Aspen Specialist Lichens	LG	Charred Snag Lichens
LG	Fencepost Lichens	LG	Moss and Ditritus Binders Lichens
LG	N-Gixing Soil Lichens	LG	Pioneer Soil Stabilizers Lichens
LG	Soil Lichens	P	*Astragalus peckii*
P	*Astragalus tyghensis*	P	*Botrychium pumicola*
P	*Caolchortus longebarbatus* var. *longebarbatus*	P	*Haplopappus radiatus*
P	*Lesquerella* sp. nov. *("pulchella")*	P	*Penstemon glaucinus*
P	*Penstemon peckii*	P	*Trifolium thompsonii*
PG	*Carex* Calcareous Peatlands Group	PG	*Carex* Ephemeral Meadow Low Moderate Elev Group
PG	*Carex* Ephemeral Meadow Subalpine Alpine Group	PG	*Carex* Mesic Meadow Low moderate Elev Group
PG	*Carex* Mesic Meadow Subalpine Alpine Group	PG	*Carex* Noncalcareous Peatlands Group
PG	*Carex* Wet Meadow Subalpine Alpine Group	PG	*Carex* Wet Meadow Low Moderate Elev Group
PG	*Carex* Sagebrush Steppe Dry Group		
Negative Effect			
BG	Aquatic Submerged Bryophyte	BG	Decayed Wood Bryophyte

Table 5.15 (continued).

Class	Name	Class	Name
BG	Humus Duff Bryophyte	BG	Rock Wet Bryophyte
BG	Soil Dry Bryophyte	L	Oceanic Fruticose
L	*Texosporium sancti-jacobi*	LG	Forage Lichens
LG	Fruticose Tree Lichens	LG	Leaf Lichens
LG	N-Fixing Epiphytes Lichens	LG	N-Fixing Riparian Lichens
LG	Oceanic Forage Lichens	LG	Oceanic Leaf Lichens
LG	Pin Lichens	LG	Rotten Log and Tree Base Lichens
LG	Tree Crusts	P	*Astragalus pulsiferae* var. *suksdorfii*
P	*Astragalus sinuatus*	P	*Astragalus solitarius*
P	*Botrychium ascendens*	P	*Botrychium crenulatum*
P	*Cypripedium fasciculatum*	P	*Howellia aquatilis*
P	*Lepidium papilliferum*	P	*Mimulus clivicola*
P	*Thelypodium eucosmum*	P	*Thelypodium howellii* ssp. *spectabilis*
PG	*Carex* Forest Riparian Group	PG	*Carex* Wet Forest Group
Prescribed Fire Seasonality			
Spring Prescribed Fire Positive Effect			
LG	Charred Snag Lichens	LG	Forage Lichens
LG	Oceanic Log Lichens	LG	Pioneer Soil Stabilizers Lichens
P	*Grindelia howellii*	P	*Silene spaldingii*
PG	Carex Sagebrush Steppe Dry Group		
Spring Prescribed Fire Negative Effect			
BG	Decayed Wood Bryophyte	BG	Epiphytic Bryophyte
BG	Soil Dry Bryophyte	L	*Texosporium sancti-jacobi*
LG	Pin Lichens	LG	Riparian Lichens
P	*Arabis fecunda*	P	*Astragalus peckii*
P	*Astragalus pulsiferae* var. *suksdorfii*	P	*Astragalus sinuatus*
P	*Astragalus solitarius*	P	*Astragalus tyghensis*
P	*Botrychium ascendens*	P	*Botrychium crenulatum*
P	*Botrychium paradoxum*	P	*Botrychium pumicola*
P	*Calochortus longebarbatus* var. *longebarbatus*	P	*Calochortus longebarbatus* var. *peckii*
P	*Cypripedium fasciculatum*	P	*Lesquerella carinata* var. *languida*
P	*Lesquerella paysonii*	P	*Lomatium erythrocarpum*
P	*Lupinus cusickii*	P	*Mimulus clivicola*
P	*Mimulus pulsiferae*	P	*Mirabilis biglovii* var. *retrosa*
P	*Mirabilis macfarlanei*	P	*Oryzopsis hendersonii*
P	*Penstemon glaucinus*	P	*Penstemon peckii*
P	*Phacelia lutea* var. *mackenseorum*	P	*Rubus bartonianus*
P	*Stanleya confertiflora*	P	*Thelypodium eucosmum*
P	*Thelypodium howellii* ssp. *spectabilis*	P	*Trifolium thompsonii*

Table 5.15 (continued).

Class	Name	Class	Name
Late Summer or Fall Prescribed Fire Positive Effect			
LG	Charred Snag Lichens	LG	Pioneer Soil Stabilizers Lichens
P	*Astragalus applegatei*	P	*Astragalus peckii*
P	*Astragalus tyghensis*	P	*Botrychium pumicola*
P	*Calochortus longebarbatus* var. *longebarbatus*	P	*Cypripedium fasciculatum*
P	*Mimulus clivicola*	P	*Penstemon lemhiensis*
P	*Penstemon peckii*	P	*Silene spaldingii*
PG	*Carex* Dry Meadow Low Moderate Elev Group	PG	*Carex* Ephemeral Meadow Low Moderate Elev Group
PG	*Carex* Ephemeral Meadow Sublapine Alpine Group	PG	*Carex* Mesic Meadow Low Moderate Elev Group
PG	*Carex* Mesic Meadow Subalpine Alpine Group	PG	*Carex* Sagebrush Steppe Dry Group
Late Summer or Fall Prescribed Fire Negative Effect			
BG	Aquatic Submerged Bryophyte	BG	Decayed Wood Bryophyte
BG	Epiphytic Bryophyte	BG	Rock Wet Bryophyte
BG	Soil Dry Bryophyte	L	*Texosporium sancti-jacobi*
LG	Oceanic Log Lichens	LG	Pin Lichens
LG	Riparian Lichens	LG	Rotten Log and Tree Base Lichens
P	*Arbis fecunda*	P	*Astragalus pulsiferae* var. *suksdorfii*
P	*Astragalus solitarius*	P	*Botrychium ascendens*
P	*Botrychium paradoxum*	P	*Cypripedium fasciculatum*
P	*Grindelia howellii*	P	*Haploppus radiatus*
P	*Mimulus pulsiferae*	P	*Silene spaldingii*
P	*Thelypodium howellii* ssp. *spectabilis*		
Early Historic Fire Suppression Activities Long-term Effects			
Positive Effects			
BG	Aquatic Submerged Bryphyte	BG	Decayed Wood Bryophyte
BG	Epiphytic Bryophyte	BG	Humus Duff Bryophyte
BG	Rock Wet Bryophyte	BG	Soil Bry Bryophyte
L	*Texosporium sancti-jacobi*	LG	N-Fixing Epiphytes Lichens
LG	N-Fixing Riparian Lichens	LG	N-Fixing Soil Lichens
LG	Oceanic Forage Lichens	LG	Pin Lichens
LG	Riparian Lichens	LG	Soil Lichens
LG	Tree Crusts	P	*Rubus bartonianus*
Negative Effect			
BG	Rock Other Bryophyte	L	Oceanic Fruticose
LG	Aspen Specialist Lichens	LG	Charred Snag Lichens
LG	Excess Nitrogen Indicator Lichens	LG	Forage Lichens
LG	Fruticose Tree Lichens	LG	Moss and Ditritus Binders Lichens
LG	Oceanic Leaf Lichens	LG	Oceanic Log Lichens

Table 5.15 (continued).

Class	Name	Class	Name
LG	Oceanic Tree Crust Lichens	LG	Pioneer Soil Stabilizers Lichens
LG	Rotten Log and Tree Base Lichens	P	*Allium aaseae*
P	*Allium nevii*	P	*Arabis falcifructa*
P	*Aster jessicae*	P	*Astragalus anserinus*
P	*Astragalus atratus* var. *inseptus*	P	*Astragalus mulfordiae*
P	*Astragalus oniciformis*	P	*Astragallus paysonii*
P	*Astragalus peckii*	P	*Astragalus pulsiferae* var. *suksdorfii*
P	*Astragalus sinuatus*	P	*Astrgalus tegetariodes*
P	*Astragalus yoder-williamsii*	P	*Botrychium ascendens*
P	*Botrychium crenulatum*	P	*Botrychium pedunculosm*
P	*Botrychium pumicola*	P	*Calochortus longebarbatus* var. *longebarbatus*
P	*Calochortus longebarbatus* var. *peckii*	P	*Calochortus nitidus*
P	*Castilleja chlorotica*	P	*Castilleja christii*
P	*Castilleja pilosa* var. *steenesis*	P	*Chaenactis cusickii*
P	*Collomia mazama*	P	*Cypripedium fasciculatum*
P	*Douglasia idahoensis*	P	*Erigeron latus*
P	*Eriogonum novonudum*	P	*Grindelia howellii*
P	*Hackelia cronquistii*	P	*Haplopappus liatriformis*
P	*Haplopappus radiatus*	P	*Lepidium davisii*
P	*Lepidium papilliferum*	P	*Lesquerella carinata* var. *languida*
P	*Lesquerella paysonii*	P	*Lesquerella* sp. nov. (*"pulchella"*)
P	*Lomatium greenmanii*	P	*Mimulus clivicola*
P	Mirabilis biglovii var retrosa	P	*Mirabilis macfarlanei*
P	*Penstemon glaucinus*	P	*Penstemon lemhiensis*
P	*Penstemon peckii*	P	*Phacelia inconspicua*
P	*Phacelia lutea* var. *calva*	P	*Phacelia lutea* var. *mackenxeorum*
P	*Phacelia minutissima*	P	*Phlox idahonis*
P	*Silene spaldingii*	P	*Stanleya confertiflora*
P	*Thelypodium eucosmum*	P	*Thelypodium howellii* ssp. *spectabilis*
P	*Trifolium douglasii*	P	*Trifolium thompsonii*
PG	*Allium* Riparian Spp Group	P	*Botrychium* Forest Spp Group
PG	*Botrychium* Marsh Spp Group	PG	*Botrychium* Meadow Spp Group
PG	*Carex* Dry Forest Group	PG	*Carex* Dry Meadow Low Moderate Elev Group
PG	*Carex* Ephemeral Meadow Low Moderate Elev Group	PG	*Carex* Ephemeral Meadow Subalpine Alpine Group
PG	*Carex* Mesic Meadow Low Moderate Elev Group	PG	*Carex* Mesic Meadow Subalpine Alpine Group
PG	*Carex* Sagebrush Steppe Dry Group	PG	*Carex* Wet Meadow Low Moderate Elev Group
PG	*Carex* Wet Meadow Subalpine Alpine Group	PG	*Penstemon cinicola* complex

Human activities that result in carrion (fresh dead animals) might benefit the set of carrion-feeding species including turkey vulture (*Cathartes aura*), bald eagle, gray jay (*Perisoreus canadensis*), common raven (*Corvus corax*), American crow (*Corvus brachyrhynchos*), wolverine, and coyote, depending on type and location of the carrion.

Key Ecological Functions of Species

This discussion presents findings on species' key ecological functions associated with the major terrestrial ecological subsystems of the Basin (table 5.16). The major ecological functions we addressed were: species that predominate in the biomass of ecosystems; herbivory; nutrient cycling relations; interspecies relations; soil productivity; wood decomposition; and water quality. Understanding and maintaining ecological functions, including nutrient cycling and fire relations, are critical facets of maintaining ecosystem health for inland Northwest ecosystems (DellaSala and others 1995). Identifying such ecological functional groups of species may be more useful for management of Federal lands in the Basin than would attempting to identify individual keystone species.

This section summarizes information derived from the SER database under key ecological functions (KEFs). Information on species' KEFs is incomplete, particularly for plants and invertebrates. Information on KEFs for plant species and plant groups was gathered only for those species currently listed as C1 or C2 candidates or for species and groups which the plant expert panels and contractors deemed deserving of additional conservation focus, that is, potential C1 or C2 candidates. The plant information cited below is typically for plants that are scarce; other plant species with particular functions are not discussed here. The information on invertebrates is also an incomplete representation of that fauna as the database contains only example species of a much larger invertebrate fauna. Our intent was to outline some of the major categories of species functions within the Basin rather than to list exhaustively all species with each ecological function.

Major Biomass

Species that predominate in or affect the biomass of an ecosystem can have a major controlling function in storage and flow of nutrients and energy through the trophic levels. Many species, including plants, can dominate as major biomass of various environments. Among invertebrates, soils can be dominated numerically by mites, springtails, and other species. Western spruce budworm (*Choristoneura occidentalis*) and Douglas-fir tussock moth (*Orgyia pseudotsugata*) can greatly affect production of major biomass, as they are key to carbon and nutrient recycling, plant biomass turnover, soil productivity, and energy flow dynamics in some forest ecosystems.

In litter and duff layers of many forests, amphibians often comprise either a major biomass component or at least serve to mediate energy flow through trophic levels. This may be surprising to those who would guess that only the larger or more visible vertebrates perform this function. Specifically, throughout the Basin, at least nine salamander species and three frogs act as key energy gates or major biomass components. Collectively, these amphibians are most sensitive to changes in down wood, litter, and duff depths and characteristics; still and flowing water quality and quantity; and precipitation quality and weather patterns. Thus, manipulating these components through management activities can influence the distribution and abundance of associated amphibians and thus their ecological functions.

Herbivory

Herbivory functions of invertebrates were discussed earlier. In summary, at least one example species of tree bole feeder, five bark beetles, and 22 defoliators (including cankerworms, budworms, leaf beetles, miners, moths, shoot borers, sawflies, and others) can serve to alter plant succession, create new vegetative conditions for other wildlife, decrease primary production of host plants, and impose other changes on vegetation substrates and ecological processes of their host environments.

Table 5.16— A simple classification of ecological subsystems found in the Basin.

1. Terrestrial Above-Ground Environments
    (a) Upland terrestrial conditions - forests
        Tree canopy, subcanopy
        Shrub layer
        Grass/forb layer
    (b) Upland terrestrial conditions - shrublands and grasslands
        Trees
        Shrubs
        Grass/forb layer
        Cryptogamic crusts (soil surface)
2. Terrestrial Below-Ground Environments
    (a) At- and below-surface zones: coarse wood, litter, duff
    (b) Soil (O, A Horizons)
    (c) Root sphere influence zones
3. Riparian influence zone
    Riparian shade, leaf litter, large wood
4. Aquatic systems
    (a) Lotic systems
        Stream size scale and gradient type
        Bank and channel stability; side slope angle and erosion potential
        Reach type; habitat characteristics and processes (edge effects,
            storage of organisms, hydrology, particle size sorting)
    (b) Lentic systems
        Water body size
        Water permanence
            lake or pond
            astatic lake or pond
            intermittent pond
            wet meadow, seep, bog, fen

Vertebrates with key herbivory functions include all the ungulates discussed previously, as well as at least five species of waterfowl (four geese and brant), sage grouse, at least three species of vole, and the black-tailed jackrabbit and other rabbits. All of these major herbivores are capable of altering plant community structure and plant species composition, particularly the ungulates as studied in the Blue Mountains by Irwin and others (1995). Even the voles can modify grassland structures.

Nutrient Cycling

Species with key roles in determining cycling rates of nutrients (for example, nitrogen, phosphorous, and carbon) include those involved in physical transfer of substances, nitrogen cycling, and carbon sequestration. First are species that particulary affect the physical transfer of substances for nutrient cycling. In turn, this key ecological function serves to support vegetation succession and to alter the composition and enhance the productivity of the environments. This function is performed by various animals including 21 example invertebrate

species among 13 families. Two examples are large aspen tortrix (*Choristoneura conflictana:* Tortricidae) and pandora moth (*Coloradia pandora*: Saturniidae). Many more invertebrates with this function occur within the assessment area. Vertebrates with this function number at least 32 species among 12 families; the species include 11 amphibians [two examples are Pacific chorus frog (*Pseudacris regilla*) and rough-skinned newt (*Taricha granulosa*)], one bird [Canada goose (*Branta canadensis*)] and 21 mammals [two examples are the bushy-tailed woodrat (*Neotoma cinerea*) and the little brown myotis (*Myotis lucifugus*)].

Second are species specifically affecting nitrogen cycling. These include nitrogen-fixers, nitrogen-immobilizers, and sources for nitrogen mineralization. Among the species listed in the SER database, 1 bryophyte group, 7 lichen groups, and 32 vascular plant species are mostly nitrogen-fixers. The dry soil bryophyte group harbors nitrogen-fixing bacteria and is found in all general soil categories. The seven nitrogen-fixing lichen groups include groups labelled in the SER database as excess nitrogen indicators and nitrogen-fixing groups of epiphytes, riparian and seepage species, rock and soil associates, and tundra sod builders. Rare vascular plants affecting nitrogen cycling, as listed in the SER database, include some 22 species of milk-vetch, as well as lupines, monkeyflower, crazyweeds, clovers, and others. (Additional leguminous and other vascular plants in the Basin also perform nitrogen fixation; these are not included in the SER database at this time).

Invertebrates and microorganisms with nitrogen relation functions include the competitive bacterium *Bacillus thermophilus*, the nitrogen-immobilizing bacterium *Klebsiella panticola*, and many rotifers. The bacterium serves to decompose labile and intermediate-labile carbon:nitrogen substrates and act as a source for nitrogen mineralization. The rotifers participate in nitrogen-retention in soil.

A third key function is carbon sequestration. Many trees and shrubs contribute to sequestration of atmospheric carbon, acting as part of a global buffer system involving cycling of carbon, in various forms, from atmosphere to vegetation to soils and back. Among the species listed in the SER database with this function are seven *Carex* (sedge) plant groups found in calcareous and noncalcareous peatlands; dry low-elevation meadow vegetation communities; and mesic and wet meadow vegetation communities at low, moderate, and alpine elevations. Carbon-cycling models (for example, Harmon and others 1990, Turner and others 1995) can help estimate the rate of contribution of forests to carbon stores.

Interspecies Relations

Every species interacts with others. However, several key interactions may be of interest to ecosystem management, including insectivory, pollination vectors, transport of plant disseminules, nest parasitism, cavity nesting, and burrow excavation. These interactions affect productivity, diversity, and structure of ecological communities.

Many insectivorous (that is, insect-feeding) vertebrates within the assessment area act as biocontrol agents. While these biocontrol organisms may not eliminate irruptive insect populations, they may play a significant role in reducing the amplitude of insect outbreaks. Insectivorous vertebrates with such biocontrol potential include an amphibian (tiger salamander *Ambystoma tigrinum*), 12 birds, and 9 mammals. Insectivorous birds include trumpeter swan (*Cygnus buccinator*), American kestrel (*Falco sparverius*), flammulated owl (*Otus flammeolus*), common nighthawk (*Chordeiles minor*), black-backed woodpecker (*Picoides arcticus*), barn swallow (*Hirundo rustica*), northern rough-winged swallow (*Stelgidopteryx serripennis*), mountain chickadee (*Parus gambeli*), mountain bluebird (*Sialia currucoides*), hermit thrush (*Catharus guttatus*), red crossbill (*Loxia curvirostra*), and evening grosbeak (*Coccothraustes vespertinus*). The mammals include deer mouse (*Peromyscus maniculatus*) and many bats.

This list of species could have important economic implications because some insectivorous species feed on insect pests. The evening grosbeak and mountain chickadees are primary feeders of spruce budworms. Red crossbill, associated with mature and old conifer forests, feeds on spruce budworm larvae. The silver-haired bat is a moth and beetle pest predator in forests. Common nighthawk, big brown bat (*Eptesicus fuscus*), and pale western (that is, Townsend's) big-eared bat (*Plecotus townsendii pallescens*) feed on insects in agricultural and urban environments. Black-backed woodpeckers feed on bark beetles, especially during outbreaks. Little empirical work has been done for most of these species to quantify rates of feeding and its specific effects on the amplitude of insect population outbreaks. Koplin (1969) suggested that black-backed woodpeckers can suppress the amplitude of bark beetle outbreaks. Takekawa (1984) evaluated the silvicultural economic advantage of providing for evening grosbeaks.

Another interspecies relation of potential interest to ecosystem management is pollination vectors. Pollination vectors are species which aid production of native fruit and seed-bearing plants that, in turn, feed mammals, birds, ants, and other insects. There is no master catalogue of such vectors for the Basin, but the SER database contains a sample of 63 invertebrate species (among 12 families) with this key function. Among vertebrates, at least five species of hummingbirds and one songbird [northern oriole (*Icterus galbula*)] act as angiosperm pollinators. The hummingbirds pollinate tubular flowers; the rufous hummingbird (*Selasphorus rufus*) in particular is co-evolved with red tubular flowers.

Another interspecies relation is dispersal of fungi, plants, plant parts, and invertebrates. At least 153 vertebrate species engage in transportation of seeds, spores, or other plant disseminules. Some of the vertebrate dispersers of fungi include southern and western red-backed voles (*Clethrionomys gapperi* and *Clethrionomys californicus*), pika (*Ochotona princeps*), flying squirrel (*Glaucomys sabrinus*), Columbian mouse (*Peromyscus keenii*), least chipmunk (*Tamias minimus*), Douglas' squirrel (*Tamiasciurus douglasii*), and Rocky Mountain elk. The western red-backed vole disperses nitrogen-fixing mycorrhizae. Douglas' squirrel and southern red-backed vole, and probably others, disperse lichens. Most of the waterbirds, including waterfowl, shorebirds, grebes, herons, and others, disperse aquatic plants, algae, and invertebrates.

The largest groups of vertebrate dispersal agents are those that disperse seeds and fruits (at least 85 identified vertebrate species) and those that disperse plants or non-seed or fruit plant parts (60 vertebrate species). The seed- or fruit-dispersers include a wide variety of aquatic and terrestrial birds and mammals, covering a wide range of environments within the Basin area. A few seem to be specialists. For example, Clark's nutcracker (*Nucifraga columbiana*) is a key element in regeneration of whitebark pine–which is declining in the Basin–as well as pinyon pine, by caching (that is, burying) seeds in the ground. White-headed woodpecker disperses ponderosa pine seeds and California ground squirrel (*Spermophilus beecheyi*) disperses oak (further west and south from the Basin, tanoak) acorns and seeds. Rodents, especially red-backed voles, play key roles in re-establishing trees by burying seeds and spreading spores of beneficial symbiotic fungi, especially after timber harvest or fires. However, some evidence suggests that if the clearing is too large, they will aid in re-establishment of trees only along the edge of forest cover (Mills 1995).[35]

Bird nest parasitism is a specialized breeding function of the brown-headed cowbird (*Molothrus ater*). At least 30 other bird species suffer as nest hosts to this species. Affected species include forest-inhabiting vireos, warblers, and sparrows; marshland blackbirds and yellowthroats; shrubland sparrows and flycatchers. To our knowledge, no study has determined the extent to which

[35] Also, personal communication. 1995. Allen E. Thomas, Fish and Wildlife Biologist. U.S. Department of Interior, Bureau of Land Management, Idaho State Office, 3380 Americana Terrace, Boise, Idaho 83706.

cowbird nest parasitism is a factor in declines in other bird species. Studies in the Sierra Nevada of California have suggested that there could be severe, negative affects on host species.

The 17 vertebrate species that function as primary cavity excavators in trees include 11 woodpeckers, 3 nuthatches, and 3 chickadees [chestnut-backed chickadee (*Parus rufescens*), included here, is an occasional primary cavity excavator]. Collectively, these species reside in a variety of pine, fir, and hardwood woodlands and forests in the assessment area.

At least another 14 species act as secondary cavity users, using natural tree cavities or cavities created by the primary excavators, for roosting or nesting. These include wood duck (buffleheads, mergansers, and a few other waterfowl may also serve this role), 5 small owls, 3 chickadees, 2 swallows, white-breasted nuthatch (*Sitta carolinensis*), ash-throated flycatcher (*Myiarchus cinerascens*), and common raccoon (*Procyon lotor*). Doubtless, other species can be added to this list.

Competition for cavities may be high in forest conditions lacking trees or snags of adequate dbh with cavities. Northern saw-whet owls (*Aegolius acadicus*) nest early in the season and thus may displace other later-nesting secondary cavity users. Likewise, boreal owls (*Aegolius funereus*) occupy larger tree cavities and nest earlier than many other secondary cavity users, and may displace flying squirrels. On the other hand, flammulated owls, our only neotropical migratory owl, are late nesters and may not find adequate nest sites if they are occupied by earlier nesting species. Northern pygmy-owls (*Glaucidium gnoma*) likely compete for cavities with passerines (songbirds). Western screech owls (*Otus kennicottii*) may actively usurp nests from squirrels and flickers. Among songbirds, violet-green swallows (*Tachycineta thalassina*) are an active competitor for nesting cavities.

As a parallel to the cavity-using species, another species set engages in primary burrow excavation in a variety of habitats and conditions. Among the invertebrates, this set includes a variety of bark beetles which create distinctive galleries of burrows in the tree cambium beneath the bark. Two other primary ground-burrowing invertebrates are the thatch ant *Formica obscuripes* (Formicidae), whose nests are home to many arthropod species and serve as wintering burrows for small mammals, and *Arctosa littoralis* (Lycosidae: Araneida), whose 15 to 25 centimeter deep burrows in sand, dug for diurnal hiding, might possibly influence the structure of sandy beach habitats. Many other burrowing invertebrates occur in the Basin.

The primary burrow-excavating vertebrates constitute about 41 taxa (38 species and two subspecies of northern pocket gopher listed individually in the SER database), which include 1 amphibian (Great Basin spadefoot), 3 birds [bank swallow (*Riparia riparia*), belted kingfisher (*Ceryle alcyon*), burrowing owl (*Athene cunicularia*)], and the rest mammals. Great basin spadefoot is a primary excavator in sandy soil and uses mammal burrows in other substrates. The mammals include mountain beaver (*Aplodontia rufa*), the rare pygmy rabbit (*Brachylagus idahoensis*), striped skunk (*Mephitis mephitis*), mink (*Mustela vison*), American badger (*Taxidea taxus*), 2 moles, 6 gophers, 14 squirrels or chipmunks, 7 mice or rats, and 2 foxes. The mountain beaver, skunk, badger, and foxes in particular dig large burrows used by a slightly different constellation of other species.

The secondary burrow-using species depend on the primary burrow excavators for their tunnels. This set includes at least 13 vertebrate species (3 amphibians, 3 reptiles, 1 bird, and 10 mammals): 2 salamanders and spadefoot; longnose leopard lizard, striped whipsnake, and gopher snake; burrowing owl; and Virginia opossum, striped skunk, 3 mustelids (ermine, long-tailed weasel, and mink), and northern grasshopper mouse. In particular, the longnose leopard lizard depends on rodent burrows (kangaroo rats, pocket mice) for cover. Striped whipsnake uses deep underground crevices in cold weather and is also a secondary user of mammal burrows for egg-laying.

Soil Productivity

Species with ecological functions affecting soil productivity include a variety of plants, invertebrates, and vertebrates in seven function categories: physical soil turnover, nitrogen retention or uptake, soil stabilization, rock weathering, detoxificaion of xenobiotics, metal accumulation, and vegetation succession. Soil productivity can be related to complex processes. For example, Seasted and Knapp (1993) reported that grassland ecosystem productivity can display "transient maxima," which are related to how grazing and fire affect water, nitrogen, and light availability.

In one sense, all plants die, decompose, and thus contribute to soil organic matter and composition. In particular, one bryophyte group (rock calcareous bryophytes), 2 plant groups (*Carex* ephemeral meadow low-moderate group and *Carex* subalpine groups), and 13 plant species, listed in the SER database, significantly contribute to soil formation and soil organic material, particularly in poorly developed or nutrient-poor soils and limestone or rock substrates. Many other species and plant groups not listed in the SER database also contribute to this function.

Some 51 example invertebrate species or subspecies distributed over seven families are included in the database as examples of invertebrates that recycle soil layers and nutrients, and influence soil structure, porosity, and aggregation by their physical digging actions. Among vertebrates that perform this function are a number of fossorial mammals listed above as primary burrow excavators. In particular, western and Woodhouse's toads, broad-footed and coast moles (*Scapanus latimanus* and *Scapanus orarius*), shrew-mole *(Neurotrichus gibbsii)*, 4 ground squirrels, white-tailed antelope squirrel (*Ammospermophilus leucurus*), and water vole (*Microtus richardsoni*) significantly contribute to soil aeration and affect soil structure. The water vole contributes to soil aeration and drainage of wet soils.

Bacteria, nematodes, rotifers, and protozoa play critical roles in nitrogen retention or uptake in soils. Groups of competitive rhizosphere (root sphere) bacteria, bacterial pathogens, and beneficial bacteria, are responsible for nitrogen retention and mineralization in soils. Bacteria-feeding nematodes (*Acrobeloides* spp.) engage in mineralization of nitrogen immobilized in bacterial biomass, and may be responsible for up to 40 percent of plant available nitrogen. Rotifers (virtually unstudied in the assessment area) and the bacterial-predator protozoa such as *Amoeba amoeba* also engage in mineralization of nitrogen immobilized in bacterial biomass, and may be responsible for up to 50 percent or more of plant-available nitrogen in some agricultural systems. In addition, saprophytic fungi enter the process, as most plant-available nitrogen must cycle through soil fungal biomass in forest soils.

Many plants contribute to soil stabilization, including 6 bryophyte groups, 9 lichen groups, 22 plant groups, and at least 1 recognized lichen species and, among the rare plants listed in the SER database, 76 plant species or subspecies. The specific functions performed by this diverse group include: trapping of sediments (for example, aquatic submerged bryophytes, wet rock bryophytes, and wet soil bryophytes); reducing wind erosion (for example, dry soil bryophytes); colonization of harsh sites or erodible slopes; and stabilization of stream banks and soils during flood events (for example, *Artemesia* spp., the *Carex* rocky streambed species group, the *Mimulus guttatus* species complex and *Mimulus* high-elevation wet-habitat species group, and the *Penstemon* foothills to montane meadow species group). Species that stabilize soils on post-fire sites include several species of milk-vetch (*Astragalus* spp., *Chaenactis cusickii*, *Penstemon peckii*, and others; also see table 5.15). Many other plants not listed in the SER database likely perform this function more widely throughout the Basin. The beneficial bacteria *Microcoleus* also serve to stabilize soil and prevent erosion.

Lichens excel as soil stabilizers, with 11 lichen species groups occurring in a wide array of environments serving to weather rock substrates. Additionally, seven vascular plant species in the

SER database, including penstemons, a rockmat, an ivesia, and a phacelia, also perform this service. Rock weathering is often a prelude to further soil formation and provides a substrate for other colonizers needing mineral soils.

The ectomycorrhizal mat-forming fungi *Hysterangium* may detoxify some types of pesticides, herbicides, and pollutants. The vesicular fungus *Glomus mossae* and the ectomycorrhizal mat-forming fungus *Hysterangium* may sequester heavy metals in fungal hyphae, preventing heavy metals from damaging or killing plants.

By definition, vegetation succession proceeds by new plant species invading a site. Many plant species of the Basin are colonizers. Some bacteria groups, exemplified by the bacterium *Rhizobium melliotii* and the beneficial bacteria group *Microcoleus*, aid preparation of the soil for succession by nitrogen-fixation.

Wood Decomposition

Wood decomposition is a highly complex process that can involve several thousand species of bacteria, microfungi, macrofungi, nonvascular and vascular plants, invertebrates, and vertebrates. A single down log can undergo decay succession; many species are present only at specific wood decay stages. One invertebrate in particular, the carpenter ant *Camponotus modoc* aids in decomposition of standing and down wood. It operates at the hub of a complex ecological process involving insectivorous predatory birds, primary and secondary cavity nesters, and defoliators. Partially decomposed standing wood provides nest, feeding, and roost sites for many other species (see above, under species associated with snags, dead parts of live trees, and exfoliating bark); decomposing down wood is also used by a variety of other species (see above, under species associated with down wood and litter and duff).

Among vertebrates that might aid wood decomposition are the rubber boa (*Charina bottae*) and sharptail snake (*Contia tenuis*), which excavate rotten logs for cover and prey; the pileated woodpecker (feeds more frequently on large down logs compared to other woodpeckers) which breaks logs apart while foraging for insects and larvae; and the black bear and grizzly bear, which may contribute to soil nutrient cycling by breaking logs apart in search of food.

Bioindicators of Water Quality

Algae and aquatic invertebrate species can act as bioindicators of water quality. Pond- and lake-dwelling high country salamanders and frogs also are sensitive indicators of acid precipitation and changes in water quality. The tailed frog is sensitive to, and is probably a very good indicator of, increases in temperature and sedimentation in mountain streams. Additionally, some 19 species of shorebirds, including sandpipers, yellowlegs, plovers, and others, probably are good indicators of pollution of inland nesting and stopover sites.

Identifying Keystone Species

The term keystone has been used in the ecological literature to refer to species whose functions directly or indirectly affect the presence and abundance of many other species. Keystones can be plants and allies, invertebrates, or vertebrates. The above reviews demonstrate that species assemblages can be identified as those closely associated with specific environmental substrates or with ecological functions. Collectively, all such species are "keystone" in that they, as a group, define the structures and processes of ecosystems.

At our present knowledge level, few species can be demonstrated as being individually "keystone" in that their removal from the ecosystem would greatly diminish the diversity and functions of the system. Further, Mills and others (1993) argued that the concept of keystone species is wrought with ambiguity and imprecision, and that land managers instead should explicitly consider the complexity of interactions in natural systems. Following their suggestion, we have not identified a small set of species as keystones or "indicators."

One problem with the use of the indicator species concept on Federal land management has been described as, "the problem of objectively defining which species are keystones makes it likely that subjectively chosen subsets of species will be so labeled, whereas other species of similar importance will be ignored" (Mills and others 1993).

We use the term "key environmental correlates" (KEC) here to connote the major environmental requirements of a species. A given KEC, such as cliffs, can have many associated species, and a given species can have many KECs. Thus, if a management objective is to maintain the full set of species in an area, we recommend, along with Mills and others (1993), that the full set of KECs of all species be provided rather than arbitrarily focusing on only a few species and KECs.

We classified KECs and KEFs into two hierarchies of categories (appendices 5F, 5G). In these hierarchies, each KEC and KEF category is given a unique code and can be related to species in several levels of specificity in the SER database. For example, all species with KECs including the general category of non-vegetation terrestrial substrates (KEC level 3, appendix 5F) can be identified. A subset of these species would be those associated much more specifically with lithic (rock) substrates (KEC level 3.3). And then, a subset of that subset of species would be those associated much more specifically with cliffs (KEC level 3.3.3). In this manner, general as well as specific associations of species with environmental and habitat conditions can be depicted. The hierarchy of key ecological functions of species (KEFs, appendix 5G) operates the same way. Ultimately, then, it is the full set of all species and their environmental correlates and ecological functions that can be depicted in the SER database and that collectively define biotic processess and biodiversity of ecosystems.

Use of Ecologically Functional Equivalents

Do species with the same categories of key ecological functions perform the same ecological service? In a broad sense, by definition of functional categories, yes. For example, black-tailed jackrabbit (*Lepus californicus*), meadow vole (*Microtus pennsylvanicus*), greater white-fronted goose (*Anser albifrons*), and Ross' goose (*Chen rossii*) all perform functions of herbivory (that is, all are herbivores) (maps 5.3a, 5.3b). However, each species in the above list performs its function under different sets of environmental conditions and geographic areas (maps 5.3a, 5.3b) using different behaviors and affecting their food sources in different ways. Ultimately, each species is unique in its set of behaviors, distribution, and functions, so that no two species are exactly interchangeable. Thus, we do not suggest viewing species with common, general ecological functions such as herbivory as equivalent and mutually replaceable in management objectives.

Endemism, Biodiversity, and Natural Areas

With major contributions from expert panels, we mapped centers of concentration of (1) species rarity and endemism and (2) high biodiversity. We defined centers of concentration of species rarity and endemism as locations with unusually high numbers of species that are rare or that are locally or regionally endemic. We defined centers of concentration of high biodiversity as locations with unusally high numbers of species of all abundance classes and all types of geographic distributions. Within this framework, the expert panels identified centers of concentration variously based on high species richness, high landscape diversity, uniqueness of species communities, or high density of rare plant occurrences. Many of the high biodiversity centers of concentration, especially in the plant panels, were the same as the centers of many rare and endemic species as initially defined by the plant expert panels.

All panels identified centers of rarity and endemism in the southwestern Oregon portion of the Basin (Southern Cascades, Upper Klamath, and Northern Great Basin ERUs), along the Snake River (Owyhee Uplands ERU), the Columbia River Gorge (including the Northern Cascades

Map 5.3a— Vertebrate species with the key ecological function of herbivory: Meadow vole and blacktailed jackrabbit.

Map 5.3b—Vertebrate species with the key ecological function of herbivory: Greater white-fronted goose and Ross' goose.

ERU) and the desert steppe in central and southern Washington (Columbia Plateau ERU) (table 5.17). Centers of rarity and endemism of plants and animals occurred in nearly all major landforms.

The centers of concentration of rarity and endemism seemed to pertain to taxonomic groups with low mobility. This may be because species with low mobility may be more apt to develop endemic forms adapted to local conditions. Centers of concentration of rarity and endemism were mapped based on distributions of species of vascular plants, reptiles, amphibians, and fish. Invertebrates were mapped only to family level due to lack of research on species taxonomy and field ecology. Few nonvascular plant species were identified in this mapping exercise due to lack of field studies. Small mammals species were included in the mapping, but large mammals were not because their larger home ranges generally precluded identifying specific sites as centers of concentration. Panelists did not identify centers of concentration of rarity and endemism for birds and bats because of the high mobility of these species. Instead, correlations between species and habitat for birds and bats were identified (SER database; TS 1995).

We also listed the species associated with the centers of concentration and commented on each area and possible causes for local conditions. For example, we identified when an unusual soil type, geological formation, management activity or condition appeared to contribute to the rarity or endemism of associated species. This documentation was provided in a geographically referenced database linked to individual centers. Some of the factors contributing to rarity and endemism were: thermal hot springs, alkali pools, high topographic relief that served to isolate mountain tops or canyons, agricultural activities, springs, seeps, wetlands, and riparian habitats.

Disturbance regimes likely play a role in maintaining biodiversity of some centers of concentration, although more remains to be learned of such relations. Huston (1994), among others, hypothesized that relatively high biodiversity can be maintained with disturbances that reduce or eliminate dominant species. Such disturbances can include biotic factors such as predation, herbivory, parasitism, disease, and complete emigration of a dominant competitor, or abiotic factors such as floods, fires, severe windstorms, and extreme weather.

The centers of concentration of high biodiversity or high occurrences of plants and aquatic species were more dispersed across the Basin than were the centers of concentration of species rarity and endemism, but they corresponded well to large blocks of natural areas. This may be because the large natural areas and roadless areas receive less human disturbances and are more likely to provide conditions for the full set of naturally-occurring species. Two notable exceptions were the large wilderness blocks in central Idaho and the east Cascades in Oregon, which contained few centers of high biodiversity.

Centers of concentration were mapped separately for taxonomic groups of plants and animals. When overlayed, locations with three or more centers defined smaller "hot spots" of rarity and endemism, and high biodiversity, for plants and animals combined. We identified 12 hot spots of rarity and endemism (table 5.17, map 5.4) and 7 hot spots of high biodiversity within the Basin (table 5.18, map 5.4). Doubtless, additional hot spots may be identified at finer scales and levels of geographic resolution than we used in this project. Collectively, these hot spots mainly occurred in the northern glaciated and unglaciated mountains, central and southern Cascade mountains, Washington and Oregon plateau country, Great Basin plains, and the Snake River valley (maps 5.4, 5.5).

The plant and amphibian/reptile panels were the only panels that identified areas of high biodiversity or high plant occurrences. The biodiversity map themes and the rarity/endemism map themes were developed using different sets of criteria among the panels, for reasons explained above. This approach provides a starting assessment for further exploration of hot spots and their relation to species distributions.

Table 5.17—Hot spots of species rarity and endemism[1] (see map 5.4 for location of numbered areas).

Number[2]	Description/Location	Natural Area[3]	Road Density[4]	Human Density[5]	Vegetation	Ownership
RE1	Washington: Columbia Basin shrub - steppe, Vantage, Washington area and Saddle Mtns. High degree of disturbance around the area due to agriculture and grazing. Remnant steppe areas rare, populations limited.	Hanford RNA	Mod., some low	Mostly low - very low	Desert salt shrub, basin sagebrush, mountain big sagebrush	Almost all private, small BLM, no FS
RE2	Washington/Oregon: Columbia River Gorge, both sides, from Cascade Locks to east of Biggs, north to Yakama Reservation, west outside project boundary. Rapid elevation changes, climatic contrasts. Gorge and river are corridors but highway and cliffs can be barriers.	Small: TNC reserve; SIA; Wilderness	High to west; mod.-low north, south, and east	About 1/3 in high density, rest in low	Mixed, contrast: fir, hemlock, cedar to west; ponderosa pine, mountain big sagebrush and agricultural, grass-lands north, south, and east.	Most private, 2 National Forests; no BLM; National Recreation Area in Gorge
RE3	Oregon: Crest of Umatilla Mtns., elevational changes. Many westside species are isolated and disjunct on mountain tops. Seeps, riparian and springs important. Diverse, mosaic.	About 1/3 wilderness; 1 RNA; 1 TNC reserve	Mod-high outside wilderness, none within	Low-very low	Grand fir, interior ponderosa pine, subalpine herb, lodgepole pine, spruce/fir	All Umatilla National Forest, no BLM
RE4	Oregon: Wallowa Mtn. Peaks, Sacajewea Peak, diverse, mosaic, sharp elevational ranges. Rocky Mtn. and boreal species on Mtn. top islands, isolated. Unusual geology (limestone, greenstone, argillites), cold, snowy, many wetlands and springs.	Almost all wilderness; 2 RNAs within wilderness	No roads	Very low density	Very mixed: subalpine herb, spruce/fir, grand fir, lodgepole	All Wallowa Whitman National Forest, no BLM
RE5	Oregon: Deschutes, Three Sisters area, special habitats due to volcanos and other geological patterns.	Some wilderness to west, edge of Wild and Scenic River; TNC reserve; ACEC; RNA	Mod-low. Small area of high. None in wild.	Some areas of high density to east, low-very low to west	Interior ponderosa pine, Douglas fir, spruce/fir, Mtn. big sagebrush	2 National Forests, BLM, about 1/3 private/ other
RE6	Oregon: Upper Klamath Lake, many spring, alkali lakes, thermal areas, unique habitats for fish, invertebrates and plants. Human disturbance high in some areas.	Small: FWS refuge; ACEC; SIA; RNA	High, a little mod.	Mod., range from high to low	Interior ponderosa pine, agriculture, rangelands, sagebrush, marsh vegetation.	Mostly National Forest, some BLM and private/ other

Table 5.17 (continued).

Number[2]	Description/Location	Natural Area[3]	Road Density[4]	Human Density[5]	Vegetation	Ownership
RE7	Oregon: Summer Lake (westshore), marsh areas, fresh and alkali spring, important to fish, invertebrates, plants.	Slight: edge of WSA and SIA; RNA	High, very little low	Low	Interior ponderosa pine, rangelands, wheatgrass, sagebrush, marsh vegetation.	National Forest, a little BLM, small private/other
RE8	Oregon: Warner Lakes, Crump Lake, Hart Mtn. Refuge. Lakes, springs, alkali areas, important to fish, invertebrates and plants.	FWS refuge small ACEC, RNAs and WSA edge	Mod-low	Mod-low	Agriculture, salt desert shrub, sagebrush, wheatgrass, marsh vegetation.	Most FWS, BLM, no National Forest, small private/other
RE9	Oregon: Alvord Lake, Steens Mtns., alkali lakes, springs, lake, marshes, Great Basin species, insect research, high human disturbance.	Some WSA, 2 ACEC, RNA	Mod-low, small area of high	Low density	Salt desert shrub, wheatgrasses, antelope bitterbrush, sagebrush steppe, agric. and rangelands	Mostly 2 BLM, no National Forest, some private/other
RE10	Oregon: Ontario north to Huntington, Snake River, Weiser River. Sand pockets, gravels, lake beds, extremely low diversity in some areas, limestones, Great Basin arid grass/shrub communities, Snake River Canyon.	Small RNA	Mod	Very low to high, about 1/3 in mod-high	Mostly agricultural, rangelands, salt desert shrub, basin sagebrush, wheatgrass	2 BLM, private/ other, no National Forest
RE11	Idaho: Snake River from Oregon Idaho border to Grand View, part of Bird's of Prey Area. High contrast in river canyon to surrounding. River is corridor and unique habitat, geology, steep slopes, disjunct populations from south, limestone, sand, ash, unique soils. Grazing and mining conflicts.	Small ACEC, TNC	Mod-low	Very low to high, recreational use	Desert salt shrub, basin and Wyoming big sagebrush, agriculture and wheatgrass	A lot of BLM, no National Forest. Some private/ other
RE12	Idaho: Hot Springs south to Bruneau. Some Dept. of Defense. Hard bottom playa, clay soils. May have been isolated in past. Some highly adapted species, hot spring important to snail, inverts.	ACEC, WSA, WSR	Mod	Low-very low	Wheatgrass, rangelands, desert salt shrub, sagebrush, agriculture	A lot of BLM. No National Forest. Dept. of Defense, private

[1]Hot spots are defined as intersection areas of three or more centers of concentration of species' rarity or endemism among all taxonomic groups mapped.

[2]See map 5.4 for specific locations.

[3]Natural Areas: RNA = Research Natural Area, SIA = Special Interest Area, WSA = Wilderness Study Area, TNC = The Nature Conservancy reserve, FWS = Fish and Wildlife Service, WSR = Wild and Scenic River, ACEC = Areas of Critical Environmental Concern.

[4]Road Density: From predicted road density classes [ICBEMP GIS data (1 km^2 rater data)]: None = 0.00-0.01 km/sq km, very low = 0.01-0.06 km/sq km, low = 0.06-0.44 km/sq km, moderate = 0.44-1.06 km/sq km, high = 1.06-2.92 km/sq km, extremely high = 2.92+ km/sq km.

[5]Human density: Low = 0-3 people/sq km, moderate = 3-6 people/sq km, high = 6-30 people/sq km.

Table 5.18—Hot spots of species biodiversity[1] (see map 5.4 for locations of numbered areas).

Number[2]	Description/Location	Natural Area[3]	Road Density[4]	Human Density[5]	Vegetation	Ownership
B1	Washington: North Cascade, eastern edge, Pasayten Wilderness tied into Cathedral Park (BC), North Cascade and Manning (BC) National Parks. Glaciated landscape, rounded peaks, elevation and climatic contrast to surroundings, wetlands, bog, meadows, many rare plants. Large carnivores, amphibians, BC linkage.	1/3 Wilderness, WSA, TNC, 2 RNA (FS, Washington State)	None in north, low in south	Low	Subalpine fir/spruce, Douglas Fir, alpine and western larch, lodgepole, subalpine herb, Mtn. sagebrush, interior ponderosa pine	Mostly National Forest, and state forest, a little BLM and private.
B2	Washington: Saddle Mtn. to Yakima, part of Hanford (DOE) and Yakima Firing Range (DOD). Remnant sage/steppe, desert salt shrub, a lot of reptiles, breeding birds, amphibians. Active sand dunes, seeps, talus, riverine, slopes with deep soils, playa bottoms.	A little FWS refuge, a little WSR, Hanford and Yakama Firing Range have some reserve areas	Low in east, mod-high in south, none in middle. Some restricted	1/4 high (SW), rest low-mod.	Sagebrush/ bunchgrass, wheatgrass, agricultural, rangelands, desert salt shrub, bitterbrush	BLM, Dept. of Defense, Dept. of Energy, private/ other
B3	Washington/Oregon: Columbia Gorge from Cascade Locks to Mosier, Mt. Adams to north. Highly diverse, high elevation and climate contrast. Gorge/river is corridor and barrier. Unique plant communities, geology, soils. Volcanic activity, spring, falls, highly disturbed. West side outside ICBEMP boundary.	Small part of wilderness, FWS refuge, SIA. Gorge National Recreation Area; RNA	High	1/4 or more in mod-high, rest in low	Fir, hemlock, cedar, Douglas fir, oak woodlands, grand fir, ponderosa pine, rangelands, agricultural, sagebrush	2 National Forests; Columbia Gorge NRA; Yakama Reservation; private/other
B4	Oregon/Idaho: Wallowa - Whitman National Forest to Salmon River, Hell's Canyon, elevation and climate extremes, refuge and corridor. Basalt, limestone, granite, steep. Dry with springs/seeps/creeks as micro-sites. Very diverse. Heavy grazing in some areas.	WSR, wilderness, RNA	Mod-low	Low recreation pressure mod-high	Wyoming big sagebrush, wheatgrass, bunchgrasses, some subalpine herb	Mostly National Forest, some BLM and private/other.

Table 5.18 (continued).

Number[2]	Description/Location	Natural Area[3]	Road Density[4]	Human Density[5]	Vegetation	Ownership
B5	Idaho: Upper Snake River from Idaho Oregon border to Mt. Home A.F.B. Birds of Prey area. High elev. and micro-climate contrast. High diversity, as canyon acts as corridor between basin, mountains and valleys.	ACEC, TNC	Mod, none in canyon	1/4 mod high, rest low	Wyoming big sagebrush, Idaho fescue, desert salt shrub, agriculture, wheatgrass, rangelands	BLM, Dept. of Defense, private/other
B6	Idaho: Panhandle, St. Joe River, Clearwater. Some checkerboard ownership. High amphibian diversity, canyon refuge for many species from coast. Some warm, moist, low elevation. Ferns, red alder, cedar forests. Some heavy logging.	WSR, RNA	Mod	Low, some mod.	Interior ponderosa pine, cedar, Douglas fir, lodgepole	Almost all National Forest, some BLM, private/ other
B7	Montana: Flathead, Glacier Park, Blackfoot Reservation into Alberta to the north. Eastern portion out of ICBEMP boundary. Large carnivores, intact plant communities, subalpine and alpine Rocky Mtn, relatively undisturbed except in lower elevations.	Most in natural areas, 1/2 National Park; WSR; RNA; wilderness.	East: low to none, far west: mod-high	Low except in far west, and park visitor areas	Spruce/fir, interior Douglas fir, lodgepole, seral shrub, subalpine herb, alpine tundra, some agric. in west	Most National Park Service, some Blackfoot Reservation, National Forest, a little private.

[1]Intersection areas of 3 or more centers of concentration of biodiversity among all taxonomic groups mapped.

[2]See map 5.4 for specific locations.

[3]Natural Areas: RNA = Research Natural Area, SIA = Special Interest Area, WSA = Wilderness Study Area, TNC = The Nature Conservancy reserve, FWS = Fish and Wildlife Service, WSR = Wild and Scenic River, ACEC = Areas of Critical Environmental Concern.

[4]Road Density: From predicted road density classes [ICBEMP GIS data (1 km^2 rater data)]: None = 0.00-0.01 km/sq km, very low = 0.01-0.06 km/sq km, low = 0.06-0.44 km/sq km, moderate = 0.44-1.06 km/sq km, high = 1.06-2.92 km/sq km, extremely high = 2.92+ km/sq km.

[5]Human density: Low = 0-3 people/sq km, moderate = 3-6 people/sq km, high = 6-30 people/sq km.

Fewer centers of concentration and hot spots were delineated in the eastern portion of the Basin than in the western portion for several reasons. First, there were fewer available inventories and research studies of rare and endemic species in the eastern portion, especially northeast Washington and central Idaho, than in the western portion. Second, there appear to be more centers of concentration of species rarity and endemism in transition areas between the Pacific coast and the east side of the Cascades Mountains, and between the northern Great Basin and the southern Rocky Mountains, with fewer areas in the heart of the Rocky Mountians and central Idaho which have more uniform environments. Third, the panel members may have had greater experience in Washington and Oregon environments than further east in the assessment area. Although an effort was made to represent expertise from Idaho, Montana, Utah, and Wyoming, many panelists were from Oregon.

Of the 12 hot spots of rarity and endemism, nine occurred wholly or partly in Oregon, two on the Upper Snake River of the Owyhee Uplands and one in the Columbia steppe in Washington (map 5.4). Only three of these hot spots of rarity and edemism (Umatilla Plateau Mountains, Wallowa Mountains, and Snake River) had 25 percent or more of their area within designated existing natural areas. The remaining nine hot spots had about 10 percent or less within natural areas. This means that most of the hot spots of rarity and endemism are not necessarily being managed to protect the species and conditions identified by the panels.

The Umatilla Mountains, Wallowa Mountains, and Deschutes and Snake River areas appeared to be rarity and endemism hot spots because topographic, climatic, and geologic conditions have created unique and isolated habitats. The remaining areas also have some unique habitat features, especially thermal springs, alkali lakes, and marshes in southern Oregon, but they also contained rare remnants of native desert scrub and shrub steppe communities, which have declined rapidly in this century due to agriculture, livestock grazing, roads, noxious weeds, seeding, and human settlement. There also appear to be some critical habitat areas in southern Oregon that may have little protection for maintaining hot spots of rarity and endemism.

The Columbia River Gorge had the greatest convergence of centers of concentration of rarity and endemism, as well as many centers of high biodiversity. The unique topographic, geologic, and climatic extremes in this area and the dispersal corridor and barrier caused by the Columbia River and Gorge have created high species diversity and a high concentration of rare and endemic species. The area also may have received a higher degree of scientific inventory and study than other areas because of its proximity to Portland, and its scenic beauty, accessibility, and history. Tracts of private lands have been acquired by the Forest Service for addition to the National Recreation Area. Intensive visitor use could threaten this sensitive area. The rugged terrain provides some degree of natural protection to sites within the gorge, but the adjacent uplands have experienced greater human disturbance.

The Upper Snake River and Saddle Mountain areas of the Owhyee Uplands also appear as hot spots for rarity, endemism, and biodiversity. The Upper Snake River is similar to the Columbia Gorge, it has high topographic diversity, high contrast in climate and elevation, and unique geology. Like the Columbia River and Gorge, the Snake River and Gorge also serve as both a major dispersal corridor and a dispersal barrier for various species.

Map 5.4— Distribution of hot spots of species rarity and endemism and centers of biodiversity, with Ecological Reporting Units. These are locations that are particularly rich in species of plants, invertebrates, and vertebrates. See tables 5.17 and 5.18 for descriptions of each site.

Map 5.5— Distribution of centers of concentration of species rarity and endemism of plants and animals.

The Upper Snake area, where Great Basin species converge with Columbia Basin species, has high biodiversity, but it also has a high degree of species rarity and endemism because of the unique habitats and the effects of management activities in surrounding uplands. The Saddle Mountain Area is a refuge for some of the last intact areas of desert salt shrub and sagebrush steppe, which have been converted within the Basin to agriculture and livestock range. The Handford Energy Reserve and Yakima Firing Range have served to protect some areas of native sagebrush steppe from development, but this area contains virtually no BLM- or FS-administered lands.

Hot spots for biodiversity overlapped more with existing natural areas, especially wilderness areas, than did hot spots of species rarity and endemism. The natural areas tended to be in the upper elevation, forested portions of the hot spots, leaving at least some of the lower elevation portions of the hot spots unprotected from ground-disturbing human activities. For plants and large carnivores, there is likely a correlation between centers of biodiversity and natural areas or roadless areas.

Natural Areas Characterization

Natural areas fall into 26 categories of existing land allocations on FS- and BLM-administered lands, with varying management objectives, selection criteria, allowed uses, size ranges, and agency or organization administration. In the four western states most encompassed by the Basin (that is, eastern Oregon, eastern Washington, most of Idaho, and western Montana), Federal land management agencies administer a total of 41.63 million hectares. On these lands, 28 percent or 11.72 million hectares occur in natural areas (TS 1995).

Natural areas throughout the Basin were designated under a single management objective or strategy, in contrast to more consistent approaches to natural area management in British Columbia, Canada, and in New Zealand, India, or other countries (Joshi and Gadgil 1991, Pressley 1994).

Some Ecological Reporting Units (for example, Central Idaho Mountains and Northern Glaciated Mountains) have large natural areas, whereas others (for example, Columbia Plateau, Upper Snake) have only very small and isolated natural areas, and throughout the Basin the locations of natural areas do not consistently correspond to centers of concentration or hot spots of biodiversity or species rarity or endemism.

Based on home range sizes of vertebrates, even the smallest natural areas (less than or equal to 50 ha) could support at least one individual, and perhaps small populations, of 70 percent of vertebrate species (fig. 5.8). Based on area alone, natural areas larger than 650 hectares could support 90 percent of the vertebrate species from the region; approximately 50 percent of the natural areas are larger than 650 hectares. Natural areas would have to be at least 10,000 hectares in area before 99 percent of the vertebrate species could be supported. Only 16 percent of the natural areas are larger than 10,000 hectares.

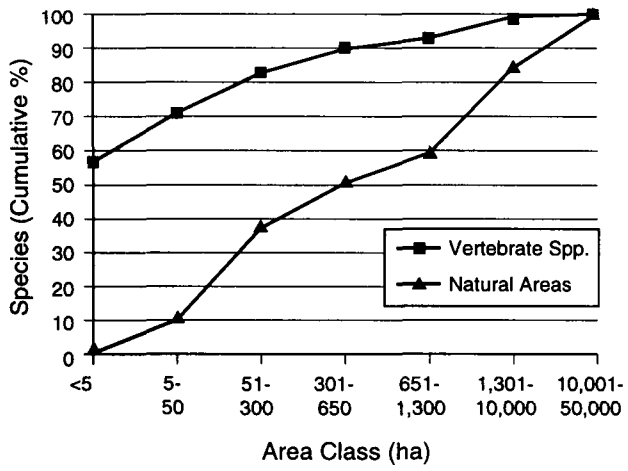


Figure 5.8—Cumulative percentages of vertebrate species by home range area, as compared with cumulative percentages of natural areas by size.

Expectations of species occurrence based on home range size does not necessarily mean that a particular size natural area would contain viable populations of all associated species. Natural areas would have to be several times larger than the area of an individual home range of most species to support enough individuals for a viable population. The area multiplier necessary for sustaining viable populations would depend on the population structure, life history, habitat relation, and behavior of the species. Habitat composition, pattern, disturbance regimes, and connectivity throughout surrounding landscapes also are critical considerations.

Of the 389,009 kilometers of streams in the Basin, 51,293 kilometers (13%) occur within existing natural areas. Most streams are within wilderness or wilderness study areas with the headwater, high gradient and steep portions of streams over-represented as compared to the low gradient, lower elevation portions. Only 7 of the 132 4th-field Hydrologic Units [HUC] inventoried did not have at least 1.6 kilometers of stream within a natural area. An average of 386 kilometers of stream occurred per 4th-field HUC. Some categories of natural areas, namely the research natural areas, areas of environmental concern, special interest areas, and wild and scenic river areas, have been established specifically to protect only a portion of a stream, lake or river. These areas are generally small and linear and do not include protection of uplands that may be critical to maintaining the health of the aquatic system. There are 2,150 lakes covering 97,242 hectares within natural areas.

Biogeography

Much of the above discussion of species groups has touched upon various aspects of biogeography of species. In particular, reasons for distribution and abundance and response of population to broad-scale biophysical attributes has been discussed. We identified species with disjunct, peripheral, scattered, regionally endemic, and locally endemic distributions. We also identified some species closely associated with some of the nine landform classes. Some species are closely associated with single biophysical factors, although many species are likely correlated with multiple factors. Most ERUs had at least some unique species, although many species overlapped several units. A few additional examples here help illustrate some general principles of species biogeography within the Basin.

Landforms

Nine general landform categories have been identified in the Basin. In some cases, significant biogeographic correlates with some species distributions are readily apparent by simply matching species distribution with these landforms. An example of a species that tightly associates with highland landforms (glaciated and unglaciated mountains and breaks) is the carpenter ant (map 5.6). Likewise, pronghorn shows alignment of its distribution with lowland landforms (map 5.7) as well as with areas of low precipitation (map 5.8); and lowland landforms and low precipitation are correlated. The distribution of pronghorn also demonstrates another simple biogeographical principle, that species can be shown to be distributed according to several biophysical factors, themselves correlated.

Disjunct Distributions

Another example of biogeography of species in the Basin pertains to disjunct distributions. In some cases, species such as mountain goat (maps 5.9a, b, c) that are associated with highland landforms appear as several disjunct populations because of the disjunct distribution of such landforms within the Basin. The mountain goat has been mapped as having 12 disjunct population centers in the Basin. The mountain goat seems closely tied to high elevation and high topographic relief, specifically with the highest elevation marked in each 6th-field HUC as mapped in the Basin.

The map of mountain goat distribution and highlands (map 5.9a) also illustrates a lesson in how map resolution affects interpretation of species biogeography. At the broadscale used in this assessment (1 km^2 map cells), east-central Idaho is shown as very high elevation and thus as potentially suitable habitat for, and within the range of, mountain goat. At a finer resolution, however, this area contains three valleys separated by narrow mountain ranges (Big Lost River-Challis Creek valleys, Little Lost River-Pahsemeroi River valleys, and Birch Creek-Lemhi River valleys). It is unlikely that any mountain goats that may occur in the inner ranges would travel between these three ranges.[36] Thus, at a finer resolution, there may appear smaller and more localized, disjunct goat populations than were indicated by the broad-scale information.

Species with disjunct ranges pose interesting biogeographic questions. Some, such as the longnose snake (see map 5.2b), are poorly known. The longnose snake's disjunct pattern in the southern periphery of the Basin and along the Snake River is as yet unexplained. It selects for open or closed, low and medium shrub environments, sometimes near agricultural land and urban areas, and probably occurs in a wider range of habitat types than current literature suggests. It may be that its apparent disjunct distribution is an artifact of inadequate sampling. The same may be true, to some extent, with the California mountain kingsnake and western ground snake (map 5.2b). On the other hand, the disjunct pattern of wild turkey (map 5.2b) most likely is due to selective introductions in the Basin.

Local Endemics

Distributions of collective "hot spots" of locally endemic species were discussed above. Specific examples of locally endemic vertebrates are shown in map 5.10a and 5.10b (appendix 5H). In these examples, many of the species are restricted to specific ranges because of their high habitat specificity. One example is Coeur d'Alene salamander, which selects sites with talus, seeps, and spray zones of waterfalls, with a slope of 10 to 60 percent, above elevations of 400 meters. Suitable sites usually have at least 25 percent canopy cover. At the broadscale, they are found in fractured belt rock formations in the northern Rocky Mountain extension in northern Idaho and northwestern Montana. At the mid-scale within these sites, they select for appropriate elevations, slopes, vegetation cover, and stream or waterfall proximity.

Ultimately, distributions of local endemics can be a result of contracted ranges due to habitat loss or extirpations, overall scarcity of suitable environments, or other factors. The extent to which glaciation and paleoclimates played a role in determining current distributions of locally endemic populations, particularly of invertebrates and plants, in the Basin is not well studied.

Endemics tend to be less studied than other species, at least among vertebrates. The median confidence levels in scientific knowledge as ranked by the expert panelists were significantly lower for the 39 locally or regionally endemic vertebrate species than for all other vertebrates ($P<0.001$, log-likelihood ratio test, $G=859.27$, $DF=3$).

Other Patterns of Endemism and Distribution

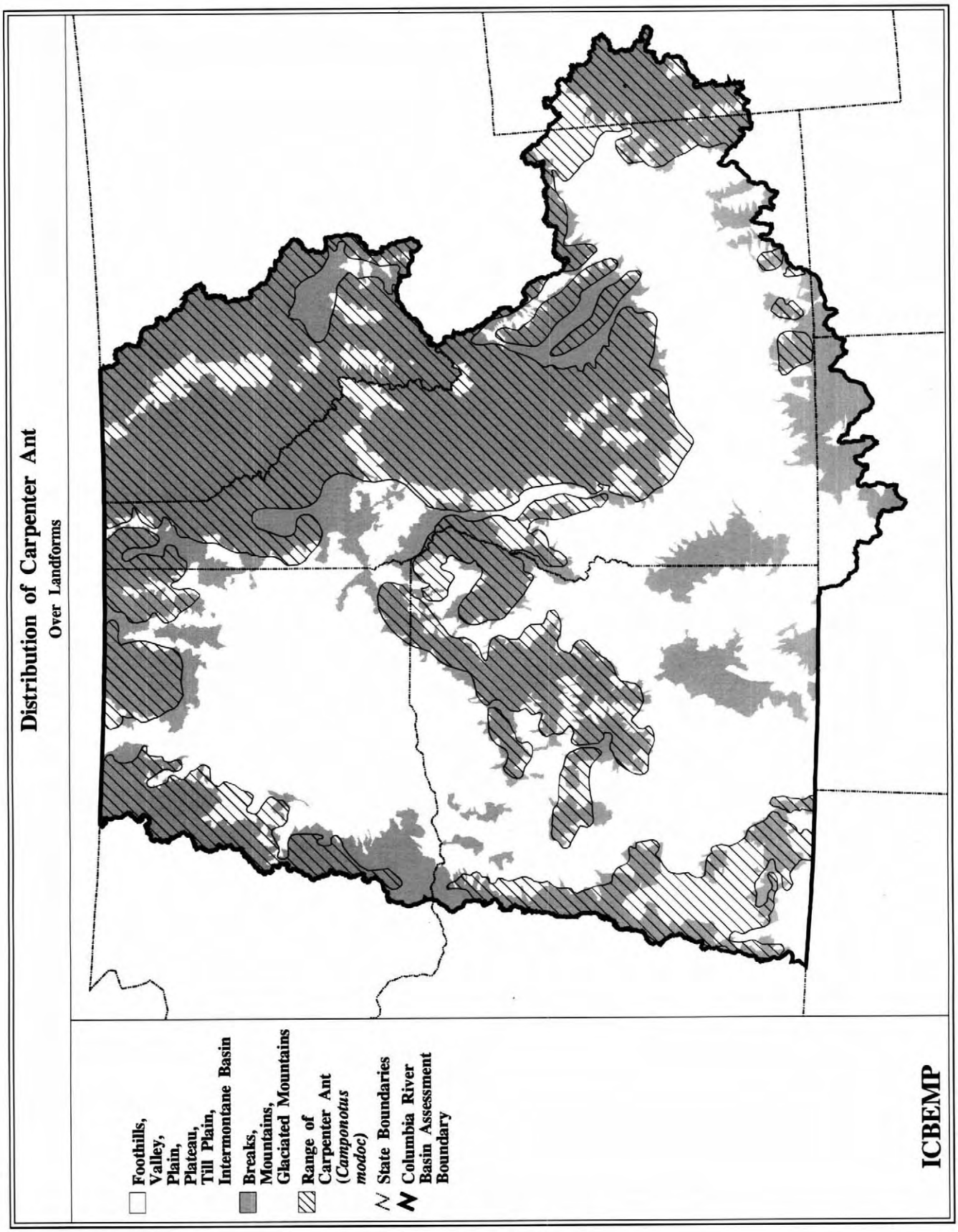
Plants and allies and vertebrates were specifically coded in the SER database according to the five classes of species distribution (that is, scattered, regionally endemic, locally endemic, peripheral, and disjunct). Species of plants and allies included in this study are those listed as threatened, endangered, or candidate, or those suggested by the plant expert panels for such listings.

[36]Personal communication, 1995. Allen E. Thomas, Fish and Wildlife Biologist. U.S. Department of Interior, Bureau of Land Management, Idaho State Offic, 3380 Americana Terrace, Boise, Idaho 83706.

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Map 5.6— Distribution of carpenter ant (*Camponotus modoc*) over landforms.

Map 5.7— Distribution of pronghorn (*Antilocapra americana*) over landforms.

Map 5.8— Distribution of pronghorn (*Antilocapra americana*) over precipitation.

Map 5.9a— Distribution of mountain goat (*Oreamnos americanus*) over elevation.

Map 5.9b— Distribution of mountain goat (*Oreamnos americanus*) over precipitation.

Map 5.9c— Distribution of mountain goat (*Oreamnos americanus*) over topographic relief.

Map 5.10a— Examples of vertebrates that are locally endemic peripherally or within the interior Columbia River Basin Assessment Area: Coeur d'Alene Salamander, Idaho ground squirrel, Washington ground squirrel, Larch Mountain salamander, Oregon slender salamander.

Map 5.10b— Examples of vertebrates that are locally endemic peripherally or within the interior Columbia River Basin Assessment Area: White Salmon pocket gopher, Idaho giant salamander.

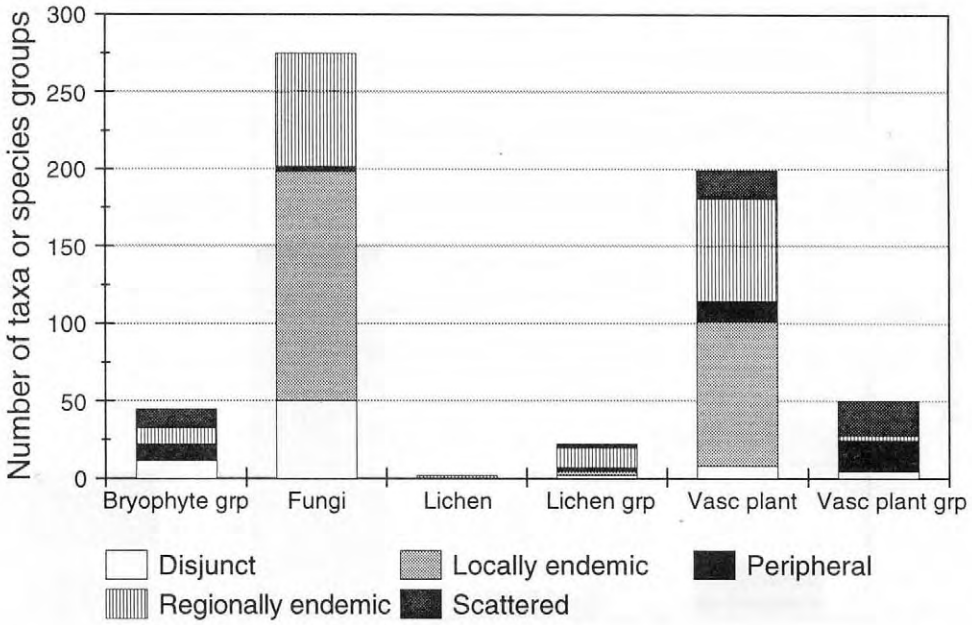


Figure 5.9— Numbers of endemic taxa of plants and allies by endemism category, and taxonomic or species group.

Thus, they already include many of the rarer taxa. In the Basin, bryophyte groups were equally numbered among categories of scattered, regionally endemic, peripheral, and disjunct distributions; none were identified as locally endemic (fig. 5.9). Nearly 70 percent of the lichen groups were identified as regional endemics. Most of the vascular plant groups were either scattered or peripheral, with a few regional endemics and disjunct distributions.

Among individual species, most of the 394 fungi for which distribution patterns were identified were local endemics (about 55%). Others were largely regional endemics or had disjunct distributions. Distributions of vascular plant species listed in the database included scattered (over 40%) or peripheral (approximately 40%) patterns, with the rest (approximately 20%) regionally endemic or disjunct. However, patterns of the entire flora of the Basin, including more common species and species not listed or of specific conservation concern would likely differ.

Among all vertebrates in the Basin (figure 5.10), amphibians and mammals each included all five endemism classes. Reptiles included (in decreasing frequency) species with peripheral, scattered, and disjunct distributions, with none locally endemic. Many birds were peripheral or scattered in distribution, with only a few regional endemics; none was locally endemic. The lack of local endemics at least among reptiles and birds may be explained by the geologic youth of much of the Basin (particularly in the largely volcanic Owhyee Uplands and Columbia Plateau ERUs, and the Northern Glaciated Mountains ERU).

The numeric pattern of local and regional endemics among amphibians, reptiles, birds, and mammals was not significantly different than the pattern among all non-endemic vertebrates; local and regional endemics were not more apt to be of one particular vertebrate class ($P>0.99$, log-likelihood ratio test,$G=-469.06$, $DF=2$). However,

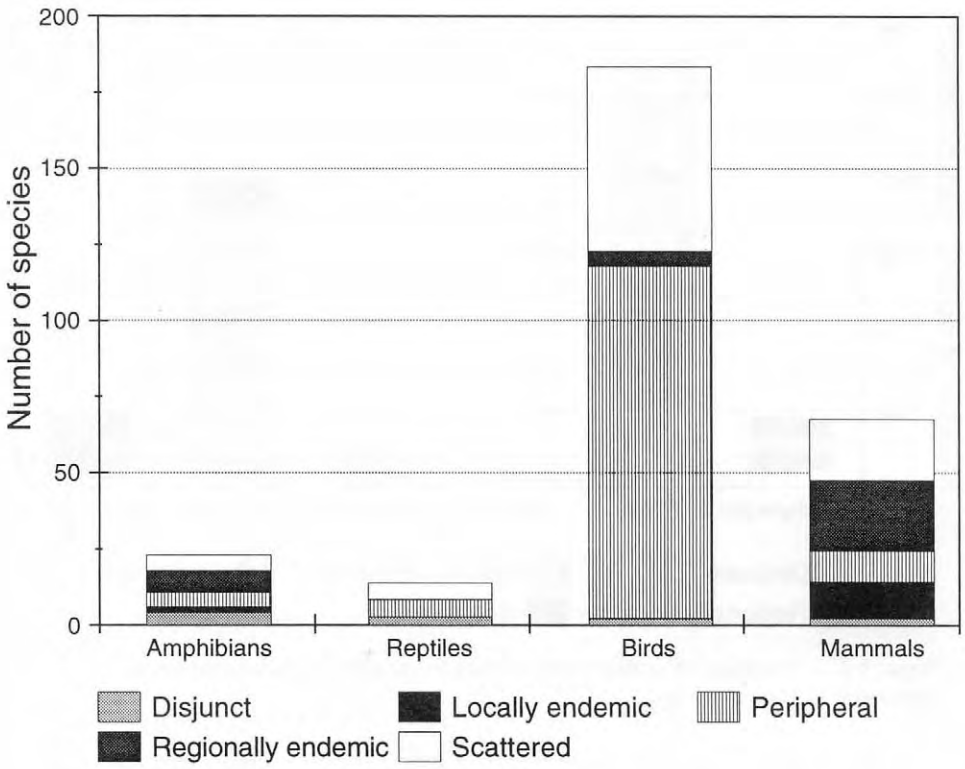


Figure 5.10— Numbers of endemic taxa of vertebrates by endemism category and taxonomic class.

locally and regionally endemic vertebrates did tend to be federally listed more often (as C2 candidate species) than did non-endemic vertebrates ($P<0.01$, log-likelihood ratio test, $G=10.43$, $DF=2$). This is explainable in that endemics, in general, tend to be more subject to greater viability risk.

Some boreal and mid- to high-elevation vertebrate species, including common loon, pine grosbeak, water vole, and hoary marmot, appear to occur as disjunct populations in the northern portion of the Basin along the Canadian border. Actually, these species join in distribution further north in British Columbia. Other northern species, including the great gray owl, spruce grouse, chestnut-backed chickadee, northern flying squirrel, and northern bog lemming, nearly show this disjunct pattern but join in a narrow band in the United States along the northern Washington-Canada border, making this portion of the Basin key in linking such northern vertebrate populations within the United States. In addition, the inclusion of the portion of the northern Great Basin in southeastern Oregon accounts for many of the peripheral species on these lists (see discussion below).

Thus, apparently peripheral, disjunct, and scattered distributions of some species may be an artifact of the location and size of the area of interest, even with an area as large as the Basin of the present study. This principle operates at several scales. For example, at the global scale, distributions of Palearctic species such as boreal owl and Neotropic migratory species such as flammulated owl would seem peripheral or disjunct in North

America alone unless their entire global range were considered. Thus, to better understand the contributions of local conditions, local species distributions should be interpreted in context of one or two larger geographic areas.

A number of the ERUs host unique vertebrate assemblages for a variety of reasons (table 5.19). In some cases, species are specific to particular ERUs because their ranges correlate with landform, vegetation, climate, or other biophysical parameters of the inland Northwest. In other cases, species appear somewhat peripheral to the Basin because they associate with other major ecosystems of the continent, such as the Great Basin, Klamath Lakes, central Rocky Mountains, or even the prairie region.

Certainly, not all species can be shown to have such obvious correlates with broad-scale biophysical features. One result of our investigation suggests that the specific environmental requirements of a number of species simply cannot be adequately analyzed or depicted at the scale of this assessment. Such species include most invertebrates and many rare plants, which often associate with conditions that can be described only at highly site-specific levels. Reviewing their general distribution at the broadscale is only a prelude to conducting further, more in-depth viability analyses. Additional factors come into play at more local geographic areas and finer resolutions (De Cola 1994).

Table 5.19—Unique vertebrate assemblages found in various Ecological Reporting Units (ERUs) within the Basin. Listed are at least some of the species (grouped by taxonomic class) within the assessment area that are found mostly or solely within the identified ERUs.

Upper Klamath Basin ERU

Most of these species are found only in the extreme southwest corner of the assessment area, in the Upper Klamath Basin ERU outside the Columbia River Basin *per se*. Most of these species' ranges extend south to California or west over the crest of the Cascade Range. These are largely species associated with coastal influence.

western pond turtle (also in Columbia Gorge)
foothill yellow-legged frog
acorn woodpecker
wrentit
California towhee
tricolored blackbird
red-shouldered hawk
green heron
Brazilian free-tailed bat
Botta's pocket gopher
broad-footed mole
California kangaroo rat
dusky-footed woodrat

Owyhee Uplands ERU

Most of the ranges of these species enter the assessment area from the south. Some of these species ranges also overlap slightly into the adjacent Northern Great Basin ERU to the west (also see list below). Most of these species belong to arid grassland or steppe habitats but do not extend further north into the Columbia Plateau ERU or Snake River Plain ERU.

western whiptail
mojave black-collared lizard
desert horned lizard
longnose snake
ground snake
kit fox
Wyoming ground squirrel
desert woodrat
little pocket mouse

Table 5.19 (continued).

Northern Great Basin ERU

These are species of the northern Great Basin, only a small portion of which occurs within the assessment area, and which is outside the Columbia River Basin *per se*. These species are part of a much more extensive and characteristic Great Basin fauna more fully represented further south beyond the assessment area. Most of these species' ranges extend further east and south out of the assessment area. Some of them also overlap slightly into the Owyhee Uplands ERU to the east within the assessment area.

rose-breasted grosbeak
(also disjunct in Snake Headwaters ERU, below)
western snowy plover
chisel-toothed kangaroo rat
dark kangaroo mouse

Amphibians in the Columbia Gorge

This is a special set of species—all amphibians—which just enter the assessment area east of the crest of the Cascade range, through the Columbia River Gorge (mostly along the northern reaches of the South Cascades ERU, which includes much of the western section of that portion of the Gorge that occurs in the assessment area). The Columbia Gorge provides unique mesic conditions and habitats allowing this assemblage to extend just east into the assessment area.

Dunn's salamander
Larch Mountain salamander
Cascade torrent salamander
red-legged frog
Oregon slender salamander

Spine of the Cascades

This set of species occurs mostly along the spine and west of the Cascades in Washington and Oregon (mostly the North and South Cascades ERUs, but in some cases further south into the western edges of the Upper Klamath Basin ERU). There, they edge into the westernmost periphery of the assessment area along the Cascades high country and eastern slopes.

Cascades frog
rough-skinned newt
northwestern salamander
Cope's giant salamander
ensatina
northern spotted owl
hermit warbler
Trowbridge's shrew
shrew-mole
Cascade golden-mantled ground squirrel
Pacific jumping mouse
mountain beaver
western red-backed vole
creeping vole
black-tailed deer

Snake River Headwaters ERU

This assemblage consists mostly of mid-continental and eastern United States species that just edge into the assessment area in western Wyoming.

yellow-bellied sapsucker
brown thrasher
bay-breasted warbler
chestnut-sided warbler
summer tanager
rose-breasted grosbeak
(also disjunct in Great Basin ERU, above)
dickcissel
Sprague's pipit
black-throated blue warbler
red-throated loon
whooping crane
black scoter
parasitic jaeger
Uinta chipmunk
American bison

Table 5.19 (continued).

Upper Snake River ERU

A few species enter the assessment area from the south into the Upper Snake River ERU in southeastern Idaho.

Virginia's warbler
cliff chipmunk

Northern Glaciated Mountains ERU

A few species barely range into the assessment area from the north in a portion of the Northern Glaciated Mountains ERU. Some, like northern hawk owl, snowy owl, gyrfalcon, boreal chickadee, lynx, and others, occur in the north fringes of the assessment area, largely in the Northern Glaciated Mountains ERU and adjacent northern ERUs. Some of these species occur only in winter during irruptive, southward range expansions. At least the three following species, however, appear to occur permanently mostly in very northern Idaho and northeastern Washington.

wood frog
green frog
caribou

Columbia Plateau ERU

There appear to be few vertebrate species found solely in the Columbia Plateau ERU.

Washington ground squirrel

Central Idaho

These species occur solely or mainly in the Lower Clark Fork ERU or Central Idaho Mountains ERU.

Idaho giant salamander
Gambel's quail
Idaho ground squirrel

Western Montana

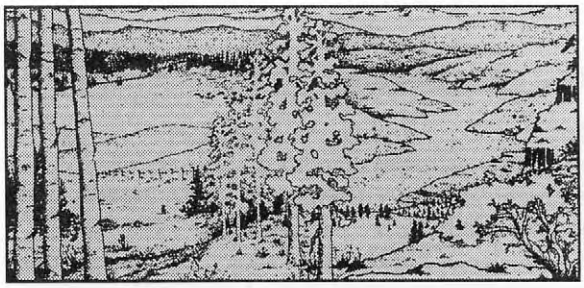
A few species distributed more easterly or northerly enter the assessment area in western Montana, in the Lower and Upper Clark Fork ERUs or the Northern Glaciated Mountains ERU.

Tennessee warbler
clay-colored sparrow
Baird's sparrow
Le Conte's sparrow
chestnut-collared longspur
ovenbird

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CONCLUSIONS AND INTERPRETATIONS

This chapter has provided an overview of the status of terrestrial species and ecological communities in the Basin. This chapter has focused, in part, on species of current viability concern, particularly species currently designated as endangered, threatened, or candidate, and species of potential concern for persistence because of management activities. This species-centric focus is but one facet of the broader evaluation, however. Equally vital to meeting the demands of a new era of ecosystem management is an understanding of species (and other taxa) relations and their ecological functions, and how these affect long-term ecosystem productivity, biodiversity, and sustainability of resource use. To this end, we have collected a vast amount of information on species and communities in the form of contract reports, databases, maps, and internal reports.

Our work provides an ecosystem context for management of habitats and environments for terrestrial species and communities. We provide a classification system for environmental correlates and for ecological functions of species, and identify functional groups of species based on their ecological roles. Although the Forest Service and Bureau of Land Management are primarily charged with habitat management, knowledge of such ecological roles of species and the dynamics of plant and animal communities provides a stronger knowledge base and ecological foundation for ecosystem management.

In this chapter we have not considered future scenarios or planning alternatives, and thus do not project future viability of species. However, this assessment sets the stage and provides base information, such as distribution of species, habitats and key environmental correlates of species, and effects of management actions, as a basis for viability evaluation.

Our work also addresses ecosystem restoration in several ways. We suggest selection of bioindicators for monitoring environmental changes and for assessing problems of grassland deterioration and specific actions for mitigation and restoration.

Some policy questions and issues can be addressed at a broad regional scale. Additional work is necessary for (1) further describing historical trends and current conditions and threats for species at finer scales of resolution that this current study affords, and (2) collecting basic scientific knowledge on life history, ecology, and distribution of many species.

Our work provides a basis for considering species in ecological and spatial contexts, and listing species according to biological criteria. One example likely deserving greater exploration for its utility in management is The Nature Conservancy's global ranking system. This system ignores administrative boundaries, lists species based on ecological criteria by ecosystem, is widely accepted, and contributes meaningfully to conserving biodiversity.[37]

[37]Personal communication. 1995. F. Samson, U.S. Department of Agriculture, Forest Service, Northern Region, Ecosystem Assessment and Planning, P.O. Box 7669, Federal Building, Missoula, Montana 59807.

Major Findings

Biological Diversity

Based on our research, the total biodiversity for the Basin is greater than 43,000 species of macroorganisms. The enormity of the biota is matched only by the paucity of our scientific knowledge of life history, ecology, and response to management activities of most species. Among terrestrial species, the better-known forms include some of the commercially valuable plants, a few of the rarer plants, the more conspicuous or economically important vertebrates, and defoliator insect species. The rest of the terrestrial biota is largely unstudied in the Basin. The enormously diverse microbiota—the microfungi, bacteria, protozoa, rotifers, nematodes, and others, vital to soil productivity and ecosystem function—is virtually unknown.

We identified numerous centers of concentration of plant and animal species rarity and endemism, and of high biodiversity, throughout the Basin. Where these centers overlap, they formed 12 hot spots of species rarity and endemism and 7 hot spots of high biodiversity. Our identification of "hot spots" of species rarity, endemism, or biodiversity can be the starting point for considering management for such conditions [for example, see Kruckeberg and Rabinowitz (1985) on conservation of rare and endemic plant species]. For example, hot spots are areas of intersection, not union, among pertinent species; they do not capture all potential sites with rare or endemic species or areas with high biodiversity.

Other aspects of a broader biodiversity conservation strategy can address protecting type locations of rare fungi, lichens, bryophytes, and vascular plants; protecting unique plant communities; *ex situ* plant conservation measures; providing for plant and animal species associated with rare or declining vegetation communities, especially native grasslands, native shrublands, and old-growth forests; ensuring adequate habitat for plant and animal species of interest to American Indian tribes; and conserving locations still containing all top vertebrate carnivores. Also, natural areas of various kinds might be "realigned" or enhanced to better coincide with hot spots of species rarity and endemism and hot spots of high biodiversity. Criteria for selection of new natural areas could be based on consistent ecological themes.

We have also provided some information on maintaining biodiversity by addressing the role of natural areas, changes of habitats and species on Federal and non-Federal lands, identifying sets of substrates and environmental correlates associated with individual species, and other information.

The models of Joshi and Gadgil (1991) also suggest that refuges for renewable resources, such as for harvestable plants or animal populations, can significantly contribute to long-term sustained use throughout a region. Such centers of renewal also can contribute to ecosystem management objectives for maintaining biodiversity, and might be considered in management planning.

Species at Risk

We have developed a complete catalogue of all federally listed threatened, endangered, and candidate species. The database also includes information on

The Nature Conservancy and Heritage Program rare plant categories, and state- and agency-specific listing categories of all species. We have provided summaries of conservation plans and useful management actions for federally listed species. It is evident, though, that some of the threatened and endangered species, and many of the additional species of potential conservation concern, are dependent on environmental or habitat components not evaluated at the broadscale.

We also identify a number of additional taxa, especially plants and invertebrates, worthy of additional attention. These potentially include: 394 fungi species; 40 functional groups of lichen species; sundry types of microbiotic crusts (not classified); at least 400 apparently regionally rare bryophyte species; 280 individual vascular plant species and 82 rare plant communities; 144 rare

and endemic invertebrates (gastropods and insects); and various vertebrates, including the more aquatic-dwelling amphibians, reptiles susceptible to ground-disturbing management activities, and birds and mammals associated with habitats that are now scarce, declining, or increasingly fragmented, including native grasslands, sagebrush, and old low- and mid-elevation forests. Basic inventories are needed for many of these species to determine their true rarity.

However, we do not advocate a species-by-species approach to management of all such species at risk. Many of the species of these lists can be assessed in groups; inventories, where desired, could aim at gathering information for many species simultaneously; and management guidelines could address their collective habitat and environmental requirements, or locations of joint occurrence.

Species and Habitat Trends

Conclusions made regarding habitat trends, particularly regarding potential effects on species, must be treated as tentative working hypotheses. The lack of specific data on population size, structure, and functional and numerical response means that much inference has to be made from changes in habitat abundance and gross distributional patterns. Actual population response to changing habitats and environmental conditions might differ. Likewise, many finer-grained attributes of vegetation and habitat substrates and spatial patterns of suitable environments cannot be accounted for because of the necessarily broad geographic extent and coarse resolution of this project. These, too, might act to affect true population response. Thus, one working hypothesis arising from this project is that habitat amount, distribution, and trend as analyzed in this study reflects true population size, distribution, and trend at both broad and finer scales of spatial resolution. Obviously, this hypothesis must be tempered by local knowledge of environments and populations when using the results of this study to guide land management.

Given these cautions, our research (also see Biophysical and Landscape Dynamics chapters) supports the hypothesis that species incurring the greatest likely changes from habitat conditions prevalent during the early nineteenth century seem to have been those associated with native closed shrublands (for example, big sagebrush), native grasslands (for example, *Fescue*-Bunchgrass and *Agropyron* bunchgrass), late-successional forests, and old open ponderosa pine forests. Most of the decrease in these areas has occured on non-Federal lands, although Federal (FS, BLM) lands also share some decrease.

Among vertebrates closely associated with old forest stages, which have greatly declined since historic times, are: three federally listed species or subspecies that occur on the periphery of the Basin (marbled murrelet, northern spotted owl, woodland caribou); and three woodpeckers (Lewis' woodpecker, pileated woodpecker, and Williamsons' sapsucker).

Six vertebrate species are highly associated with old forest structural stages (that is, occur in old forest structural stages and also use less than 20% of all 10 other possible structural stages): flammulated owl (*Otus flammeolus*), boreal owl (*Aegolius funereus*), brown creeper (*Certhia americana*), band-tailed pigeon (*Columba fasciata*), white-winged crossbill (*Loxia leucoptera*), and western grey squirrel (*Sciurus griseus*). An additional 17 old-forest species also use less than 30 percent of all 10 other possible structural stages, an additional 13 old-forest species also use less than 40 percent of other stages, and an additional 19 old-forest species also use less than 50 percent of other stages; these are all species allied to old forests but in decreasing degrees of requirement (TS 1995).

Overall loss of habitat is but one of several means by which species can decline. At least four types of declines can be identified (for example, see Gilpin and Hanski 1991). (The same categories can be used to explain increases, as well.) Altering total area of suitable habitat is only one measure. The four categories of species decline can be used as part of a process for better identifying species sensitive to particular land management activities.

First, species can decline by loss of portions of their distributional range but species' density in remaining habitats is more or less unchanged. This is the major kind of change analyzed in this project. It is the kind most amenable to broad-scale analysis.

Second, species can decline by loss of range-wide density, retaining their overall distributional range. For some species this is a matter of scale; loss of one stand of old trees might eliminate a red tree vole colony and cause overall densities of the voles to decline over a broader landscape area, even though their overall distributional range is unchanged. Some of the wider-ranging predators, including northern goshawk, wolverine, American black bear, and mountain lion, have likely suffered this kind of decline. We have not been able to quantify this kind of decline for species at the broadscale.

Third is a change in the degree of connections among habitats. Imposition of unsuitable conditions might act as behavioral or physiological barriers to species movement or colonization. In this case, overall range and ecological densities might remain mostly the same, but there is a low likelihood of occupying more fragmented or isolated habitats. This might have occurred with some of the aquatic species including some amphibians and aquatic mammals, whereby water diversions or dams could impose dispersal barriers to reaching habitats. Other examples could be disruption of transitional range of some ungulates that altered their migration between, and use of, summer and winter ranges. At the broadscale, our analyses of connectivity of vegetation cover types and of size classes of natural areas as compared to species' home range sizes attest to this kind of decline. Our findings on effects of mid-scale fragmentation of habitat patches will help identify vertebrate species and groups affected by this third kind of decline.

The fourth type of decline is a combination of range loss, density declines, and habitat made inaccessible. Probably all the species affected by the first three types of decline also suffer, to some degree, from changes in all categories. Also as revealed in our evaluations, various management activities can change species ranges, densities, and habitat accessibility.

Implications for Ecosystem Management

Using an ecosystem approach to land management implies maintaining the biodiversity, productivity, and sustainablility of renewable resources. Our work has highlighted aspects of biodiversity that may be considered under such an approach: identifying taxonomic diversity of species; diversity of species groups; diversity by ecological functions; areas of high species richness and species rarity or endemism; unique species assemblages by ERUs; and trends, current status, and needs for listed and candidate species.

Our results suggest that long-term conservation of inland ecosystems would entail focusing not only on specific taxa at risk but also the key ecological functions afforded by both rare and widespread elements of the biota. To help organize thinking on which substrates and ecological functions pertain to maintaining biodiversity and ecosystem processes, we developed the first classifications of key environmental correlates (appendix 5F) and key ecological functions (appendix 5G) that span all taxonomic groups of macroorganisms in the Basin. These classifications can be used to organize assessments of management activities and as a basis for developing more site-specific databases to help ensure that all major groupings of substrates or correlates and ecological functions are considered in management planning.

Classifications of environmental correlates and ecological functions can be used with the Species-Environment Relations (SER) database, itself just a first step in developing a fuller knowledge base of all taxa, to determine species associated with: vegetation cover types, structural stages, and specific substrates, as well as other environmental correlates, ecological functions, and, for some species groups, potentially threatening management activities. In this way, potential conflicts

between a species-oriented planning strategy and a "systems"-oriented one resolve into one coherent approach.

Grouping species by key environmental correlates or by key ecological functions is an ecologically-based approach. However, this should not preclude addressing management needs by also grouping species according to more political or management criteria. One classic such grouping is that of game species (or more focally, big game) and more recently, nongame species. Other examples might include species addressed by interest groups, such as particular sets of "old-growth species." The SER database approach can facilitate exploring ecological characteristics of such species groups as well. On a more ecological basis, species associated with snags, cavity use (primary or secondary), down wood, native grasslands, native shrublands, and old-growth forests also can easily be identified in the SER database and the Heritage Program databases of rare plant locations (integrated into the ArcInfo® data files). Managers often need to be able to assess species groups defined based on such political or management criteria and to monitor sustainability of their particular habitats. It must be remembered, however, that some entire taxonomic classes, such as most invertebrates and plants, likely respond to environmental conditions at scales far finer in resolution than currently afforded in the broad-based scope of the SER database.

One of the specific objectives for ecosystem management could deal with maintaining the long-term evolutionary potential of species lineages (properly, ecosystems, communities, and species groups do not evolve *per se*). Provision of the following key components would help meet this objective:

- all populations of species with disjunct distributions;
- locally and regionally endemic species;
- locally endemic subspecies, particularly those at the edges of their range;
- unique assemblages of species and their ecological functions and interactions, even if on the periphery of the Basin;
- all categories of species' ecological functions rather than allowing one species with a similar function or habitat orientation to "substitute" for another (no ecologically functional equivalents);
- the full array of vegetation cover types, structural stages, and substrates, particularly those in greatest decline since early historic times in the Basin; and
- both *in situ* and *ex situ* plant conservation measures.

In addition, further work is needed to describe the genetic constituents of many populations, for at the heart of long-term evolutionary potential is a species' ability to adapt to changing environments by tapping into a genetically diverse gene pool.

Given the ever-changing nature of ecological communities in the Basin, particularly regarding potential effects of fire, perhaps the very concept of defining "desired future conditions" for planning could be replaced with a concept of describing "desired future dynamics." That is, long-term evolutionary potentials can be met only by accounting for potential future changes in conditions. No one condition can be static for long; witness the recent eruptive, intense fires in parts of the Basin, resulting, in part, from a long history of fire suppression and vegetation changes. Impending changes in regional climates, too, have the capacity of causing great shifts in composition of ecological communities. For example, providing for elevational "corridors" to allow upslope shifts of vegetation over the next several decades may be vital to helping conserve the long-term evolutionary potential of individual species.

Maintaining evolutionary potential also entails conservation at various taxonomic levels. To this end, further work is needed in detailing community structure, historic and future changes, and levels of habitat specificity and endemism of

genera, families, and orders. Studying special conditions of allospecies complexes, sibling or cryptic species, species at the periphery of their overall range, locally endemic subspecies, and hybridization, provide unique opportunities for exploring mechanisms and instances of the speciation process (natural evolution of new species lines). Evolutionary potential is not indexed solely by a catalogue of species and their habitats. Additional study is needed on how manipulation of natural processes, such as fire and ecological succession, can influence genetics and viability of populations clearly dependent on those processes.[38]

A number of individuals or groups of species can serve as "early warning" indicators of ecosystem health. Presence and condition of microbiotic crusts on rangelands can act as indicators of soil properties and grazing effects. Impending problems of soil productivity can be indexed by tracking disruptions of soil processes, decreases in soil bacterial or fungal activity, decreases in soil fungal or bacterial biomass, change in the ratio of soil fungal to bacterial biomass, decreases in the number of soil protozoa, change in soil nematode numbers, and soil nematode community structure or maturity index. Butterflies and other invertebrate herbivores can help indicate general trends of total ecosystem diversity. Additional bioindicators can include selected macrofungi, lichens, and bryophytes (see Plants and Allies).

Research Information Needs

A first-ever catalogue of biodiversity of the Basin revealed diverse communities of plants, invertebrates, and vertebrates. However, many species groups are largely unstudied. During our process of collecting information on species for this assessment, particularly during the expert panel surveys, we catalogued areas of major scientific information gaps on each species. This information was constructed as an RDA (research, development, and application) database in Paradox. This database can be searched with key words on taxonomic groups or by subject to determine additional, species-specific information needs. Examples include information gaps on relations of species with livestock grazing, pesticides, timber harvest, and roads. Following is a summary of the major research information needs identified during this assessment.

Basic Systematics of Major Species Groups

Entire taxonomic groups, particularly many of the invertebrates, still require basic systematics research. Many species of arthropods, particularly canopy-dwelling forest arthropods and soil mesoinvertebrates, remain undescribed. About 86 percent of arthropods, 67 percent of fungi, and 51 percent of mollusk species estimated to occur in the Basin not have been studied, surveyed, or, in some cases, even identified. Much inventory and basic systematics work remains to be done on these groups. Soil microorganism groups and microbiotic (soil) crusts of the Basin, although critical for maintaining soil productivity, are poorly known and little studied.

Most of the soil microbiota of the Basin is undescribed. This biota includes viruses, bacteria, protozoa, rotifers, nematodes, and soil microfungi, as well as algae. Even though we consider such taxa as species groups, basic empirical work still is needed on taxonomy, diversity, and ecological roles of these species, particularly in how they aid soil productivity and maintain health of forest and rangeland ecosystems.

Monitoring for Population Status of Species and Health of Ecosystems

Basic information on population status of most species is lacking in the assessment area. While it is infeasible to expect monitoring studies on most, or even many, of the species known or projected to occur in the Basin, monitoring studies can be designed to focus on species groups and indicators of biodiversity and trophic health of ecological communities and ecosystems. In this way, both species and ecosystems would be addressed in a coherent, complementary manner. See the sections

[38]See footnote 37.

below for discussions pertinent to specific taxonomic groups. Certainly, continued coordination with other agencies and organizations on monitoring and research studies provides for greater efficiency.

Plants and Allies

Fungi—Inventory of fungi is likely needed with those species potentially rare but that may have been undersampled in the past. Owing to the ephemeral nature of the sporocarps and their strong dependence on abiotic factors, such as precipitation for spore production, fungal species community analysis requires 5 to 10 years of collecting to adequately and comprehensively inventory the species in any one area. We also have no data on how fungi populations shift or move through the soil matrix. In some cases, a particular fungal colony may take decades to migrate by way of hyphal growth. Thus, it seems reasonable to expect such inventories to be part of a broad-based and long-term survey rather than mandated prior to every land management activity.

Type locations of rare fungi could be protected in small, site-specific mycological preserves of varying size depending on habitat and life history of the species, until further inventories or studies determine the species' status.

Lichens—Baseline inventories and studies to document lichen species presence, abundance, biomass, habitat requirements, and geographic distribution are needed. Inventories of lichens may be added to other biological inventory efforts with mapped locations. Standardized methods for sampling forest epiphyte lichens are needed. Inventory data could be verified with voucher specimens deposited in herbaria. From this information, identification guides and annotated catalog for lichens in each physiographic region of the Basin can be developed.

Status survey reviews can be conducted for the rare lichen species. This information could be shared with the State Heritage Programs in each state to complement information from private and State lands. Conservation strategy plans can then be developed for rare species which conserve and enhance their populations.

Successional studies of lichens are needed, including establishment, diversity, and abundance of lichens in vegetation stands of various ages and in different plant associations, substrates, and vertical strata. Studies are also needed to determine lichen recovery after fires, and their dispersal patterns by species, by groups of species, and by forest types.

Monitoring and research plans can be developed to evaluate effects of forest and rangeland management practices, including timber harvesting and other silvicultural practices, livestock grazing, and recreation. Other topics that need study include:

- determination of the lichen species in retention trees by topographic position, tree symmetry, crown type, and aggregation of the retention trees;
- determining the effects and advantages of selecting leave trees that contain a diversity of lichen species;
- determining how lichens on retention trees act as centers of dispersal;
- determining nitrogen fixation rates of lichens in microbiotic crusts in different rangeland cover types;
- determining the quantity and nutrient content of lichen litter-fall in the forest cover types;
- addressing the role of lichen through-fall and litter-fall in the nutrient cycling and biomass production of the various types and ages of forests;
- determining and quantifying the rates at which small mammals (flying squirrels and red-backed voles) eat lichen litter-fall, and the role of lichens in the trophic dynamics of small mammals and their predators such as forest predators (for example, boreal owl);
- researching the role of lichens as habitat and food for forest invertebrates;

- effects of burns on lichen viability and recovery;
- basic systematics and taxonomic studies of the tumbleweed or vagrant ground lichens; and
- applied research on the management of tumbleweed or vagrant ground lichens and their role as forage for native pronghorn antelope.

Bryophytes—Specific localities, habitats, and research needs for areas of the seven states within the Basin are on file (TS 1995). The data for Nevada and Utah are scanty. Despite the fact that thousands of collections of bryophytes have been made in the Basin over the last 150 years, vast areas have not been collected systematically or at all. In particular, liverworts have been undercollected and chronically misidentified, and need careful attention in future work.

The rare taxa listed in appendix 5D could be sought throughout the study area to better determine distributions and abundance. The localities of the taxa listed in appendix 5D as occurring at the edge of their range (for example, species primarily of eastern North America) are important for study for their role in migration or as relictual areas.

Arid habitats of all types are undercollected throughout the Basin. These include desert, shrub-steppe, pinyon-juniper woodland, oak woodland, and ponderosa pine forest. The composition and function of soil crusts, while relatively well studied in the Great Basin, particularly in Utah, is virtually unknown in the Columbia River basin. Some general collecting has been done in a few areas, but the problem needs to be approached on a regional basis, studying crusts in different plant associations and on different soil types. The effects of livestock trampling should be included in any such studies.

Most of the issues centered on old-growth and late-successional forests, as identified in Thomas and others (1993), also apply to forested areas of the Basin and need not be repeated here. The greatest similarities in the bryophyte flora and relative biomass in such forests occur in the mesic forests of the so-called "maritime extension" area in Idaho and Montana. If this flora is to be managed for long-term commercial harvest, then regulation and monitoring would help ensure that rare or disjunct species are not being depleted, and that recruitment is adequate to sustain harvest levels. Ponderosa pine forests have few bryophytes as epiphytes or in the understory, but representative stands may be protected and managed correctly to maintain associated bryophytes.

Calcareous substrates provide habitat for a distinctive group of bryophyte species. A few calcium-rich areas have been collected, particularly in the northern Rocky Mountains and elsewhere in Idaho, but those of Oregon and Washington are poorly known and may need further work.

Mineral deposits, usually occurring in areas previously mined for gold, silver, copper, mercury, and other materials, often provide substrate for a distinctive group of bryophytes. While these areas have received some attention in the Rocky Mountains, other sites within the study area have not been surveyed adequately for these species. The same sulfides that provide suitable conditions for some bryophytes, especially in mine runoff, also pollute streams and groundwater for other organisms. Mine tailings and debris undoubtedly have increased suitable habitat for some of these species, which often select disturbed or barren soils.

Until recently, wetlands were ignored by land managers, and a good history of collecting in these sites is provided by only a few individuals. With the advent of wetland fill regulations and community classifications, these areas are receiving more attention and some taxa now thought rare should become more common. Included with these wetlands are bogs and fens, the latter occurring on calcium-rich sites, which have been poorly collected for bryophytes outside of the Rocky Mountain region. Effects on bryophytes from grazing in peatlands have received little attention in the Pacific Northwest, but observations suggest that bryophytes are severely affected by trampling, as noted in the wet soil group.

Flood plain habitats have received recent attention because of wetland and riparian protection. Thomas and others (1993) identified how important floodplains were for bryophyte species diversity, and how many species, particularly liverworts, were concentrated in old-growth forests occurring there. A similar situation exists in the Columbia River basin, especially in the "maritime extension" areas of Idaho and Montana, where species depend on shade, wet soils, logs and other organic debris, and humid microclimate. As with the aquatic and splash-zone species in streams, this group of species can be affected to some degree by land ownership patterns and adverse conditions originating upstream on non-Federal lands, although effects would be less pernicious because few of these species are in the stream channel. The effects of livestock trampling should be included in any such studies.

Geothermal areas are sometimes known for unusual assemblages of plants that survive outside of their normal distributional limits, because heated ground provides snow-free conditions and a longer growing season (Given 1980, Lange 1973). Although many bryophyte specimens were collected from hot springs in Idaho and Montana, none appears to be restricted to this habitat on a regional basis or to exhibit an unusual distributional pattern. Eversman (1990) found lichens to be absent from geyser areas, presumably because of particulate matter and sulfurous fumes from geysers, but the flora was more normal near thermal springs. More work needs to be done in these areas to better describe their effects on bryophytes.

Steep, narrow canyons and isolated gorges provide ideal conditions for bryophytes to persist in areas outside their normal distributional limits. Shade, moisture, and cold air drainage all contribute to unusual species being found in these areas, sometimes as relics from cooler periglacial climates. Effects from livestock and humans are often limited here because of restricted access. More work needs to be done to inventory such sites, particularly those with historical bryological collecting that can be used for comparative purposes to monitor changes in the flora.

Aquatic and splash-zone bryophytes are subject to the same effects described by Thomas and others (1993). In addition, galvanized culverts, like roof flashing, may be toxic to aquatic bryophytes and may diminish species diversity on some streams.[39]

Vascular Plants—Inventories are needed of rare plant species and unique plant communities to better determine distribution and potential sensitivity to land management activities. Type locations of plants known to be rare could be protected from ground-disturbing activities.

Both *in situ* and *ex situ* plant conservation measures need to be considered. *Ex situ* measures include storage of seeds and spores of rare plants in seed banks, and use of botanical gardens for maintaining off-site populations of rare and at-risk species.

Additional research information needs on vascular plants include:

- basic biology;
- reproductive biology;
- basic demographics;
- seed-bed ecology;
- interactions with weeds;
- interactions with seed predators or herbivores;
- disturbance ecology; and
- building computer aided applications for botany, including GIS and geographic databases.

The CRBFLORA database developed for this assessment represents only the beginning of what could be a much larger product. There is tremendous potential for this database to be used for additional analysis. An example of the potential for this kind of analysis was demonstrated by K. Urban (1995) in his analysis of Floristic Biodiversity of the Camas Ecosystem Analysis Area. Using a matrix database that contained 1,234 vascular plant species over seven plant association groups, Urban analyzed:

[39]Personal communication. 1995. David H. Wagner, independent contractor, Eugene, Oregon 97401.

- the number of vascular plant species presently occurring in the analysis area;
- a comparison of the floristic richness of the analysis areas with other areas on the Umatilla National Forest;
- ecological distributions and habitat affinities for the species within the plant association groups selected;
- the occurrence of historically listed or presently listed sensitive plant species;
- determination of other "at risk" plant species in the analysis area;
- a ratio of introduced to native species in the planning area;
- a list of noxious weeds; and
- the continued harvestability of a list of culturally significant plants.

Completion of the CRBFLORA database cataloging all vascular plants of the assessment area, would aid efforts in inventory and monitoring and could greatly aid in the determination of species at risk.

Invertebrates

Microorganisms—We do not suggest a species-specific approach to microorganism management. However, to better provide for productive and sustainable ecosystems, we would need to understand which bacteria and other microorganisms species groups are favored and which are impaired by management activities. This entails further study on determining which microorganism species groups are present in various grassland, shrubland, forest, and riparian settings; how the species groups are affected by management activities; and how changes in microorganism groups directly or indirectly affect diversity, productivity, and sustainability of resource production.

Predators—An adaptive management monitoring study could test the working hypothesis that management activities aimed at maintaining only general conditions of soil productivity would also adequately protect taxa or functional groups of soil invertebrates, particularly predators, and their ecological functions. Such working hypotheses could be tested by a set of monitoring activities.

Controlled management experiments are needed to determine the distribution, biology, and response to management activities of a few selected arthropod predator species chosen on the basis of rarity, presumed ecological importance, and/or sensitivity to particular management activities. These species could be studied within the context of controlled management experiments to assess how human activities influence their abundance and distribution. Effort also could be placed on understanding how management of forests influences the process of predation. This can be accomplished through a continuing inquiry on predator-prey relationships.

Pollinators—Sampling is needed in sandy environments for presence and abundance of pollinator species, particularly for endemic bee species and to determine effects of recreational vehicle use. Surveys would determine dunes with particularly high bee diversity and endemism. Off-road vehicle activity not only reduces floral resources necessary as a food resource for bees, but also destroys bee nests and potential nest sites. Because assemblages of pollinator species can vary markedly among sandy substrates, information on species presence and absence will indicate which dunes have particularly high bee diversity and endemism. A next step could be to monitor bee composition and abundance under various management regimes.

The intricate relations between arthropods and plants, as exemplified by flowering plant-pollinator interactions, highlight the need for parallel development of plant and invertebrate databases. A pollinator database has been initiated for the current project ARS, at the Bee Laboratory, Logan, Utah and many databases for both general and rare plants are being and have been compiled by a variety of agencies (also see previous section on CRBFLORA database below). These systems

need to be compatible to better aid our understanding of the relations between pollinators and flowering plants in the Basin.

To develop an understanding of basic life history and ecological characteristics of pollinators, relatively large-scale, controlled, and replicated studies are also needed. Information on breeding biology and pollinator behavior is needed to design reintroductions and to evaluate effects of exotic plant and pollinator species. For instance, knowledge of dispersal distances of a pollinator can help determine the size of the area in which habitats and host plant species could be provided and where effects of exotic species can be expected.

Grassland Herbivores—Studies examining the effect of range management practices on plant successional changes may be undertaken to more fully understand the effects of these activities on the associated insect herbivores. Responses of grassland herbivores to designated management systems could be assessed in a variety of habitat conditions.

Many options of grazing including rotation timing, intensity, spatial and temporal extent, and length of deferment, could be developed on a site-specific basis. Rather than studying all possible options, a few major factors could be evaluated on a variety of vegetation types. For instance, the effects of the season of grazing on vegetation regrowth, plant forage quality for grassland invertebrates herbivores, soil compaction, and soil nitrogen content need to be examined in various grassland types.

The implications of prescribed burning on plant and subsequent invertebrate diversity are unknown. Factors such as fire interval, intensity, duration, season, patchiness, and spatial extent need to be examined to determine their effects on plant community composition and diversity and abundance of invertebrate herbivore and predators.

Little is known about the competition of exotic weeds and most native rangeland plants, particularly with respect to renovation efforts. Proposed introductions of exotic organisms to control native pests need to be accompanied by research to determine the effect of the exotic in displacing other native species that perform the same function.

Given that insecticides are a tool in pest management, the ecotoxicology of these chemicals as affecting non-target invertebrates needs to be studied. Research must look beyond immediate effects on target species to long-term and residual effects of treatment on the whole fauna. This includes investigations of effects on breeding vertebrates and on bioaccumulation chemicals in the food chain.

Invertebrates can be used as sensitive measures of range and grassland health using an ensemble of species that, in a sense, would feel the pulse of the system. Selected species could be relatively easy to monitor and could represent various trophic levels. For instance, butterflies are a group that can be monitored visually by non-entomologists with relatively brief training (Hammond 1994). Harvester ants are another excellent species for monitoring as they occur throughout many parts of the food web.

Forest Herbivores—Needed, and generally lacking, is research on invertebrate herbivores in forests to examine long-term or beneficial effects of individual insect species, insect assemblages, and associated diseases (Huffaker and others 1984, Stark 1987).

The management of pest species may continue to warrant research due to the need to monitor and control species that threaten forest management objectives. The protection from bark beetle infestation of harvestable timber stands, as well as individual or groups of trees in campgrounds, historic sites, and riparian buffers are examples of resources that need to be protected against adverse damage by specific pest species. The development of hazard rating systems are a priority for a number of species including bark beetles and pests that damage tree regeneration.

Research and monitoring of forest herbivores can include population monitoring, control of pests such as bark beetles, the use of herbivore assemblages as bioindicators of forest health, and other topics. Adaptive management studies can monitor areas treated by different silviculture practices, particularly various intensities of forest thinning and salvage harvests, to help determine conditions under which insect-caused tree damage or mortality occur.

A monitoring program can entail sampling arthropod forest herbivores, particularly butterflies, to index localized and short-term changes in the environment from management practices. Butterflies would indicator total ecosystem diversity and other invertebrate herbivore groups afford similar opportunities to index important ecosystem functions or ecosystem diversity. (See the section on Invertebrates for more detail on selection of invertebrate bioindicators.)

Lastly, studies aimed at gaining a better understanding of the various ecosystem functions that forest herbivores perform are necessary. For instance, whereas it is known that herbivores provide a prey base for numerous arthropod and vertebrate predators, little is known about the specific dietary preferences of bats, birds, amphibians, and other predators on invertebrate herbivores. Likewise, the role of invertebrate herbivores in contributing to wildlife habitat is relatively unexplored. One opportunity that is beginning to be examined is the manipulation of bark beetles using semiochemicals to produce snags for wildlife. This type of research both expands our basic knowledge of invertebrate functions in forest ecosystems and lays the groundwork for further development of practical management tools.

Research and Monitoring Priorities for All Invertebrate Groups—The practice of ecosystem management has increased our awareness of the multitude of essential roles that invertebrates play, which encourages a broadening of the scope of invertebrate investigations beyond those only of forest insect pests. Studies are needed on invertebrate specialists in the context of the entire ecosystem to determine the extent to which their ecological functions influence structure and function of ecological communities and growth and production of desired plant and animal populations. Integrated qualitative and quantitative studies are needed on the role of invertebrates in organic matter decomposition and nutrient cycling, and in providing a food base for vertebrates.

Research on invertebrates, as on other facets of ecosystems, could benefit from integration of the applied science disciplines. For instance, invertebrate specialists could provide more useful results by studying species in the context of the entire ecosystem. Similarly, wildlife, plant, and other specialists could address vital functions that invertebrates provide, such as prey sources and nutrient cyclers. As applied to invertebrate research, adaptive management, where working hypotheses are tested and revised, would advance basic knowledge about both these organisms and the effects of management activities on their survival and function. Integrated research can also take advantage of the unique expertise and perspective of sundry agencies, universities, and other concerned groups.

Research Emphasis—Little information exists on the effects of management practices on invertebrates because the importance of these organisms' ecological functions have previously not been recognized. Much of the information we do have comes from related species from other geographical areas, which often have very different conditions. Accordingly, effective extrapolation is limited. To better understand the effects of management, we suggest that our "best guess or professional opinions" be considered as working hypotheses. In the context of adaptive management, the working hypotheses may be tested. A landscape-scale set of adaptive management "tests" could be considered.

Land managers could likely use tools such as stand hazard rating schemes (indexes of a forest stands' susceptibility to insect pest outbreak), predictive monitoring, and non-pesticide control methods (for example, semiochemical and biological control methods) that are the result of applied research. However, basic research, including studies

on basic biology and taxonomy, dispersal behavior, and natural enemies, lays the foundation for such products.

Because insects and other invertebrates constitute the bulk of the biosphere's faunal biomass, their function as a food source to many species of birds, reptiles, amphibians, and small mammals also deserves additional research attention. Invertebrates are found at all trophic levels (except primary producers) and, by virtue of their bewildering abundance, play a major role in nutrient flow through ecosystems. Also, their importance as decomposers is obvious but often overlooked.

Monitoring Emphasis—Short generation times and high reproductive potential make invertebrates excellent indicators and "early warning" organisms. In addition, they can yield information on effects of treatments on small spatial scales because of their limited dispersal capabilities which, in certain situations is down to less than one hectare. These factors, plus the ubiquitous nature of invertebrates in all habitats, their unsurpassed diversity, and immense contribution to the faunal biomass make invertebrates unique and useful bioindicators of ecosystem change.

Indicator taxa may be useful for monitoring changes resulting from management activities in two fundamentally different ways. First, their abundance or biomass may be an index or surrogate for a critical ecosystem function. As such, they indicate trends of, or effects on, entire functional groups of invertebrate species, rather than an individual component species. For instance, the ratio of total bacterivorous nematodes to fungivorous nematodes may reveal critical dynamics of how the decomposer microbial food web functions or is changed by management practices, but does not indicate trends of individual nematode species.

Second, the richness and diversity of invertebrates may serve as an index of total ecosystem diversity which may differ under various management activities. The abundance and distribution patterns of an individual uncommon species may indicate subtle changes in specific microenvironments of interest. For these studies, taxa are significant at a species-level of resolution, and to be useful on a general basis, must be amenable to this degree of taxonomic precision and sampling ease. For instance, total ant species richness may be a useful index of community diversity, whereas the presence of *Amblypone oregonense* may indicate undisturbed old-forest floor conditions. Thus, candidates for indicator status can include the most abundant, widespread and species-rich assemblages or the most habitat-constrained and thus, uncommon, individual species depending on the monitoring objectives.

The key to using invertebrates as bioindicators is practicality. Candidate taxa for monitoring should, in general, be:

- relatively well-known (in terms of the functional role they play in a community) and functionally important,
- species-rich (contain enough species to avoid statistical errors inherent in small numbers but not so rich as to overwhelm sampling protocols),
- amenable to capture or observation with standardized, low-technology techniques,
- common and widespread (see above for exceptions),
- relatively easy to identify (to an appropriate level of resolution, not necessarily to species), and
- relatively large and showy, when possible.

Vertebrates

Amphibians—Increased interest and concern regarding the effects of resource projects on amphibian distribution and abundance has resulted in increased awareness and inventory on Federal lands. Basic inventories are needed on most amphibian species. Survey protocols are being developed for Washington and Oregon (Cochran and Thomas 1995).

Research is needed on the effects of changes in water quality on larval stages of amphibians, influence of vegetation canopy on breeding ponds and streams (shading/sunlight ratios), and habitat used for dispersal. Studies of the influence on amphibians and habitats from eutrophication of water bodies and increases in ultraviolet radiation and acid precipitation need to be conducted as well.

Monitoring changes in vegetation cover type and structure may not be adequate to determine trends of amphibian population densities and distribution. Determining these parameters entails inventory and monitoring of specific substrates such as down wood, and microhabitat conditions such as deep, moist talus. Studies are also needed on effects on amphibian populations and habitats from livestock grazing and pesticide use.

Reptiles—Surveys for presence are needed of species that (1) currently seem to be patchily distributed with apparently disjunct populations, to determine occurrence in potentially unoccupied portions of their range; (2) species currently listed by agencies as sensitive but which may be more common or more widely distributed than originally reported; and (3) species that appear to be declining in parts of their range for unknown reasons. Survey should be conducted during optimal times of the day or night and in optimal habitats for specific species, such as night snakes and sharptail snakes.

Neotropical Migratory Birds—Research is needed on neotropical migratory birds to better understand environmental and habitat conditions affecting population trends. Continued monitoring, as through Breeding Bird Surveys and tracking trends of habitats, would provide useful information.

Other Birds—Studies are needed on effects of fire occurrence, fire suppression, season of burn, and changes of vegetation pattern resulting from burns and fire suppression on ground-nesting birds and their habitats. Other studies are needed on species-specific effects of livestock grazing, changes in distribution and density of nest parasites (brown cowbird), changes in insect populations, and availability of free water. Trends of arid-land raptors may deserve monitoring.

Bats—Basic inventories for presence and distribution are needed particularly for the more rare bat species. Key unknowns and research needs for bats include the effects of ectoparasites, pesticides, and timber removal. It is well known that parasites are present on bats but the effects are not well understood. The same is true for the effects of pesticides. Very little is known or understood regarding the effects of timber removal on bats. It is recognized that some species of bats use snags and other large trees, either the cavities or deep-furrowed bark, for roosting. However, it is not well understood how forest structures and landscape patterns around the snag or tree influences site selection by bats.

Carnivores—Further research is needed on current distribution of forest carnivores (American marten, fisher, lynx, and wolverine) and on their habitat requirements in terms of kinds, amounts, and arrangements of environments at multiple ecological scales and across all geographic regions of the Basin. For the same species, information is needed on the influence of sex, age, and social structure on habitat selection. Information also is needed on how these species respond to human-altered habitats (landscapes). Lastly, we need information on how habitat quality gradients affect dispersal rates, directions, and distances.

Other Mammals—Monitoring the status of populations of carnivores and ungulates (particularly those potentially impacted by livestock grazing activities) would provide use information for evaluating or guiding future activities.

Caveats

Overall, conducting evaluations on a broad geographic scale is difficult when additional, finer-grained information on populations and environments is not available. Because this is the first compilation of information over so vast a set of environments and taxonomic groups in the

Basin, several cautions in using and interpreting the information are in order. These include confidence in the information, inclusion of species, resolution of environmental data, use of expert rule sets, and limitations concerning species models and environmental correlates.

The first caution treated here deals with confidence in the species information. Most of the information compiled for this project did not come from empirical field experiments with controls and adequate sample sizes for statistical analysis; it came from surveys, personal observations from species experts, unpublished data of experts, and ongoing studies. Such information is reliable in that it came from among the best, often the only, local experts. However, because of the dearth of scientific studies on most species, experts often expressed only moderate to low confidence levels in how well species are scientifically understood. Also, as evidenced by the range of confidence scores among experts for given species, experts sometimes disagreed on the level of confidence they placed in scientific knowledge of individual species. Our panel approach attempted to ameliorate such differences by collecting the full array of knowledge among experts rather than by trying to reach consensus on information.

The species information in this study, particularly in the SER database, is imprecise on a local scale because it applies to a wide array of sites and habitats at the broadscale. None of the species considered in this assessment has been studied across the full range of habitats and environmental conditions present throughout the Basin. Of the species studies that are available, none has looked at the full array of key environmental correlates and key ecological functions. Also, few if any species studies rate as replicable, with controls; experimental manipulation; large sample sizes; empirical, validated relations; and peer review with publication in primary scientific journals. We expect that, over time, local information and well-designed studies can substantially improve at a finer resolution much of the broad-scale information we have gathered and broad-scale patterns we have deduced. However, some information, such as range-wide location data on rare plants and range maps of vertebrates, can only be produced at the broadscale.

A second caution is that limits of time and funding and the absence of prior comprehensive analyses of this type meant focusing the work for plants on listed and potentially at-risk species. For invertebrates, it meant describing an important but selected set of ecological functions of species groups and detailing information on only a small sampling of individual species. A fuller knowledge of vertebrates allowed us to address nearly all species. A thorough analysis, beyond the scope of this study, still needs to be done on the entire flora and on a broader invertebrate fauna of the Basin. For example, we have not described diversity and functions of parasitoids and parasites and of the many micropathogens present in the area. Disease and pathogenic effects may be critical factors limiting some plant and animal populations.

Much of the base information we used to gauge historical changes in habitats and species was developed at a broad scale using 1-square-kilometer resolution. This level of resolution is far too broad to identify patch- or site-specific conditions and substrates that are important to describing habitats for most plants and invertebrates. Our work must be seen as an initial step toward more site-specific evaluations.

Essentially, the evaluations of the ecological relations between species and their environment presented in this chapter constitute expert rule sets. They can be further formalized as Bayesian models of species-environment relations by representing them as conditional probabilities, estimating the strength of those probabilities, and predicting potential outcomes in terms of population response. This is one approach to further depicting uncertainties and building a quantitative species model as a prelude to validation.

For example, for species thought to be vulnerable to specific management activities, a simple Bayesian belief network can be described as

P(Sp | KEC1, KEC2, ...), where P = probability of effects, Sp = species response (realized fitness, numerical response, or functional response), and KEC = key environmental correlate (fig. 5.11). KECs can take on various levels, most simply depicted as low (L) or high (H). One testable premise of this approach is that probabilities of levels of KECs are joint; that is, the species responds to the combination of all factors. By formalizing species information as conditional probabilities, specific hypotheses on species effects can be generated and tested through observation or experimental studies in the field.

Additional caveats pertaining to the species-environment relations information gathered for this study include the following. First, species models that should otherwise include a number of environmental correlates tend to "degenerate" into simple community (vegetation cover type and structural stage) models for three major reasons. (1) Many key environmental correlates were not fully quantified or specified for each species. Thus, the GIS models resulting from the SER database information must be considered "first generation" species models built at the wide geographic extent of the Basin. Also, correlates often were a combination of environmental associates and requirements. (2) GIS environmental correlates for species often were specified at a spatial resolution finer than that used in this broad-scale assessment. The current analysis (typically 1-km^2 resolution) lacks the GIS data at finer resolutions necessary to truly determine environments and effects for many sessile or small-bodied species. (3) The models cannot be fully specified at this time because of incomplete scientific knowledge. There is a basic lack of empirical data on species' environmental correlates.

Another reason why some of the key environmental correlates cannot be modeled in GIS at this time includes direction specified in contracts and expert panels to not necessarily tie descriptions of correlates only to available GIS themes and attributes. The purpose was to broaden our understanding of the kinds and levels of resolution of correlates needed to fully describe suitable environments for species, and not to be anchored by available data sets.

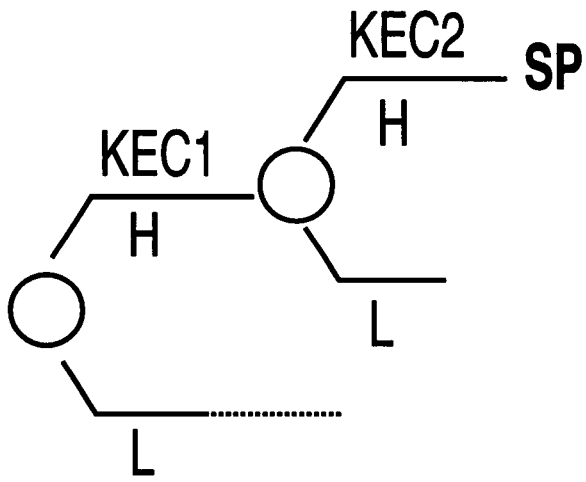
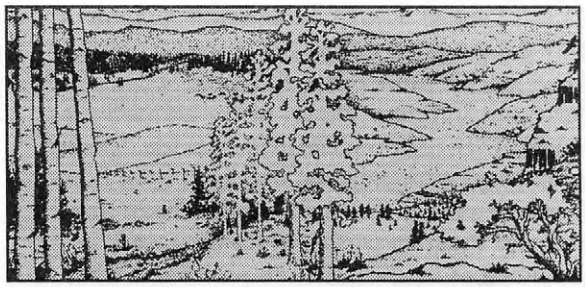


Figure 5.11— Schematic for a Bayesian belief model of species-environment relations. Circles denote potential conditions, such as a key environmental correlate (KEC) occurring with high probability (H) or low probability (L), ultimately affecting the overall likelihood of species presence (SP).

One result of not being able to model in GIS all key environmental correlates of species is that, at least for generalist species, potential habitat was grossly overestimated, particularly considering analyses not involving using the current species' range as a "mask" in the analysis. This is because many such models simplify to estimates of vegetation cover types and structural stages. Such analyses also tended to be insensitive to changes in environmental components represented poorly or not at all in the GIS models, such as snags, down wood, climatic factors, and human density. The solution is to develop more finer-grained GIS data for specific portions or habitats within the Basin, thereby explicitly representing these other unmodeled correlates in the species GIS models.



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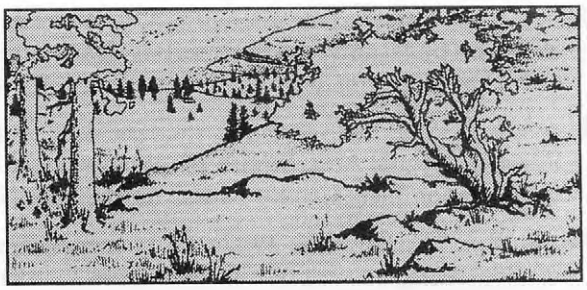
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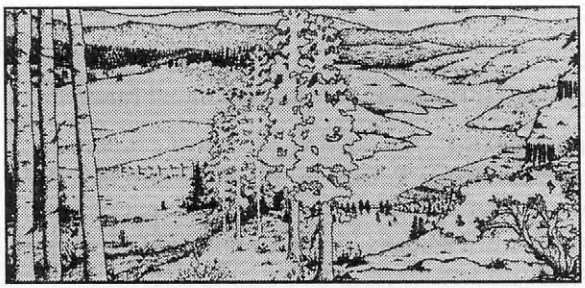
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Whisenant, S.G. 1990. Changing fire frequencies on Idaho's Snake River Plains: ecological and management implications. In: McArthur, E.S.; Romney, R.M.; Smith, S.D.; Tueller, P.T., eds. Proceedings - symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management. Gen. Tech. Rpt. INT-GTR-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 4-10.

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GLOSSARY

detritovory - Ingestion of detritus (dead or decaying organic matter)

disseminule - Seeds, spores, or other fruiting or vegetative parts of plants that serve to distribute species across space.

ecological process - A general description of species interactions, or transmission of substances, nutrients, or energy, throughout an ecosystem. An example is organic matter breakdown within, and incorporation into, soil.

ecological subsystem - A portion of an ecosystem identified by physical substrates and a unique assemblage of species and their ecological functions. An example is the tree canopy subsystem, as part of the terrestrial above-ground environments found within terrestrial forest ecosystems.

ectomycorrhizae - Species of (usually) thread-like fungus that binds onto roots of trees or other plants, that aid in nutrient uptake.

endemism and endemic species - Endemism refers to the condition in which a species is found only within a specific area and nowhere else. Endemic species were classified in the following categories:

locally endemic: Populations are restricted to a very small area (that is, one portion of a mountain range, one canyon, etc.) These taxa may also be restricted to highly specialized habitats. The range may lie entirely within, or on the assessment area boundary.

regionally endemic: Populations inhabit a larger geographic area than that of the local endemics (that is, southeast Oregon, the Palouse etc.) These species may also be closely associated with certain habitats, and their range may lie entirely within, or on the Assessment Area boundary.

peripheral: Populations lie on the margins of the assessment area boundary or in the case of some bird species, completely outside of the Basin. Birds such as the Pacific loon are casual visitors away from the normal species range.

disjunct: Populations in the assessment area are substantially separated geographically from the remainder of the species range.

scattered: Populations are sparsely distributed within the assessment area. In the case of birds this might indicate specialized habitats for wintering, migrating or breeding.

common: Not to be confused with abundance which refers to populations. Populations can be common but not have a large number of individuals. For example, mountain lion populations are probably common within the northwest. However, each population has a relatively small number of individuals. In contrast some species such as the spotted frog in eastern Oregon may have just a few scattered populations with many individuals in each population. The spotted frog would go into the scattered category.

environmental correlate - see key environmental correlate

ecological function - see key ecological function

expert panel - A gathering of scientific experts in species ecology, as used in this analysis to develop the species ecology databases. Expert panels were run for this analysis by the Terrestrial Staff, using a modified Delphi process, for collecting their knowledge and expertise on species ecology, key environmental correlates, key ecological functions, range distributions, and other information.

fitness - see realized fitness

hyphae - (hyphal, adj) - thread - like masses produced by some species of fungi, typically out of sight below ground or within decaying wood

key environmental correlate (KEC) - The set of habitat and other biological and physical attributes of an environment that most influences a given species' realized fitness (requirements) or that associate with species occurrences (associates). KECs include vegetation cover types (such as lodgepole pine forest), structural stages (such as open canopy stand), substrates (such as down wood), and other environmental factors not traditionally included in descriptions of species habitats (such as hunting pressure, proximity to urban areas, air quality, and trophic interactions with other species). Also see potentially suitable environment.

key ecological function (KEF) - The primary set of activities performed by organisms that affect the ecological function of their ecosystem. An example is decomposition of byproducts of decaying organic material (such as by the invertebrate *Argilophilus hammodi*), or creation of burrows (such as by American badger *Taxidea taxus*) that can be occupied by secondary burrow-users (such as longnose leopard lizard *Gambelia wislizenii*).

population viability - The likelihood of continued existence of a well-distributed population or species to a specified time period. For this analysis, the time period is 100 years. For example, high viability is a high likelihood of continued existence of well-distributed populations for a long time period (a century or longer).

population viability analysis (PVA) and population viability assessment or evaluation - The spatially-explicit, quantitative analysis and simulation modeling of a population and its environmental conditions over time under one or more management scenarios, typically to determine the likelihood of persistence of the population. Population viability is influenced by demographic, genetic, and environmental factors. When such factors are explicitly quantified and modeled, a true quantitative (sometimes called "hard-core") PVA is said to be conducted. When such factors are not quantified, such as by modeling only potentially suitable environments of a species over space and time, then population viability is only inferred. In this case, a "softer" population viability assessment or evaluation is said to be conducted.

potentially suitable environment - The full set of key environmental correlates (associates or requirements) for an individual species or species group. In this analysis, potentially suitable environments are mapped and their total area and spatial patterns are assessed, as one indicator of potential effects on population viability.

realized fitness - The vitality of offspring of animals or propagules of plants under actual conditions in the field. When a population is viable, it is at least able to replace itself, and the realized fitness of its individuals allow for continued reproduction over time.

saprophyte - An organism, including plants usually lacking chlorophyll, that lives off other decaying or dead plants.

symbiont - A species of plant or animal that lives closely associated (sometimes necessarily so) with another species.

APPENDIX 5A

Disposition of species groups in the terrestrial ecology staff database. (Many other species were additionally treated through contract reports, see appendix 5B for list.)

Species group	Individual species or species groups included in the Terrestrial Species-Environment Relations (SER) database
fungi	rare species are treated individually, as identified by Mike Castellano
lichens	functional groups of species, as identified by Roger Rosentreter
bryophytes	functional groups of species, as identified by John Christy
vascular plants	C1 and C2 candidate species treated individually; selected others by species lists or communities, as identified by expert panels, in contract reports, and the plant task group's leader, Lisa Croft, and staff
soil bacteria	general functional species groups, as identified in contract reports by Ingham (1995) and Muehlchen (1994)
soil protozoa	general functional species groups, as identified in contract report by Ingham (1995)
soil nematodes	general functional species groups, as identified in contract report by Ingham (1995)
soil rotifers	general functional species groups, as identified in contract report by Ingham (1995)
other invertebrates (arthropods)	single species as representatives of functional groups of species, as identified by contract reports and expert panels
vertebrates	all single species addressed

APPENDIX 5B

List of contract and internal reports provided for this assessment.[1]

Brainerd, Richard; Zika, Peter; Newhouse, Bruce [and others]. 1995. Biogeography of the Genus *Carex* in the Columbia River Basin and neighboring lands. A report to the U.S. Forest Service, Eastside Ecosystem Management Project; contract report; contract 43-0E00-5-5042. 58 p. + appendices.

Bunting, S.C.; Peters, E.F. 1994. Impact of fire management on rangelands of the intermountain west. Moscow ID: University of Idaho, Department of Range Resources. contract report; contract 43-0E00-4-9113. 24 p. + tables.

Burkhardt, J.W. 1994. Herbivory in the Intermountain West: an overview of evolutionary history, historic cultural impacts and lessons from the past. Indian Valley, ID. 49 p.

Burkhardt, J. Wayne. 1994. Paleoecological relationships of prehistoric *Equus* in the Intermountain West: An overview with implications for management of wild horses and burros. contract report; contract 43-0E00-4-9137. 49 p.

Castellano, Michael A. 1995. Report on Fungi. 75 p.

Christensen, Alan G.; Lyon, L. Jack; Pedersen, Richard [and others]. 1995. Ungulate assessment in the Columbia River Basin. 121 p.

Christy, J.A.; Harpel, J.S. 1995. Bryophytes of the Columbia River Basin (Draft). [Portland, OR]: Oregon Natural Heritage Program. contract report; contract 43-0E00-5-5358. 26 p. + appendices.

Clark, P.E. 1994. Livestock-big game interactions: a selected review with emphasis on literature from the interior Pacific Northwest. Corvallis, OR: Oregon State University, Department of Rangeland Resources. contract report; contract 43-0E00-4-9156. 94 p.

Diedrich, J.; Evenden, A.; Greene, S.; Harmon, D.; Petersen, M.; Sater, S. No date (1994). The role of natural areas in the Columbia River Basin assessment and planning. U.S. Department of Agriculture, Forest Service. 8 p. + table.

Eddleman, L.E.; Miller, R.F.; Miller, P.M.; Dysart, P.L. 1994. Western juniper woodlands (of the Pacific Northwest): science assessment. Corvallis, OR: Oregon State University, Department of Rangeland Resources. contract report; contract 43-0E00-4-9121. 131 p.

Eversman, S. [1995]. Lichens of the Yellowstone Ecosystem. Prepared for the East Side Project, Columbia River Basin Ecosystem Management Plan. Bozeman, MT: Montana State University. contract report; contract 43-0E00-4-9195. 93 p.

Fogel, R. [1994]. Fungi from the Columbia Basin deposited in the University of Michigan Herbarium (MICH). Ann Arbor, MI: University of Michigan Herbarium. contract report; contract 43-0E0-4-9227. 21 p. + appendices.

Frest, T.J.; Johannes, E.J. 1995. Interior Columbia Basin mollusk species of special concern. Prepared for: Interior Columbia Basin Ecosystem Management Project. Seattle, WA: Deixis. contract report; contract 43-0E00-4-9112. 274 p. + tables.

[1]Material on file: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar, Walla Walla, WA 99362.

Hammer, S. 1995. The biogeography and ecology of species in the lichen genus *Cladonia* in the Columbia River Basin. Boston, MA: Boston University. contract report; contract 43-0E00-5-5100. 72 p.

Hammond, P.C. 1995. Butterflies and their larval foodplants as bioindicators for ecosystem monitoring in the Pacific Northwest. contract report; contract 43-0E00-4-9206. 36 p.

Hammond, P.C. 1994. Rare butterfly assessment for the Columbia River Basin in the Pacific Northwest. 13 p. + figs.

Harrison, R.D. [and others]. [1994]. Introduced forage grasses. Eastside Ecosystem Management Project. Logan, UT: U.S. Department of Agriculture, Forest Service. 74 p.

Ingham, E.R. 1995. Soil organisms: bacteria, fungi, protozoa, nematodes, and rotifers. Corvallis, OR: Oregon State University. contract report; contract 43-0E00-4-9225. 93 p.

James, S. 1995. Report on Columbia Basin Oligochaeta. Fairfield, IA: Maharishi International University, Department of Biology. contract report; contract 43-0E00-4-9267. 18 p. + tables.

Johnson, James B. 1995. Parasitoids of the Columbia River Basin. Contract Report # 43-0E00-4-9222. [not paginated].

Johnson, James B. 1995. Lacewings (Insecta:Neuropter) of the Columbia River Basin. Contract Report # 43-0E00-4-9222. 16 p.

Kaltenecker, J.; Wicklow-Howard, M. 1994. Microbiotic soil crusts in sagebrush habitats of southern Idaho. Prepared for: Eastside Ecosystem Management Project. Boise, ID: Boise State University. 48 p. + appendices.

Kemp, W.P. 1994. Rangeland grasshoppers (Orthoptera: Acrididae) of concern to management of the Columbia River Basin. Bozeman, MT: USDA/ARS Rangeland Insect Laboratory. contract report; contract 43-0E00-4-9249. 21 p. + appendices.

Kindschy, R.R. 1994. Part two: crested wheatgrass in the ecosystem. Vale, OR. contract report; contract 43-0E00-4-9182. 36 p.

Kindschy, R.R. 1994. Part one: riparian restoration and management. Vale, OR. contract report; contract 43-0E00-4-9168. 54 p. + illus.

LaBonte, J.R. 1995. Possible threatened or endangered terrestrial predaceous Coleoptera of the Columbia River Basin. Addendum to "Terrestrial Predaceous Beetles (Coleoptera) of the Columbia River Basin." Corvallis, OR. contract report; contract 43-0E00-5-5353. 31 p.

Lattin, J.D. [1995]. The Hemiptera:Heteroptera of the Columbia River Basin, western United States. Corvallis, OR. contract report; contract 43-0E00-4-9221. 57 p. + tables.

Marsh, J. [1994]. Notes on ecological assessment of lichens of the Columbia Basin of Oregon and Washington. Report submitted by Dr. Bruce Ryan. (Peer review of Ryan 1994). Tempe, AZ: Arizona State University. 2 p. + appendices.

Martin, Sandra K.; Witmer, Gary; Sayler, Rodney D. 1995. Carnivore Conservation in the Interior Columbia River Basin. Issues and Environmental Correlates. 64 p. + tables.

McCune, B. 1994. Lichen species groups in the Columbia Basin: ecosystem functions and indicator values. Corvallis, OR: Oregon State University. contract report; contract 43-0E00-4-9258. 29 p. + tables.

McIver, J.; LaBonte, J.R.; Crawford, R. 1994. Terrestrial invertebrate predators of the Columbia River Basin: an assessment. La Grande, OR: Blue Mountains Natural Resources Institute. contract report; contract 43-0E00-4-9253. 71 p.

McMahan, L.R.; Guerrant, E.O., Jr. 1995. Ex-situ conservation. The Berry Botanic Garden. contract report; contract 43-0E00-5-5230. 23 p.

McNeil, D.W. [1995]. Report on *Allium*: Columbia Basin Scientific Assessment Project. Stockton, CA: University of the Pacific. contract report; contract 43-0E00-5-5062. 21 p. + appendices.

Meinke, R.J. 1995. Assessment of the genus *Mimulus* within the Interior Columbia River Basin of Oregon and Washington. Corvallis, OR: Oregon State University. contract report; contract 43-0E00-5-5073. 106 p.

Meinke, R.J. 1995. Assessment of the genus *Penstemon* within the Interior Columbia River Basin of Oregon and Washington. Corvallis, OR: Oregon State University. contract report; contract 43-0E00-5-5073. 110 p.

Miller, J.C. 1994. Assessment of invertebrates of the Columbia River Basin: understory herbivores (Lepidoptera). Corvallis, OR: Oregon State University. contract report; contract 43-0E00-4-9205. 41 p.

Miller, O.K., Jr; Miller, H.H.; Cripps, C. 1994. Checklist of Columbia Basin fungi. Blacksburg, VA: Virginia Polytechnic Institute and State University. contract report; contract 43-0E00-4-9246. 81 p.

Miller, S.L. 1994. Report on macrofungi of the Columbia River Basin. Laramie, WY: University of Wyoming. contract report; contract 43-0E00-4-9252. 150 p.

Moser, John C. 1994. Mites associated with forest insects. contract report; contract 43-0E00-4-9278. [irregular pagination].

Muehlchen, A.M. 1994. Eastside ecosystem management project: functional groups of bacteria. Philomath, OR. contract report; contract 43-0E00-4-9169. 47 p.

Newhouse, Bruce; Brainerd, Richard; Kuykendall, Keli [and others]. 1995. Ecology of the Genus *Carex* in the Eastside Ecosystem Management Project Area. Contract Report # 43-0E00-4-5036. 63 p. + appendices.

Pagel, J.E. [1995]. American peregrine falcon (*Falco peregrinus anatum*) status of species - Columbia River Basin. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region 6. 20 p. + attachment.

Rasmussen, C. 1994. Riparian community and bank response to management: a comparison of old and new surveys in the Prineville District, Bureau of Land Management. Corvallis, OR: Oregon State University, Department of Rangeland Resources. contract report; contract 43-0E00-4-9120. 32 p. + illustrations.

Ross, D.W. 1995. Report on bole and branch herbivores. Corvallis, OR: Oregon State University. contract report; contract 43-0E00-4-9224. 78 p. + maps.

Ryan, Bruce. 1994. East side lichen report for Washington and Oregon. contract report; contract 43-0E00-4-9226. [irregular pagination].

Saab, Victoria A.; Rich, Terrell D. 1996. Large-scale conservation assessment for neotropical migratory landbirds in the Interior Columbia River Basin. 94 p.

Schowalter, T.D. 1994. Coarse woody debris chewers in the Columbia River Basin: a report to the U.S. Forest Service Eastside Ecosystems Management Strategy Project. Corvallis, OR: Oregon State University. contract report; contract 43-0E00-4-9223. 12 p. + appendices.

Sheley, R.L. 1994. The identification, distribution, impacts, biology and management of noxious rangeland weeds. Bozeman, MT: Montana State University. contract report; contract 43-0E00-4-9150. 366 p.

Tepedino, V.J.; Griswold, T.L. [1995]. The bees of the Columbia Basin. Logan, UT: Utah State University. contract report; contract 43-0E00-4-9124. 10 p. + appendices.

Vogel, C.A.; Reese, K.P. 1995. Draft: Mountain quail status report: a document preliminary to a habitat conservation assessment for mountain quail. Moscow, ID: University of Idaho. 33 p. + appendices.

Wagner, M.R.; McMillin, J.D. [1994]. Eastside ecosystem assessment project: role of canopy herbivores. contract report; contract 43-0E00-4-9204. 194 p.

Weber, N.S. 1995. Report on the Pezizales (Eumycota, Ascomycotina) of the portion of the Columbia River Basin in the United States. Corvallis, OR: Oregon State University, Department of Forest Science. contract report; contract 43-0E00-4-9275. 107 p.

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Wicklow-Howard, M.C. 1994. Vesicular-arbuscular mycorrhizae from sagebrush steppe habitat in western Idaho and parts of eastern and central Oregon. Prepared for: Eastside Ecosystem Management Project. Boise, ID: Boise State University. 36 p. + appendices.

Wicklow-Howard, M.C.; Kaltenecker, J. 1994. Fungi from the Owyhee Region of southern Idaho and eastern Oregon. Prepared for: Eastside Ecosystem Management Project. Boise, ID: Boise State University. contract report; contract 43-0E00-4-9220. 76 p.

Williams, J.D. 1994. Microbiotic crusts: a review (final draft). Logan, UT. contract report; contract 43-0E00-4-9141. 56 p.

Zika, P.F.; Brainerd, R.; Newhouse, B. 1995. Grapeferns and moonworts (Botrychium, Ophioglossaceae) in the Columbia Basin. A report submitted to the Eastside Ecosystem Management Project. contract report; contract 43-0E00-5-5051. 116 p.

APPENDIX 5C

Lists of experts consulted for information on species ecology. Also see Acknowledgments for additional names, and appendix 5B for author names on contract reports and other submitted reports for this assessment.

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APPENDIX 5D

Taxa with five or fewer occurrences in the study area, categorized by endemic status, phytogeographical affinities, documented rarity or problem status. Taxa with more than 5 occurrences were included if they were well documented as rare. There is overlap in some categories depending on the taxon.

1. ENDEMIC TAXA

A. Western North America

These taxa are confined to the area in or west of the Rocky Mountains (Schofield 1984). Taxa with narrower endemism within the study area are listed separately in Sections B, C, and D.

Liverworts:
Frullania franciscana
Porella bolanderi
Riccia trichocarpa
Sphaerocarpos hians

Hornworts:
Phaeoceros hallii

Mosses:
Amphidium californicum
Anacolia menziesii var. baueri
Brachythecium bolanderi
Brachythecium holzingeri
Bryum calobryoides
Bryum gemmascens
Bryum meesioides Dendroalsia abietina
Dichodontium olympicum
Dicranum rhabdocarpum
Encalypta intermedia
Fissidens ventricosus
Homalothecium arenarium
Isothecium cristatum
Orthotrichum bolanderi
Orthotrichum praemorsum Pohlia bolanderi
Pohlia bolanderi var. *seriata*
Pohlia tundrae
Porotrichum vancouveriense
Pseudoleskea atricha
Pseudoleskea incurvata var. gigantea
Pseudoleskea radicosa var. denudata
Racomitrium brevipes
Racomitrium depressum
Racomitrium obesum
Racomitrium varium
Schistidium cinclidodonteum
Tripterocladium leucocladulum

B. Endemic to Northern or Central Rocky Mountains

Mosses:
Pseudoleskea incruvata var. *tenuiretis*
Pseudoleskea radicosa var. *pallida*

C. Endemic to Dry Intermountain Region ("Dry Interior")

Mosses:
Orthotrichum hallii
Orthotrichum holzingeri
Pseudocrossidium obtusulum
Pottia nevadensis

D. Endemic to interior Columbia River Basin

Mosses:
Bryoerythrophyllum columbianum
Grimmia brittoniae

2. MEDITERRANEAN CLIMATE IN WESTERN NORTH AMERICA

These taxa are confined to winter wet-summer dry climatic areas of the world (Schofield 1980, 1994). Those marked with an asterisk (*) are endemic to western North America as listed in Section 1.

Hornworts:
Phaeoceros hallii *

Liverworts:
Douinia ovata
Frullania franciscana *
Lunularia cruciata (a greenhouse weed in the interior Columbia River Basin)

Mosses:
Amphidium californicum *
Porotrichum vancouveriense
Claopodium whippleanum
Crumia latifolia
Dendroalsia abietina *
Desmatodon obtusifolius
Ditrichum ambiguum
Entosthodon fascicularis
Fissidens ventricosus *
Homalothecium arenarium *
Isothecium cristatum *
Racomitrium varium *
Timmiella crassinervis
Tortula laevipila
Tortula subulata

3. EASTERN NORTH AMERICA

These taxa are widespread east of the Rocky Mountains, and many have a circumpolar distribution. They occur mostly along the eastern edge of the Columbia River basin, at the western edge of their range (Schofield 1980).

Liverworts:

Blepharostoma trichophyllum ssp. *brevirete*
Calypogeia fissa ssp. *neogaea*
Calypogeia integristipula
Lophocolea bidentata
Pedinophyllum interruptum
Porella platyphylloidea

Mosses:

Amblystegium varium
Atrichum angustatum
Atrichum crispum
Barbula unguiculata
Brachythecium campestre
Brachythecium digastrum
Brachythecium oxycladon
Brachythecium populeum
Callicladium haldanianum
Campylium hispidulum
Climacium americanum
Cyrto-hypnum minutulum
Dicranella schreberiana var. *robusta*
Dicranum montanum
Dicranum viride
Herzogiella turfacea
Hygroamblystegium noterophilum
Hygroamblystegium tenax
Hypum imponens
Orthotrichum pumilum
Paraleucobryum longifolium
Philonotis fontana var. *caespitosa*
Philonotis muehlenbergii
Physcomitrium hookeri
Plagiomnium ciliare
Plagiomnium cuspidatum
Platygyrium repens
Pohlia elongata
Pohlia longicolla
Thuidium delicatulum
Tortella humilis
Tortula papillosa

4. Southern Arid Affinities

Taxa of more arid austral climates (Schofield 1980).

Liverworts:

Fossombronia longiseta
Mannia fragrans
Sphaerocarpos texanus

Mosses:

Brachythecium fendleri
Desmatodon plinthobius
Grimmia plagiopodia
Grimmia poecilostoma
Jaffueliobryum raui
Mnium arizonicum
Orthotrichum flowersii
Physcomitrium pygmaeum
Tortula bartramii

5. Circumpolar

Taxa with continuous arctic, boreal, or north temperate distributions, excluding those cited for eastern North America in Section 3. This list also excludes taxa with discontinuous distributions, which are cited in Section 6.

Liverworts:

Anthelia juratzkana
Apometzgeria pubescens
Asterella gracilis
Asterella lindenbergiana
Asterella saccata
Barbilophozia attenuata
Barbilophozia floerkei
Barbilophozia kunzeana
Barbilophozia quadriloba var. *quadriloba*
Bazzania tricrenata
Calypogeia neesiana
Calypogeia sphagnicola
Cephalozia catenulata
Cephalozia connivens
Cephaloziella elachista
Fossombronia foveolata
Gymnocolea inflata
Harpanthus flotovianus
Hygrobiella laxifolia
Jungermannia evansii
Jungermannia hyalina
Jungermannia obovata

Lophozia badensis
Lophozia latifolia
Lophozia opacifolia
Marsupella sphacelata
Marsupella ustulata
Metzgeria conjugata
Moerckia blyttii
Nardia breidleri
Nardia compressa
Nardia geoscyphus
Nardia scalaris
Pleuroclada albescens
Ptilidium ciliare
Riccardia chamedryfolia
Riccia cavernosa
Riccia fluitans
Riccia frostii
Riccia glauca
Scapania cuspiduligera var. *cuspiduligera*
Scapania paludicola
Tritomaria polita
Tritomaria quinquedentata var. *quinquedentata*

Mosses:
Aloina brevirostris
Amblyodon dealbatus
Arctoa fulvella
Brachythecium reflexum
Brachythecium turgidum
Bryum arcticum
Bryum calophyllum
Bryum cyclophyllum
Bryum pallens
Bryum schleicheri
Calliergon richardsonii
Calliergon trifarium
Campylium halleri
Campylium hispidulum
Campylium stellatum var. *protensum*
Catoscopium nigritum
Cirriphyllum cirrosum
Conostomum tetragonum
Desmatodon cernuus
Desmatodon leucostoma
Desmatodon systylium
Dicranella heteromalla

Dicranella palustris
Dicranella rufescens
Dicranella schreberiana
Dicranum acutifolium
Dicranum elongatum
Dicranum fragilifolium
Dicranum majus
Dicranum spadiceum
Didymodon asperifolius
Didymodon rigidulus var. *icmadophilus*
Didymodon tophaceus
Drepanocladus aduncus var. *polycarpus*
Drepanocladus fluitans
Eucladium verticillatum
Fissidens fontanus
Fissidens grandifrons
Fontinalis antipyretica var. *gigantea*
Grimmia trichophylla
Hypnum bambergeri
Hypnum pallescens
Hypnum pratense
Hypnum recurvatum
Hypnum vaucheri
Limprichtia revolvens
Meesia longiseta
Meesia triquetra
Meesia uliginosa
Myurella julacea
Myurella tenerrima
Orthothecium chryseum
Orthotrichum pylaisii
Orthotrichum speciosum
Oxystegus tenuirostris
Paludella squarrosa
Palustriella decipiens
Philonotis marchica
Plagiobryum demissum
Plagiobryum zieri
Plagiomnium drummondii
Plagiopus oederiana
Plagiothecium cavifolium
Platyhypnidium riparioides
Pogonatum dentatum
Pohlia atropurpurea
Pohlia bolanderi var. *seriata*
Pohlia filum

Pohlia ludwigii
Polytrichum commune var. *jensenii*
Polytrichum commune var. *perigoniale*
Polytrichum norvegicum
Pylaisiella polyantha
Racomitrium affine
Racomitrium fasciculare
Racomitrium lanuginosum
Rhytidium rugosum
Seligeria donniana
Scorpidium scorpioides
Sphagnum compactum
Sphagnum contortum
Sphagnum jensenii
Sphagnum platyphyllum
Sphagnum riparium
Sphagnum rubellum
Splachnum ampullaceum
Stegonia latifolia
Tayloria ligulata
Tayloria serrata
Tayloria splachnoides
Thuidium recognitum
Tortella arctica
Tortella tortelloides
Tortula muralis

6. Disjunct Distributions

These taxa represent disjunct elements found in Western North America, artifacts of discontinuous distribution patterns (Schofield 1969).

A. Bipolar

These taxa occur disjunctively at middle to high latitudes in both hemispheres and are absent in between.

Mosses:
Polytrichum formosum
Sphagnum palustre
Sphagnum subnitens

B. North Pacific

These taxa are distributed around the rim of the North Pacific Ocean, between north western North America and Japan. Some of the taxa extend inland to the Rocky Mountains (Schofield 1980).

Liverworts:
Blepharostoma arachnoideum
Frullania tamarisci ssp. *nisquallensis*
Radula bolanderi
Scapania bolanderi

Mosses:
Hypnum dieckii
Oligotrichum aligerum
Oligotrichum parallelum
Pogonatum contortum
Polytrichum sphaerothecium
Racomitrium muticum
Rhizomnium nudum

C. Humid Interior ("Maritime Extension", "Coastal Disjuncts")

These taxa are widely distributed west of the Cascade Mountains, and reappear in the Rocky Mountains. (Schofield 1976) Taxa with an asterisk (*) are endemic to Western North America, as listed in Section 1.

Mosses:
Dichodontium olympicum *
Ditrichum heteromallum
Hookeria lucens
Pseudotaxiphyllum elegans
Racomitrium brevipes *
Schistostega pennata
Tetraphis geniculata

D. Western North America and Western Europe

These taxa are mostly oceanic in distribution, with some occurring in alpine areas (Schofield 1969).

Mosses:
Bryum canariense
Bryum violaceum
Encalypta spathulata
Fabronia pusilla
Funaria muhlenbergii
Hygrohypnum alpinum
Hygrohypnum styriacum
Orthotrichum pulchellum
Orthotrichum striatum
Paraleucobryum enerve
Philonotis yezoana
Plagiothecium undulatum
Pottia lanceolata
Scleropodium cespitans
Tortula latifolia

E. Western North America and Eastern North America

Liverworts:
Diplophyllum obtusifolium

Mosses:
Buxbaumia aphylla
Heterocladium macounii
Neckera pennata
Pleuridium subulatum
Pohlia andalusica
Pohlia erecta
Tortella inclinata

F. Broken Circumpolar

These taxa occur in alpine areas within the Northern Hemisphere, but are absent from the arctic regions.

Liverworts:
Diplophylum albicans (suboceanic)

Mosses:
Andreaea nivalis
Buxbaumia aphylla
Campylopus fragilis
Crumia latifolia
Ditrichum ambiguum
Ditrichum pusillum
Encalypta affinis var. *macounii*
Hygrohypnum duriusclum
Hygrohypnum cochlearifolium
Hypnum procerrimum
Leskea polycarpa
Leskella nervosa
Pterogonium gracile
Schistidium pulvinatum
Schistidium tenerum
G. Circumalpine

Liverworts:
Anthelia julacea
Cephalozia leucantha
Gymnomitrion concinnatum
Gymnomitrion obtusum
Marsupella brevissima

Mosses:
Grimmia mollis
Oligotrichum hercynicum

7. Taxa Cited in the Literature as Rare in

North America

Hepaticae:
Blepharostoma arachnoideum (Schofield 1969)
Cephalozia lacinulata (Schuster 1974)
Pedinophyllum interruptum (Schuster 1980)
Scapania apiculata (Schuster 1974)
Scapania gymnostomophila (Godfrey 1977)

Mosses:

Brachythecium bolanderi (Lawton 1965)
Bruchia bolanderi (Rushing 1986)
Bryum gemmilucens (Spence 1988)
Calliergon trifarium (Crum and Anderson 1981)
Didymodon vinealis var. *nicholsonii* (McIntosh 1986)
Encalypta spathulata (Horton 1983)
Entosthodon fascicularis (Lawton 1971)
Grimmia brittoniae (Herman 1969)
Grimmia incurva (Crum and Anderson (1981)
Grimmia plagiopodia (Crum and Anderson 1981)
Hamatocaulis vernicosus (Lawton 1971)
Hygrohypnum cochlearifolium (Grout 1931)
Orthotrichum flowersii (Vitt 1973)
Orthotrichum holzingeri (Vitt 1991)
Pohlia andalusica (Shaw 1982)
Pohlia ludwigii (Shaw 1982)
Polytrichum sphaerothecium (Christy 1980)
Pottia lanceolata (Lawton 1971)
Pottia nevadensis (Lawton 1971)
Pseudocalliergon turgescens (Crum and Anderson 1981)
Pseudoleskea saviana (Lawton 1971)
Racomitrium aquaticum (Schofield 1976)
Splachnum sphaericum (Crum and Anderson 1981)
Tayloria acuminata (Crum and Anderson 1981)
Timmia norvegica (Crum and Anderson 1981)

8. PROBLEM TAXA

A. Species Concept Poorly Known

Liverworts and Hornworts:

Anthoceros fusiformis

Poorly segregated from *A. punctatus* (Frye and Clark 1947). Widespread and common in western Oregon. (Sanborn 1929). *Aspiromitus* (syn. *Anthoceros*) is a good species but Schuster (1992) does not give range information.

Lophozia wenzelii

"Much confused with other species, thus the range is poorly known". In western North America reported from Alaska and the Yukon. (Schuster 1969)

Mosses:

Atrichum hausknechtii

"Paroicous specimens of western North America, Japan and Europe can be put into *Atrichum undulatum* var. *gracilisetum*" (Crum and Anderson 1981). May be rare in North America, need to determine the chromosome number for this species (Noguchi and Osada 1960)

Brachythecium reflexum var. *pacificum*

Lawton (1971) stated that *B. reflexum* is rare in the western US, and called this species *B. reflexum* var. *pacificum*. According to Crum and Anderson (1981), this variety probably belongs to *B. reflexum*.

Bryum uliginosum

"A poorly known species". (Spence 1988)

Fissidens hallianus

Crum and Anderson (1981) did not feel that this taxon is genetically distinct from *Fissidens fontanus*.

Fissidens taxifolius

This is an eastern species. Most western material was referred by Pursell (1976) to *Fissidens aphelotaxifolius*.

Funaria americana

"Of scattered occurrence in the continental interior, especially in the prairie states." Lawton's wider range may be attributed to nomenclature confusion with *F. muhlenbergii* (Crum and Anderson 1981).

Gymnostomum calcareum

Zander (1977) combined this taxon with *G. aeruginosum*, but it is still recognized by Anderson and others (1990).

Orthotrichum palousense

There is no record of this species in Vitt (1973). Iit is probably an unpublished herbarium name.

Rhytidadelphus subpinnatus

This taxon was placed in *R. squarrosus* by Anderson and others (1990). Some feel that it is a valid species (Koponen 1971, 1975).

Sphagnum recurvum

"The complete range is somewhat uncertain owing to a confusion of taxonomic concepts" (Crum 1984).

B. Taxa Needing Verification, And If Correct Would Represent A Significant Range Extension:

Liverworts:

Barbilophozia atlantica

A high elevation taxon in New England, Great Lakes and in the Hudson Bay area (Schuster 1969). Unlikely in the Columbia River Basin (Personal communication. 1995. W.B. Schofield).

Cephalozia bicuspidata var. *ambigua*

An arctic-alpine species, the American distributions are poorly known. In Alaska and in a few high latitudes eastern locations (Schuster 1974).

Cephalozia bicuspidata var. *lammersiana*
Poorly known in North America, Schuster (1974) is skeptical of the reports from western North America.

Cephalozia loitlesbergeri
Found in southern and middle California, disjunct in Texas, Oklahoma, Kansas, Arkansas, and Louisiana (Schuster 1992).

Jungermannia gracillima
A holoarctic taxon restricted to the eastern half of the North American continent (Schuster 1974).

Jungermannia polaris
Generally a rather rare and sporadic taxon with an arctic-alpine distribution, known from alpine British Columbia sites and doubtful from Alberta (Schuster 1969). Doubtful in the Columbia River Basin (Personal communication. 1995. W.B. Schofield).

Odontoschisma sphagni
Rare and very localized in eastern North America with prior taxonomic problems (Schuster 1974). Poorly documented in Western North America (Personal communication. 1995. W.B. Schofield).

Riccia campbelliana
A northern taxon restricted in range in eastern North America, so unknown from the west (Schuster 1974).

Mosses:

Anomodon viticulosus
An eastern species (Crum and Anderson 1981).

Bartramia stricta
Probably based on an unusual morph of *B. ithyphylla* (Personal communication. 1995. W.B. Schofield).

Brachythecium calcareum
An endemic eastern North American taxon with disjuncts in Alaska, British Columbia and the Yukon Territory (Ireland 1982).

Campylopus schimperi
Mostly in northern sections of eastern North America. The only western records are from Alaska, the Yukon, and the Queen Charlotte Islands (Crum and Anderson 1981).

Cynodontium polycarpon
"May not even occur on this continent. We have seen only one North American collection correctly named... from the Lake Superior region (Crum and Anderson 1981).

Dicranum angustum
A circumpolar, subalpine-alpine taxon from Alaska and northern North America only (Persson and Holme 1961, Persson 1952).

Didymodon fallax var. *reflexus*
A circumtemperate taxon, rare in British Columbia (McIntosh 1986).

Drepanocladus brevifolius
An arctic-alpine taxon from the Rocky Mountains of Alberta; also Alaska and Greenland (Lawton 1971).

Grimmia pulvinata var. *africana*
This species "is extracted from *Grimmia orbicularis, Grimmia decipiens,* includes *Grimmia leibergii*" (Sayre 1952).

Grimmia unicolor

An eastern taxon, "records from British Columbia and Washington are presumed to be incorrect" (Crum and Anderson 1981).

Orthotrichum sordidum

Very common in the east and disjunct in Alaska (Vitt 1973).

Pottia crinita

A maritime European taxon found on moist banks (Smith 1978). On sea coasts, on rocks and banks in England (Dixon 1954).

Pottia intermedia

William's (1966) reported the first North American location as Ontario, Canada. Zander (1993) combined this into *Tortula intermedia*. It is often confused with other *Pottias*.

Ptychomitrium polyphyllum

Rare, more common in western most Norway and eastern Europe and Macaronesia, no North American sites listed (Nyholm 1960). Not listed by Anderson and others (1990).

Rhodobryum ontariense

Sporadic from Newfoundland to Alberta, south to North Carolina (Ireland 1982). This is the eastern species of *Rhodobryum*, while the *R. roseum* is found in the west, but rarely west of the Rocky Mountain (Personal communication. 1995. W.B. Schofield).

Rhodobryum roseum

Crum and Anderson (1981) considered the differences between *R. ontariense* and *R. roseum* "trivial and troublesome," and because the ranges overlap they use *R. roseum* for their plants. It is found in Alberta, Alaska and British Columbia. Schofield (Personal communication. 1995) feels that this is the western taxon.

Schistidium maritimum

A maritime taxon found along both coastal eastern and western North America (Crum and Anderson 1981).

Sphagnum fallax

This species Is apparently completely absent from the northern Rocky Mountains (Andrus and Layser 1976).

Sphagnum lescurii

An Amphiatlantic, eastern North American taxon with unclear distribution details due to the similarity between this and other related species (Andrus 1980). Crum (1984) put this species into *Sphagnum subsecundum* var. *rufescens*.

Sphagnum tenellum

An eastern taxon that also occurs in southeast Alaska and British Columbia (Crum 1984). Andrus (1980) gave the western distribution as along the Pacific Coast from Alaska to Vancouver Island, British Columbia.

Thamnobryum alleghaniense

An eastern taxon (Crum and Anderson 1981).

Timmiella anomala

A southwestern US taxon. Rrecords from Washington and British Columbia "appear to be *Timmiella crassinervis*" (Crum and Anderson 1981).

Tortula laevipila

An epiphytic taxon, Foster's Wallula collection is not very likely. The locations within the Columbia River Gorge region are probably correctly identified.

Ulota phyllantha

A maritime taxon found along both coastal eastern and western North America (Crum and Anderson 1981).

C. Taxa That Are No Longer Valid, Or Are Probably Misidentified:

Mosses:

Brachythecium acutum

Excluded from North America (Crum and Anderson 1981).

Brachythecium erythrorrhizon var. *thedenii*

Excluded from North America (Crum and Anderson 1981).

Brachythecium glareosum

Not considered a rare taxon in the assessment area, because there are 12 records. Excluded from North America (Anderson and others 1990).

Cynodontium gracilescens

Excluded from North America (Crum and Anderson 1981).

Distichium capillaceum var. *compactum*

Excluded from North America (Anderson and others 1990).

Hygrohypnum obtusifolium

This is probably a typographical error, and the name does not exist in the literature. It is probably *Scleropodium obtusifolium.*

Macrocoma sullivantii

Dale Vitt (Personal communication. 1995.) noted that this species of the southeastern United States was reported from Wyoming in error, resulting from a mix-up in specimen label data. The collection noted in error was actually *Orthotrichum rupestre.*

Plagiomnium affine

Excluded from North America (Anderson and others 1990).

Pohlia rothii var. *compacta*

Placed into *Pohlia andalusica* (Shaw 1981).

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APPENDIX 5E

Neotropical migratory landbirds in the Columbia River Basin for which Breeding Bird Survey sample size is sufficient (recorded on ≥14 routes) to quantify significant long-term declines or increases in population trends, over 10-year and 26-year periods. Numbers in table are percent changes of populations over the time periods shown.

		Decline		Increase	
Species	**Nest Layer[1]**	**26 yr**	**10 yr**	**26 yr**	**10 yr**
		percent change in population			
Osprey	CA				6.4***
Red-tailed Hawk	CA			4.3***	4.0**
Golden Eagle	CA				10.9**
Killdeer	GR	-4.3***	-10.5***		
Long-billed Curlew	GR			5.1***	
Mourning Dove	SH	-2.2***			
Red-naped Sapsucker	CA			12.0*	
Calliope Hummingbird	CA		-13.4*		
Olive-sided Flycatcher	CA	-2.9**	-4.2**		
Willow Flycatcher	SH	-2.5**	-4.3***		
Gray Flycatcher	SH				13.6**
Say's Phoebe	CA			5.4*	
Horned Lark	GR	-2.9**			
Cliff Swallow	CA			2.8***	
House Wren	CA			4.4**	5.7*
Marsh Wren	SH				8.8*
Mountain Bluebird	CA			4.0***	8.1**
American Robin	CA		-1.5*		
Gray Catbird	SH			4.0**	6.3***
Loggerhead Shrike[2]	SH	-2.7**			
Warbling Vireo	CA			4.1**	
Orange-crowned Warbler	GR			3.5*	7.5**
Yellow Warbler	SH		-2.1**		
Townsend's Warbler	CA			5.2***	
Common Yellowthroat	SH				2.8*
Black-headed Grosbeak	SH			4.8***	5.4***
Rufous-sided Towhee	GR			3.5*	7.6***
Chipping Sparrow	SH	-2.7***			
Brewer's Sparrow	SH	-1.3***	-4.3***		
Lark Sparrow	SH	-2.9**			
Savannah Sparrow	GR		-3.2*		
Song Sparrow	SH	-2.7***			
Red-winged Blackbird	SH	-1.5*	2.3*		
Western Meadowlark	GR	-0.8*	-3.7***		
Brewer's Blackbird	SH	-1.3*	-4.3***		
Pine Siskin	CA		8.8***		
American Goldfinch	CA	-2.1*			

*: $P < 0.10$

**: $P < 0.05$

***: $P < 0.01$

[1] Nest-layer abbreviations: CA=subcanopy/canopy-nesting species; GR=ground-nesting species; SH=shrub-nesting species, based on characteristics described by Ehrlich and others (1988) and Martin (1993).

[2] Federal candidate (Category 2) for listing under the Endangered Species Act.

APPENDIX 5F

Key environmental correlates (KECs)for all species in the Species-Environment Relations (SER) database. The numbered codes in this classification correspond to codes denoted for each species in the SER database.

1 **Vegetation elements**
- 1.1 cover types (Society of American Forests, Society of Range Management, ICBEMP)
- 1.2 structural stages
  - 1.2.1 SAF stages
  - 1.2.2 SRM stages
  - 1.2.3 CRB stages
  - 1.2.4 Other stages used to denote plant response
    - 1.2.4.1 regeneration cut
    - 1.2.4.2 selectively logged
    - 1.2.4.3 thinned
    - 1.2.4.4 patch clearcut
    - 1.2.4.5 shelterwood
    - 1.2.4.6 overstory removal
- 1.3 forest or woodland vegetation substrates
  - 1.3.1 down wood (includes coarse woody debris, "CWD")
    - 1.3.1.1 down wood in riparian zone
  - 1.3.2 snags (entire tree dead)
    - 1.3.2.1 bark piles at base of snag
  - 1.3.3 mistletoe brooms
  - 1.3.4 litter
  - 1.3.5 duff
  - 1.3.6 shrubs
  - 1.3.7 fruits/seeds/mast
    - 1.3.7.1 seed caching
  - 1.3.8 dead parts of live trees
  - 1.3.9 moss
  - 1.3.10 trees
    - 1.3.10.1 exfoliating bark
  - 1.3.11 flowers
  - 1.3.12 lichens
  - 1.3.13 bark
  - 1.3.14 forbs (grass)
  - 1.3.15 cactus
  - 1.3.16 fungi
  - 1.3.17 roots, tubers, underground plant parts
  - 1.3.18 peatlands
- 1.4 herbaceous vegetation elements or substrates
  - 1.4.1 herbaceous vegetation cover
    - 1.4.1.1 aquatic submergent vegetation
  - 1.4.2 fruits/seeds
  - 1.4.3 moss
  - 1.4.4 cactus
  - 1.4.5 flowers
  - 1.4.6 shrubs
  - 1.4.7 fungi
  - 1.4.8 forbs

- 1.4.9 bulbs/tubers
- 1.4.10 cryptogamic crusts
- 1.5 diversity of vegetation cover types
- 1.6 edges
  - 1.6.1 openings
  - 1.6.2 meadows
- 1.7 mycorrhizal associations

2 Biological (non-vegetation) elements

- 2.1 presence of prey species (including small mammals, insects, birds, other spp.)
  - 2.1.1 carrion
- 2.2 presence of predators
  - 2.2.1 absence of predator
- 2.3 presence of exotic species
  - 2.3.1 exotic plants
  - 2.3.2 exotic animals
- 2.4 insect irruption areas
  - 2.4.1 mountain pine beetle
  - 2.4.2 spruce budworm
  - 2.4.3 gypsy moth
- 2.5 presence of burrows or presence of burrowing mammals
- 2.6 grazing
  - 2.6.1 direct effects (trample, consumed)
  - 2.6.2 indirect effects (habitat degradation)
  - 2.6.3 seasonality of grazing
- 2.7 presence of beaver or muskrat ponds or lodges
- 2.8 presence of nesting structures
  - 2.8.1 cavities
  - 2.8.2 platforms
- 2.9 presence of other species
  - 2.9.1 positive or neutral effect
  - 2.9.2 negative effect
- 2.10 forest pathogens
- 2.11 colonial nester

3 Non-vegetation terrestrial substrates

- 3.1 rocks
  - 3.1.1 gravel
- 3.2 soils
  - 3.2.1 soil class
  - 3.2.2 soil depth
  - 3.2.3 soil texture
    - 3.2.3.1 sand/dunes
    - 3.2.3.2 soil suitable for burrowing vertebrates
    - 3.2.3.3 soil suitable for burrowing invertebrates
  - 3.2.4 soil pH
  - 3.2.5 soil temperature
  - 3.2.6 soil moisture
  - 3.2.7 soil chemistry
  - 3.2.8 soil organic matter
- 3.3 lithic (rock) substrates
  - 3.3.1 lithic series or types (including lithic formations such as Jefferson limestone)
    - 3.3.1.1 granite
    - 3.3.1.2 basalt
    - 3.3.1.3 rhyolite

3.3.1.4 sedimentary and metamorphic (fine grained rock), including limestone
3.3.1.5 calcareous rock
3.3.1.6 serpentine
3.3.1.7 sand (sandstone)
3.3.1.8 clay (alluvium)
3.3.1.9 glacial till and landslides
3.3.1.10 playa (alkaline, saline)
3.3.1.11 tuff (volcanic ash)
3.3.1.12 metal rich
3.3.1.13 pumice

3.3.2 avalanche chute
3.3.3 cliff
3.3.4 talus
3.3.5 boulder, large rocks
3.3.6 cave
3.3.7 rock outcrops/crevices
3.3.8 lava flows
3.3.9 [blank]
3.3.10 lava tubes
3.3.11 canyons
3.3.12 barren ground
3.3.13 rugged terrain
3.3.14 rocky ridges
3.3.15 ravine
3.3.16 cirque or basins (also see entry 5.7 below)

3.4 snow
3.4.1 snow depth (winter)
3.4.2 glaciers, snow fields

3.5 water characteristics
3.5.1 dissolved oxygen
3.5.2 water depth
3.5.3 dissolved solids
3.5.4 water pH
3.5.5 water temperature
3.5.6 water velocity
3.5.7 water turbidity

3.6 forages above tree canopy

4 Riparian and aquatic bodies

4.1 rivers
4.1.1 riverine wetlands
4.1.2 oxbows

4.2 streams (permanent or seasonal)
4.2.1 intermittant
4.2.2 rocks in streams

4.3 seeps or springs (including warm seeps or springs)
4.4 exposed mudflats, sand bars
4.5 sand bars, unconsolidated shore
4.6 gravel bars
4.7 shallow water
4.8 lakes or reservoirs (lacustrine)
4.8.1 lakes with submergent vegetation
4.8.2 lakes with floating mats
4.8.3 lakes with silt or mud bottom
4.8.4 lakes with emergent vegetation

4.8.5 alkaline lake beds
4.9 ponds (permanent or seasonal)
4.9.1 ponds with submergent vegetation
4.9.2 ponds with floating mats
4.9.3 ponds with silt or mud bottoms
4.9.4 ponds with emergent vegetation
4.10 wetlands, marshes, or wet meadows (palustrine)
4.10.1 bulbs or tubers in wetlands, marshes, or wet meadows
4.10.2 Phragmites
4.11 bogs or fens
4.12 swamps
4.13 islands
4.14 waterfalls
4.15 hyporheic zone
4.16 irrigation ditches
4.17 ephemeral pools
4.18 deciduous riparian, including willow and cottonwood
4.19 vernal or seasonal flooding or flood plains
4.20 bottomlands
4.21 water table

5 Topographic or physiographic elements
5.1 elevation
5.2 slope
5.3 aspect
5.4 slope position
5.5 ridge tops
5.6 plateau
5.7 convex or concave basin (also see entry 3.3.16 above)
5.8 flat
5.9 mima

6 Climate
6.1 precipitation (amount, pattern, seasonality)
6.2 Mediterranean influence (dry summers)
6.3 maritime influence (higher humidity and more moisture)
6.4 temperature
6.5 humidity
6.6 wind

7 Fire
7.1 recency
7.1.1 recent fire
7.1.2 old fire
7.2 effects of fire suppression activities
7.2.1 positive effect
7.2.2 negative effect
7.2.3 neutral effect
7.3 fire frequency
7.3.1 positive effect
7.3.2 negative effect
7.3.3 neutral effect
7.4 fire intensity
7.4.1 overstory lethal
7.4.1.1 positive effect
7.4.1.2 negative effect

7.4.1.3 neutral effect
7.4.2 overstory non-lethal
7.4.2.1 positive effect
7.4.2.2 negative effect
7.4.2.3 neutral effect
7.5 prescribed fire
7.5.1 spring prescribed fire
7.5.1.1 positive effect
7.5.1.2 negative effect
7.5.1.3 neutral effect
7.5.2 late summer or fall prescribed fire
7.5.2.1 positive effect
7.5.2.2 negative effect
7.5.2.3 neutral effect
7.6 historic fire suppression
7.6.1 positive effect
7.6.2 negative effect
7.6.3 neutral effect

8 Human disturbance elements

8.1 recreation areas and activities (including dispersed camping areas)
8.1.1 positive effect
8.1.2 negative effect
8.2 roads or trails
8.2.1 positive effect
8.2.2 negative effect
8.3 residential development
8.3.1 positive effect
8.3.2 negative effect
8.4 buildings
8.4.1 positive effect
8.4.2 negative effect
8.5 bridges
8.5.1 positive effect
8.5.2 negative effect
8.6 tunnels (for mines, see above under Non-vegetation terrestrial substrates)
8.6.1 positive effect
8.6.2 negative effect
8.7 agriculture and croplands
8.7.1 positive effect
8.7.2 negative effect
8.8 livestock (disease)
8.8.1 positive effect
8.8.2 negative effect
8.9 mines and mining activities
8.9.1 positive effect
8.9.2 negative effect
8.9.3 neutral effect
8.10 harvest (including legal hunting, legal trapping, and illegal poaching of animals)
8.10.1 positive effect
8.10.2 negative effect
8.11 fences
8.11.1 positive effect
8.11.2 negative effect
8.12 bird feeders

8.12.1 positive effect
8.12.2 negative effect

8.13 winter recreation
8.13.1 positive effect
8.13.2 negative effect

8.14 garbage
8.14.1 positive effect
8.14.2 negative effect

8.15 logging
8.15.1 positive effect
8.15.2 negative effect

8.16 nest box
8.16.1 positive effect
8.16.2 negative effect

8.17 perch structures
8.17.1 positive effect
8.17.2 negative effect

8.18 platforms
8.18.1 positive effect
8.18.2 negative effect

8.19 guzzlers
8.19.1 positive effect
8.19.2 negative effect

8.20 pesticide use

8.21 exotic plant effects
8.21.1 direct displacement
8.21.2 indirect competition
8.21.3 inhibit recruitment
8.21.4 habitat structure change

8.22 livestock grazing strategies
8.22.1 season-long
8.22.1.1 positive effect
8.22.1.2 negative effect
8.22.1.3 neutral effect
8.22.2 spring grazing
8.22.2.1 positive effect
8.22.2.2 negative effect
8.22.2.3 neutral effect
8.22.3 summer grazing
8.22.3.1 positive effect
8.22.3.2 negative effect
8.22.3.3 neutral effect
8.22.4 fall grazing
8.22.4.1 positive effect
8.22.4.2 negative effect
8.22.4.3 neutral effect

9 Barriers to movement
9.1 forest management (clearcuts)
9.2 canopy closure
9.3 agriculture

10 Natural disturbance -- floods, scouring, openings in forests

APPENDIX 5G

Key ecological functions (KEFs) of all species in the Species-Environment Relations (SER) database. The numbered codes in this classification correspond to codes denoted for each species in the SER database.

1 **Trophic relations**
- 1.1 primary producer (chlorophyllous vascular plants)
  - 1.1.1 autotrophic (fully independent chlorophyllous plants)
  - 1.1.2 hemiparasitic (chlorophyllous plants that also partially derive nutrients via attachment to other chlorophyllous plants)
- 1.2 heterotrophic consumer
  - 1.2.1 primary consumer (herbivore) (also see below under Herbivory)
    - 1.2.1.1 foliovore (leaf-eater)
    - 1.2.1.2 spermivore (seed-eater)
    - 1.2.1.3 browser
    - 1.2.1.4 grazer
    - 1.2.1.5 frugivore (fruit eater)
    - 1.2.1.6 sap feeding (sucking insects)
    - 1.2.1.7 root feeders (invertebrates)
    - 1.2.1.8 sequesters plant metabolites
  - 1.2.2 secondary consumer (primary predator or carnivore)
    - 1.2.2.1 consumer or predator of invertebrates, potentially including insects (insectivorous)
    - 1.2.2.2 consumer or predator of vertebrates (other species than itself)
  - 1.2.3 tertiary consumer (secondary predator or carnivore)
    - 1.2.3.1 consumer of soil microorganisms
  - 1.2.4 largely omnivorous (plants and animals consumed)
  - 1.2.5 carrion feeder
  - 1.2.6 cannibalistic
  - 1.2.7 coprophagous (feeds on fecal material)
  - 1.2.8 aquatic herbivore (invertebrates)
  - 1.2.9 feeds in water on algae, ooze, and plankton (invertebrates)
- 1.3 achlorophyllous vascular plants (see 1.9 below for nonvasculars)
  - 1.3.1 mycotrophic (indirectly parasitic, non-green plants that derive nutrients from mycorrhizal fungi that are also associated with a chlorophyllous species that serves as the indirect host)
  - 1.3.2 saprophytic (derive nutrients from decaying organic matter via mycorrhizal fungi)
  - 1.3.3 parasitic (derive nutrients via direct attachment to chlorophyllous plants)
    - 1.3.3.1 root parasites
    - 1.3.3.2 stem parasites
- 1.4 detritivore (feeds directly on dead organic material)
- 1.5 decomposer (feeds on byproducts of decaying organic material)
- 1.6 commutator (chewing insects, typically on wood or vegetation)
- 1.7 forage or prey relations
  - 1.7.1 forage for animals
  - 1.7.2 prey for secondary or tertiary consumer (primary or secondary predator or carnivore)
  - 1.7.3 carrion source
  - 1.7.4 forage for invertebrates
- 1.8 major biomass
- 1.9 achlorophyllous non-vascular plants (see 1.3 above for vasculars)
  - 1.9.1 mycorrhizal
  - 1.9.2 saprophytic
  - 1.9.3 parasitic
  - 1.9.4 decomposer
- 1.10 moss feeder (invertebrates)

2 **Herbivory**
- 2.1 ungulate herbivory (may influence rate or trajectory of vegetation succession and presence of plant species)
  - 2.1.1 herbivory on tree or shrub species (browsers)
  - 2.1.2 herbivory on grasses or forbs (grazers)
- 2.2 insect herbivory (may influence rate or trajectory of vegetation succession or presence of plant species)
  - 2.2.1 defoliators
  - 2.2.2 bark beetles
  - 2.2.3 tree bole feeders

3 **Nutrient cycling relations (see category 6, below, for nutrient cycling relationships in soil)**
- 3.1 aids in physical transfer of substances for nutrient cycling (Carbon, Nitrogen, Phosphorus, other)
- 3.2 nitrogen relations
  - 3.2.1 N-fixer
  - 3.2.2 N-immobilizer
  - 3.2.3 source for N mineralization
- 3.3 carbon relations
  - 3.3.1 sequestration of atmospheric carbon

4 **Interspecies relationships**
- 4.1 insect control
- 4.2 ungulate or other vertebrate population control
- 4.3 pollination vector
- 4.4 transportation of seed, spores, plant or animal disseminules
  - 4.4.1 disperses fungi
  - 4.4.2 disperses lichens
  - 4.4.3 disperses bryophytes, including mosses
  - 4.4.4 disperses insects
  - 4.4.5 disperses seeds/fruits
  - 4.4.6 disperses plants
- 4.5 commensal or mutualist with other species
- 4.6 provides substrates or cover for animals
  - 4.6.1 nesting or breeding substrate (for example, nesting material)
  - 4.6.2 thermal, hiding cover, loafing or den site
  - 4.6.3 provides microhabitat (as for invertebrates)
    - 4.6.3.1 aquatic or riparian environments
    - 4.6.3.2 terrestrial environments
    - 4.6.3.3 canopy environments
    - 4.6.3.4 tree bole environments
  - 4.6.4 creates "sap wells" in trees
- 4.7 nest parasite
  - 4.7.1 cowbird
  - 4.7.2 host for nest parasitism
- 4.8 primary cavity excavator in snags or live trees
- 4.9 primary burrow excavator (fossorial)
  - 4.9.1 creates large burrows (rabbit, badger size)
  - 4.9.2 creates small burrows (smaller than rabbit size)
- 4.10 competitor
- 4.11 uses burrows dug by other species
- 4.12 secondary cavity nester
- 4.13 parasite (invertebrates)

5 **Disease, pathogen, and parasite relations**
- 5.1 carrier, transmitter, or reservoir of vertebrate diseases (including rabies)
- 5.2 acts as pathogen or disease
- 5.3 parasite carrier or transmitter
- 5.4 carrier, transmitter, or reservoir of plant diseases (invertebrates)
- 5.5 activity increases host susceptibility to plant diseases (invertebrates)

6 **Soil relations**
- 6.1 physically affects (improves) soil structure, aeration (typically by digging)
- 6.2 aids general turnover of soil nutrients and layers
- 6.3 aids N retention or uptake in soil
- 6.4 aids soil stabilization
- 6.5 aids rock weathering
- 6.6 detoxifies xenobiotics (invertebrates)
- 6.7 metal accumulator (sequesters heavy metals)
- 6.8 soil (invertebrate) organisms which influence rate or trajectory of vegetation succession and presence of plant species

7 **Wood relations**
- 7.1 physically breaks down wood
  - 7.1.1 large logs
  - 7.1.2 smaller wood pieces
- 7.2 chemically breaks down wood

8 **Water relationships**
- 8.1 impounds water (for example, beavers)
- 8.2 bioindicator of water quality
- 8.3 hydrologic buffer
- 8.4 improves water quality
- 8.5 contributes to short-term increase in stream flow (invertebrates)

9 **Weather, climate, insolation relations**
- 9.1 affects albedo (as of soil, rock, or soil)

10 **Vegetation structure and composition relations**
- 10.1 creates canopy gap openings (tree death) (invertebrates)
- 10.2 creates standing dead trees (snags) (invertebrates)

APPENDIX 5H

Locally endemic (LE) or regionally endemic (RE) vertebrates of the Basin.

Class[1]	Scientific name	Common name	Endemism
A	*Ambystoma gracile*	Northwestern salamander	RE
A	*Dicamptodon aterrimus*	Idaho giant salamander	LE
A	*Dicamptodon copei*	Cope's giant salamander	RE
A	*Plethodon dunni*	Dunn's salamander	RE
A	*Plethodon idahoensis*	Coeur d'alene salamander	RE
A	*Plethodon larselli*	Larch mountain salamander	LE
A	*Rana aurora*	Red-legged frog	RE
A	*Rana cascadae*	Cascades frog	RE
A	*Rhyacotriton cascadae*	Cascade torrent salamander	RE
B	*Centrocercus urophasianus*	Sage grouse	RE
B	*Selasphorus rufus*	Rufous hummingbird	RE
B	*Strix occidentalis caurina*	Northern spotted owl	RE
B	*Tympanuchus phasianellus columbianus*	Columbian sharp-tailed grouse	RE
M	*Aplodontia rufa*	Mountain beaver	RE
M	*Brachylagus idahoensis*	Pygmy rabbit	RE
M	*Clethrionomys californicus*	Western red-backed vole	RE
M	*Dipodomys californicus*	California kangaroo rat	RE
M	*Dipodomys microps*	Chisel-toothed kangaroo rat	RE
M	*Microdipodops megacephalus*	Dark kangaroo mouse	RE
M	*Microtus oregoni*	Creeping vole	RE
M	*Microtus pennsylvanicus kincaidi*	Potholes meadow vole	LE
M	*Neurotrichus gibbsii*	Shrew-mole	RE
M	*Perognathus longimembris*	Little pocket mouse	RE
M	*Scapanus latimanus*	Broad-footed mole	RE
M	*Scapanus orarius*	Coast mole	RE
M	*Sorex preblei*	Preble's shrew	RE
M	*Spermophilus armatus*	Uinta ground squirrel	RE
M	*Spermophilus beldingi*	Belding's ground squirrel	RE
M	*Spermophilus brunneus*	Idaho ground squirrel	LE
M	*Spermophilus columbianus*	Columbian ground squirrel	RE
M	*Spermophilus elegans nevadensis*	Wyoming ground squirrel	RE
M	*Spermophilus saturatus*	Cascade golden-mantled ground squirrel	RE
M	*Spermophilus townsendii*	Townsend's ground squirrel	RE
M	*Spermophilus washingtoni*	Washington ground squirrel	LE
M	*Tamias dorsalis*	Cliff chipmunk	RE
M	*Tamias ruficaudus*	Red-tailed chipmunk	RE
M	*Thomomys mazama*	Western pocket gopher	RE
M	*Thomomys talpoides limosus*	White salmon pocket gopher	LE
M	*Thomomys townsendii*	Townsend's pocket gopher	RE

[1]A=amphibian; B=bird; M=mammal

List of Acronyms

ASQ	Allowable Sale Quantity
AUM	Animal Unit Month
BEA	Bureau of Economic Analysis
BLM	Bureau of Land Management
BMPs	Best Management Practices
BTUs	British Thermal Units
CFR	Code of Federal Regulations
CRBSUM	Columbia River Basin Succession Model
EIS	Environmental Impact Statement
EEIS	Eastside EIS Planning/Management Area
EPA	Environmental Protection Agency
ERU	Ecological Reporting Units
ESI	Existing Scenic Integrity
FACA	Federal Advisory Committe Act
FEMAT	Forest Ecosystem Management Assessment Team
FIRE	BEA designation, Finance, Insurance and Real Estate industries
FS	Forest Service
FSH	Forest Service Handbook
GIS	Geographic Information System
GPM	General Planning Model
GSP	Gross State Product
HUCs	Hydrologic Unit Codes
LWD	Large Woody Debris
ICBEMP	Interior Columbia Basin Ecosystem Management Project
ICRB	Interior Columbia River Basin
INFISH	Inland Native Fish Strategy
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWFP	Northwest Forest Plan
PACFISH	Pacific Anadromous Fish Strategy
PILT	Payments in Lieu of Taxes
RAC	Resource Advisory Committee
RHCA	Riparian Habitat Conservation Area
RMA	Riparian Management Area
ROS	Recreation Opportunity Spectrum
PVG	Potential Vegetation Group
PVT	Potential Vegetation Type
RVD	Recreation Visitor Day
SER	Species-Environment Relations (database)
SIC	Standard Industrial Code
SIT	Science Integration Team
TES	Threatened and Endangered Species
UCRB	Upper Columbia River Basin EIS Planning/Management Area
USDA	United States Department of Agriculture
USDI	United States Department of Interior
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

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Metric Conversion

Mile (mi)=1.61 Kilometers (km)

Kilometer (km)=.62 Miles (mi)

Square Kilometers (km^2)=.39 Square Miles (mi^2)

Centimeter (cm)=.3937 Inches (in)

Meter (m)=3.28 Feet (ft)

Hectare (ha)=10,000 Square Meters (m^2)

Hectare (ha)=2.47 Acres (ac)

Acre (ac)=43,560 Square Feet (ft^2)

Quigley, Thomas M.; Arbelbide, Sylvia J., tech. eds. 1997. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 4 vol. (Quigley, Thomas M., tech. ed.; The Interior Columbia Basin Ecosystem Management Project: Scientific Assessment).

This paper provides detailed information about current conditions and trends for the biophysical and social systems within the basin. Social and economic conditions within the assessment area differ considerably depending to a great extent on population, diversity of employment opportunities, and changing demographics. This information can be used by land managers to develop broad management goals and priorities and provides the context for decisions specific to smaller geographic areas.

Keywords: Columbia basin, biophysical systems, social systems, ecosystem.

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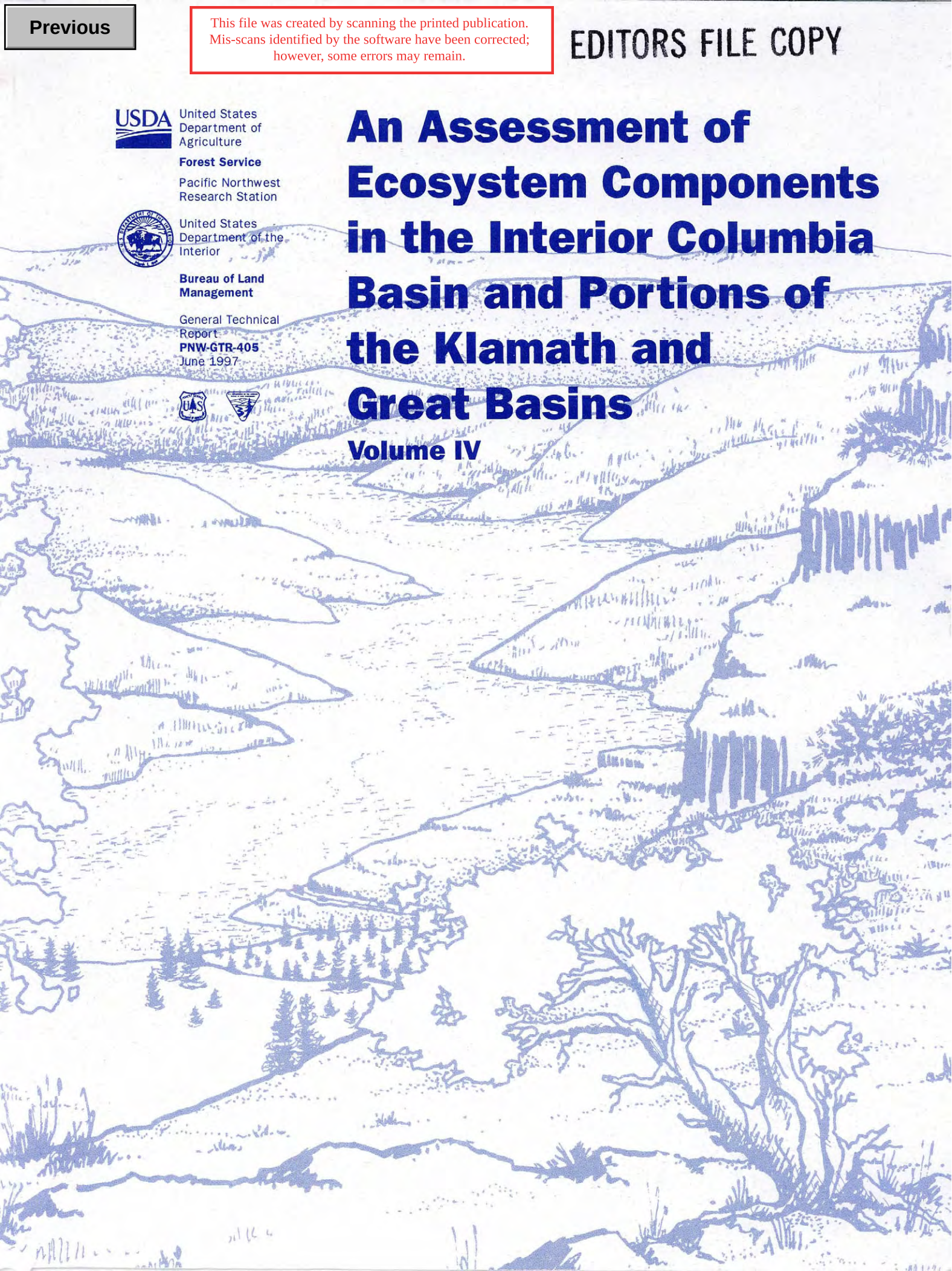
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General Technical Report
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An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins

Volume IV





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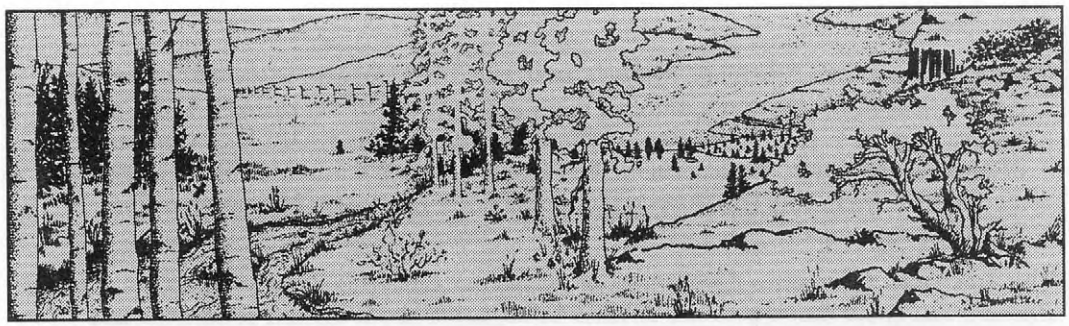


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An Assessment of Ecosystem Components in the Interior Columbia Basin

And Portions of the Klamath and Great Basins: Volume IV

Thomas M. Quigley
Sylvia J. Arbelbide
Technical Editors

Volume IV contains pages 1,715 through 2,066

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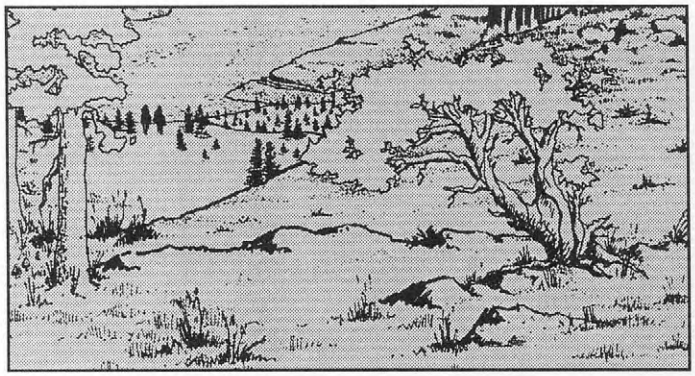
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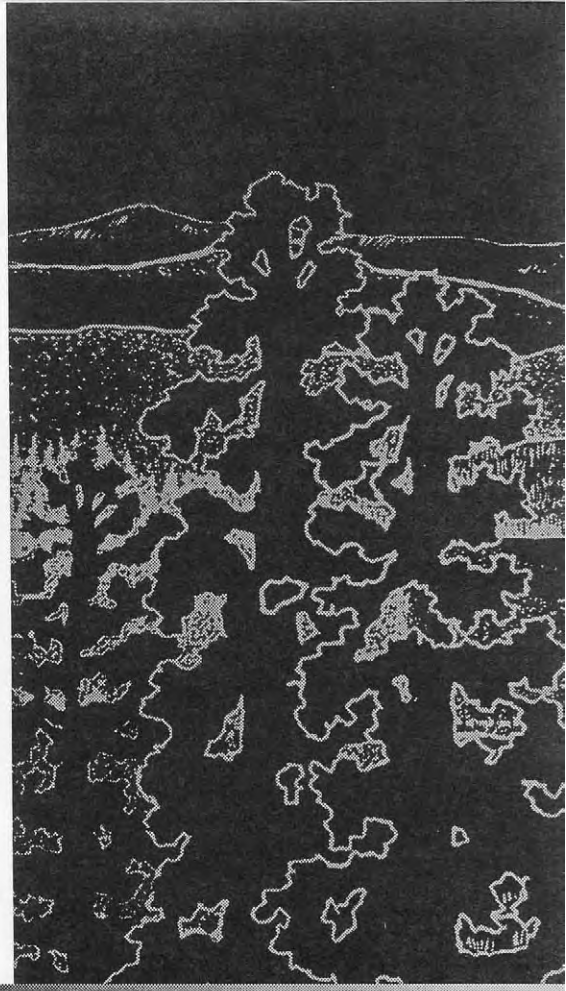
Abstract

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The *Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins* provides detailed information about current conditions and trends for the biophysical and social systems within the Basin. This information can be used by land managers to develop broad land management goals and priorities and provides the context for decisions specific to smaller geographic areas. The Assessment area covers about 8 percent of the U.S. land area, 24 percent of the Nation's National Forest System lands, 10 percent of the Nation's BLM-administered lands, and contains about 1.2 percent of the Nation's population. This results in a population density that is less than one-sixth of the U.S. average. The area has experienced recent, rapid population growth and generally has a robust, diverse economy. As compared to historic conditions, the terrestrial, aquatic, forest, and rangeland systems have undergone dramatic changes. Forested landscapes are more susceptible to fire, insect, and disease than under historic conditions. Rangelands are highly susceptible to noxious weed invasion. The disturbance regimes that operate on forest and rangeland have changed substantially, with lethal fires dominating many areas where non-lethal fires were the norm historically. Terrestrial habitats that have experienced the greatest decline include the native grassland, native shrubland, and old forest structures. There are areas within the Assessment area that have higher diversity than others. Aquatic systems are now more fragmented and isolated than historically and the introduction of non-native fish species has complicated current status of native fishes. Core habitat and population centers do remain as building blocks for restoration. Social and economic conditions within the Assessment area vary considerably, depending to a great extent on population, diversity of employment opportunities, and changing demographics. Those counties with the higher population densities and greater diversity of employment opportunities are generally more resilient to economic downturns. This Assessment provides a rich information base, including over 170 mapped themes with associated models and databases, from which future decisions can benefit.

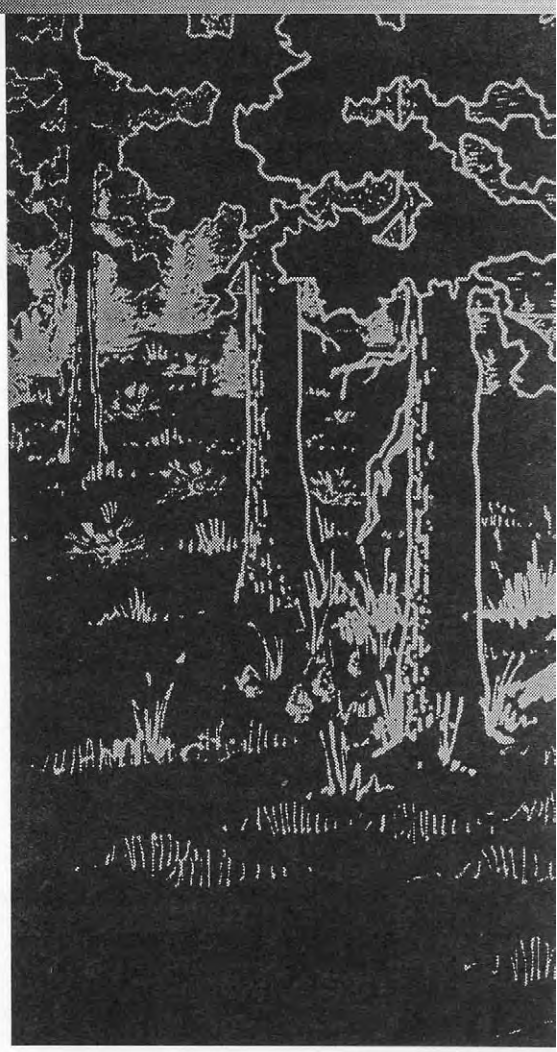
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CHAPTER 6

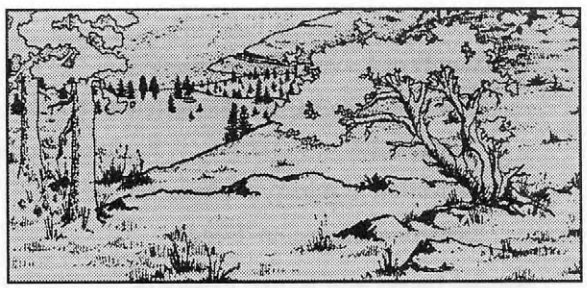
Economic Assessment of the Basin



Richard W. Haynes and Amy L. Horne

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TABLE OF CONTENTS



Introduction 1723

Temporal Scales 1724

Spatial Scales 1725

General Findings 1728

Overview 1729

Demographic and Economic Trends 1729

Current Picture 1729

Economic Strengths of the Basin 1732

Historical Perspective 1735

Differences Among Non-metropolitan Counties 1738

Outlook 1743

Trends in Resource Allocation Priorities 1744

Resource Characterization 1745

Fish 1745

Historical Perspective 1747

Future Fish Valuation Issues 1749

Minerals 1750

Overview of Recent Minerals Production 1750

Remediation Costs for Past Mining 1753

Future Mineral Development 1758

Range 1767

Western Range Overview 1767

Dependency on Federal Forage 1768

Permit Issues 1769

Projections of Livestock Production 1773

Recreation 1774

Historical Trends in Recreation 1774

Amount of Recreation Activity 1775

Who Participates in Recreation 1775
Supply of Recreational Settings 1778
Willingness-to-pay for Recreation on Public Lands in the Basin 1779
Contribution of Recreation to Regional Economies 1782
Recreation in Agency Budgets 1784
Predicting Recreation Trends 1786
Special Forest and Range Products 1788
Timber 1789
Prospective Timber Demands 1790
Prospective Timber Supplies 1790
Prospective Price Trends 1791
The Basin 1791
Timber Harvest Projections by BEA Regions 1793
Salvage Issues 1796
Water 1799
Water Allocation and Demand in 1990 1799
Future Water Demand 1801
Economic Policy Questions 1805
Community Stability and Timber Dependency 1805
Community Stability 1805
Timber Dependency 1807
Economic Well-being 1808
Economic Growth 1810
Economic Resiliency 1810
Economic Growth 1811
Tri-Cities BEA Region Example 1814
Economics of Ecosystem Management 1814
Resource Valuation 1816
Outputs and Conditions to Consider 1817
Economic Characteristics of Outputs 1818
Adding Up Values 1818
Determination of Values 1819
Methods 1820
Results 1823
Scenarios 1827
Complementarity 1829
Expenses of Ecosystem Management 1830

Revenues for Ecosystem Management 1831
Sustainability 1832
Conclusions 1835
Economic Efficiency 1835
Equity 1836
Economic Activity 1837
The Basin 1837
Counties 1838
Community Economies 1838
Characterizations of Specific Resources 1838
Fish 1838
Minerals 1839
Range 1839
Recreation 1839
Special Forest and Range Products 1840
Timber 1840
Water 1841
Acknowledgments 1843
References 1845
Appendix 6-A Response Coefficients for Agriculture, Forestry and Minerals 1855
Appendix 6-B Recreation Response Coefficients 1861
Appendix 6-C Communities Defined as Timber-Dependent 1869

LIST OF TABLES

Table 6.1 Current economic indicators for the U.S., Idaho, Montana, Oregon, and Washington. 1733
Table 6.2 Employment in economic sectors of the U.S., the Basin, and Bureau of Economic Analysis (BEA) regions for 1995. 1734
Table 6.3 Population, gross national product, and income figures for the U.S., 1929–1994 and projections to 2040. 1736
Table 6.4 Typology of non-metropolitan counties in the interior Columbia Basin: change in number of counties within each economic or policy category, 1979–1989. 1739
Table 6.5 Value of commercial fish stocks of the Basin, average annual in 1993 dollars, 1980–present. 1746
Table 6.6 Selected minerals production in the world, U.S., four northwest states, and Nevada. 1751

Table 6.7	Discovered metal resources in the world, U.S., and the Basin; production and resources remaining as of 1995.	1752
Table 6.8	World-class deposits of the Basin; cumulative production of base and precious metals as of 1995.	1754
Table 6.9	Top ten mineral-producing counties in the Basin: mining employment as a percent of county employment, 1969–1992.	1756
Table 6.10	Number of mineral sites in the Basin having output greater than $100,000 in 1992, and percentage of Basin mineral output, by commodity, 1992.	1758
Table 6.11	Activity status of discovered deposits of base and precious metals in significant mineral deposits in the Basin, 1995.	1759
Table 6.12	Probable quantities of base and precious metal resources remaining undiscovered in the Basin.	1760
Table 6.13	Potential metallic mineral and phosphate resources in each ecological reporting unit in the Basin.	1763
Table 6.14	Importance of agriculture and grazing on BLM and FS land to economies of the Basin, by BEA region.	1769
Table 6.15	Seasonality of grazing allotments, by state, on BLM, FS, and other federal land, 1994.	1770
Table 6.16	Average dependency of federal grazing permittees on federal forage, by state, 1991.	1770
Table 6.17	Cow-calf production cash costs and returns for federal grazing permittees and non-permittees in 10 western and Great Plains states, 1990.	1771
Table 6.18	Comparison of federal grazing permittees and non-permittees ranch and herd size, 1990.	1771
Table 6.19	Program costs of managing public rangeland, 1993.	1773
Table 6.20	Recreation activity days in the Basin, by activity and ERU, 1991–1993.	1776
Table 6.21	Participation rates in recreation activities in the U.S., greater northwest, the Basin, and BEA regions, 1993.	1777
Table 6.22	Supply of recreational opportunities on federal land in the Basin, 1995.	1779
Table 6.23	Distribution of recreation activities in the Basin among ROS classes, 1995.	1780
Table 6.24	Average annual willingness-to-pay for recreation in the Basin, 1991–1993.	1781
Table 6.25	Contribution of recreation activity to recreation net economic benefits in the Basin, 1991–1993 .	1782
Table 6.26	Net economic value (willingness-to-pay) of current recreation activities on FS-BLM-administered lands.	1783
Table 6.27	Percentage of employment supported by recreation activities, 1991–1993.	1785
Table 6.28	Federal revenues from recreation special use permits in the Basin, by agency, 1994.	1785

Table 6.29 Value of special forest and range products collected east and west of the Cascade crest in Oregon and Washington, 1989. 1789
Table 6.30 Effect of salvage logging on projections of softwood harvest, stumpage prices, lumber and structural panel production in the Basin, 1952–1991, salvage projections to 2040. 1792
Table 6.31 Forest sector employment in the Basin, eastern Oregon, eastern Washington, northern and southern Idaho, and western Montana, 1978–1993, and projections to 2040. 1793
Table 6.32 Projected timber harvest in the Basin, 1993–2040. 1794
Table 6.33 Softwood harvest, stumpage prices, lumber and structural panel production in the U.S., Eastside, and UCRB areas, by land ownership, to 2040. 1797
Table 6.34 Water allocation in the Basin among domestic, industrial, commercial, livestock, and irrigation uses, 1990. 1800
Table 6.35 Projected water allocation in 2040. 1802
Table 6.36 Indicator variables for outputs from FS- and BLM-administered lands suitable for ecosystem market basket. 1818
Table 6.37 Willingness-to-pay values for carbon storage, range, and recreation outputs, 1994 dollars. 1822
Table 6.38 Willingness-to-pay values for timber and chips output, 1994 dollars. 1823
Table 6.39 Percent of total value provided by individual activities, 1995 and 2045. 1826
Table 6.40 Ecosystem outputs currently having greatest relative value. 1827
Table 6.41 Relative importance of some outputs from FS- and BLM-administered lands in the Basin, 1995 and 2045. 1836

LIST OF FIGURES

Figure 6.1 Land ownership patterns in the Basin, by ERU. 1730
Figure 6.2 Population distribution among places of different sizes, U.S. and the Basin, 1990. 1731
Figure 6.3 Employment in the Basin; distribution among economic activities, 1995. 1732
Figure 6.4 Rate of population change in Basin counties according to economic typology, 1970–1992. 1740
Figure 6.5 Employment growth in Basin counties within each category of economic typology, 1971–1992. 1740
Figure 6.6 Rate of population change in Basin counties within each category of policy typology, 1970–1992. 1741
Figure 6.7 Annual change in employment in Basin counties within each category of policy typology, 1971–1992. 1741
Figure 6.8 Comparison of per capita income in recreation and manufacturing counties within the Basin. 1742
Figure 6.9 Distribution of Columbia River commercial landings of salmon and steelhead, between tribal and non-tribal peoples, 1957–1993. 1747

Figure 6.10 Annual commercial landings of salmon and steelhead from the Columbia River, in millions of pounds, 1866–1993. 1748
Figure 6.11 Location of mines and mineral deposits in the Basin, by activity status, 1995. 1754
Figure 6.12 Location of phosphate mineral resources in the Basin, 1995. 1755
Figure 6.13 Percent of Basin nonfuel mineral production value contributed by each county, average 1980–1992. 1756
Figure 6.14 Mining and mineral processing sites in operation, under development, or on standby status in the Basin, 1995. 1757
Figure 6.15 Likelihood of economic mining activity in the Basin. 1761
Figure 6.16 Likelihood of base, precious, and feroalloy metals activity in the Basin. 1762
Figure 6.17 Contribution of large unroaded areas in the Basin to supply in contiguous U.S., by size of unroaded areas. 1778
Figure 6.18 Average stumpage prices for National Forest timber, lower and upper portions of the assessment area, 1943–1993. 1791
Figure 6.19 Model of regional economic growth. 1813
Figure 6.20 Effect of FS and BLM policies on range jobs in the Tri-Cities BEA region. 1815
Figure 6.21 Effect of FS and BLM policies on recreation jobs in the Tri-Cities BEA region. 1815
Figure 6.22 Effect of FS and BLM policies on timber jobs in the Tri-Cities BEA region. 1815
Figure 6.23 Effect of FS and BLM policies on population growth in the Tri Cities BEA region. 1815
Figure 6.24 Effect of FS and BLM policies on total personal income in the Tri Cities BEA region. 1815
Figure 6.25 Net economic value: area under the demand curve minus cost of production. 1819
Figure 6.26 Passive-use value per acre of unroaded land. 1821
Figure 6.27 Current market basket value of FS- and BLM-administered lands, per acre. 1824
Figure 6.28 Projected increase in value of benefits from FS- and BLM administered land, by activity, 1995–2045. 1825
Figure 6.29 Projected annual value of scenario outputs, including range, recreation, timber, and existence of unroaded areas, 1995–2045. 1828
Figure 6.30 Hypothetical joint production function between timber harvests and scenic. integrity showing opportunities to increase output of both. 1830

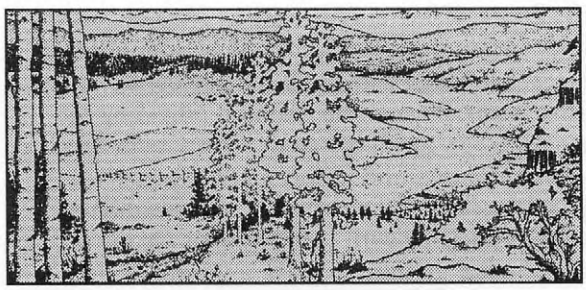
LIST OF MAPS

Map 6.1 Economic areas of the Basin. 1726
Map 6.2 Ecological Reporting Units of the Basin. 1727
Map 6.3 Timber-dependent communities, 1995. 1809

Continue

Previous

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INTRODUCTION

The Charter of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) charged the Science Integration Team to identify, among other issues, the economic outcomes associated with current Forest Service (FS) and Bureau of Land Management (BLM) activities in the assessment area. We identified three dominant economic themes having to do with (1) regional economies, (2) economic efficiency, and (3) equity. The importance of management of FS and BLM lands to regional economic activity is examined under the first theme. The theme of economic efficiency examines whether the resources associated with the Federal lands are being administered to provide society with good value. The theme of equity assesses how the benefits and costs provided by these Federal lands are being distributed throughout the population. Society is the judge of the fairness of the distribution, and it expresses its preferences through elected officials, legislation, and the judiciary.

The study area for the Interior Columbia Basin Ecosystem Management Project consists of the Columbia River basin east of the crest of the Cascades, and those portions of the Klamath and Great basins within Oregon (hereafter called the Basin). As such, it stretches through much of Oregon and Washington to the continental divide in western Montana and northwestern Wyoming, taking in nearly all of Idaho and small portions of Nevada and Utah. All or part of 100 counties lie within the Basin. The BLM and FS administer 53 percent of this land area. Private owners hold 38 percent of the area, state governments and other federal agencies manage 5 percent of the area, and tribal lands account for 4 percent of the area.

We begin this Economic Assessment with an "Overview" that characterizes the people and economies of the Basin. We describe the current situation and the trends and events that led up to it. We discuss how the economy in the Basin works, what it responds to, how sensitive it is to national business cycles, and what factors are driving economic growth. The FS and BLM administered lands that provide society with many benefits, few of which are pure private market goods. Because of this, a complete discussion of economics must go beyond prices and quantities. Many of the benefits provided by these lands have no prices and their quantities are not routinely measured. Laws and regulations reveal the importance society places on these benefits and shape the manner in which they are produced and used. The legal and political backdrop helps us understand society's preferences in allocating its scarce public resources.

A "Resource Characterization" section examines economic issues related to particular resources managed by the FS and BLM: fish, minerals, range, recreation, special forest and range products, timber, and water. For each resource in this section, we describe the current condition of the resource, the trends affecting resource demand and supply that led to the current condition, and what

the future of the resource may be. We discuss the importance of Basin FS- and BLM-administered lands, compared with lands outside the Basin or other ownerships in the Basin, in providing the resource, how much economic activity exists because of this resource, and how economic behavioral patterns relate to the resource. We also discuss values associated with each resource; we use the term "value" to mean relative importance, and express it in dollar terms. Because, for many reasons, market prices may not fully capture relative importance, "value" does not necessarily reflect money that changes hands.

Our "Economic Policy Questions" section provides a picture of (1) how important FS and BLM management activities are to community stability in the Basin, (2) how important FS and BLM management activities are to the development of regional economies in the Basin, (3) how future FS and BLM management may influence the ecosystem value provided society by these lands, and (4) an economic discussion of sustainability. The Economic Staff created the "Economic Policy Questions" section by weaving together information from earlier sections, conducting literature searches, and using computer modeling techniques.

In the "Economics of Ecosystem Management" subsection we explore the economic efficiency of alternative scenarios for management of FS and BLM lands in the Basin. We combine projections of resource supply and demand to examine the value of the "outputs" produced by different management regimes. We use "outputs" quite broadly to refer to the whole array of ecosystem goods, functions, and conditions people want from public lands. "Ecosystem goods" are specific components of ecosystems—minerals, timber, forage, mushrooms, salmon, or grizzly bears. "Ecosystem functions" are processes such as carbon storage or sediment filtration. "Ecosystem conditions" are systemic or integrated states such as "old-growth" forests, roadless areas, scenic integrity, or healthy ecosystems. "Value" refers to the strength of preference for or relative worth of an ecosystem output. We try to include most sources of value whether or not the outputs are traded in markets, and whether or not the people holding the values live in the Basin (Field 1994). By combining all this information, we attempt to display complementary outputs and tradeoffs associated with different management regimes; we examine how different public land management directions will affect the societal value of ecosystem goods, functions, and conditions produced by FS and BLM lands in the Basin.

Temporal Scales

Being explicit about temporal scales is critical to an economic assessment. Time must be treated explicitly because economic phenomena exist only at a point in time. A price, for example, is set by the instantaneous intersection of supply and demand; it will shift through time in response to changes in the underlying determinants of one or both. Time is similarly important in understanding behavior pertaining to non-market goods, particularly ones for which societal preferences have changed significantly.

We document historical resource use and economic activity as far back as Basin-wide data of consistent quality are available, often only to 1969. Our discussion of the future is based on 50-year projections gathered from the Resource Planning Act Timber Assessment (Haynes and others 1995), the CRBSUM computer model,[1] the Bureau of Economic Analysis (U.S. Department of Commerce 1992), and U.S. Bureau of the Census (Day 1993, Campbell 1994). We display projected trends in activity of various economic sectors to show how the economy is expected to evolve over the next half century. We also display trends in net economic values over time to reveal allocation of benefits between current and future generations; this is in lieu of the more traditional present net value (PNV) analysis. These projections allow greater precision in evaluating the relative importance of any changes, rather than generalizing to "the economy improves" or "jobs shift."

[1] CRBSUM is the spatially explicit dynamic model developed by the Landscape Ecology staff of the Interior Columbia Basin Ecosystem Management Project.

Spatial Scales

A principle of ecosystem management is to set and understand context one level higher than the primary scale of interest and to examine and understand processes one level lower than the primary level. Our primary spatial scale of interest is the Basin. When using county-level data, we have defined the region as the 100 counties into which any part of the Basin falls, although for some of these counties the land area and economic activity that occur within the Basin are minor. To set context, we discuss market and non-market economic phenomena at the national level. To understand processes, we have defined two sets of subregions within the Basin: one set is used to examine regional economies, the other to examine the societal value of what might be supplied by BLM and FS lands in various ecosystems.

When discussing the regional economy, we use nine economic regions, shown in map 6.1, modified from a recent publication by the Bureau of Economic Analysis (BEA) (U.S. Government 1995). The BEA defined functional economic units by identifying economic nodes and the surrounding counties economically related to them. Work commuting patterns are the primary factor used to determine economic regions. The goal is to include, as far as possible, both the place-of-work and place-of-residence of the labor force. Some parts of the Basin function as part of economic units that include areas outside the ecological boundary; Redmond-Bend, Oregon, for example, is not a stand-alone economic node, but is associated with the larger economic unit related to Portland west of the Cascades. For this analysis, we modified BEA regions to include only those counties in which the Basin falls, but the point remains that economic regions and ecosystems are often not coincident. Further, we consider the BEA regions to be the smallest economic unit relevant to conducting an economic assessment of an area the size of the Basin. They do not, however, operate independently; rather, they function as part of larger regional and global economies.

When exploring the question of what ecosystem goods, functions, and conditions the FS and BLM lands in the Basin provide society, we are really concerned about supply, or rates at which outputs are produced. Hence in the "Economics of Ecosystem Management" subsection we use the 13 Ecological Reporting Units (ERUs) developed by the Aquatic, Landscape Ecology, and Terrestrial staff areas (map 6.2). (The decision by the ecologists to use groupings of subbasins instead of or in addition to ERUs occurred too late for us to redo our analyses.) These ERUs are regions in which lands have similar capacities to produce the various ecosystem goods, functions, and conditions desired by society. Different ecosystems have inherent differences in their ability to supply society with certain outputs. For example, the Central Idaho Mountains ERU is a better place to put ski resorts than the Northern Great Basin; the Blue Mountains ERU is a better place to grow trees than the Upper Snake ERU.

One observation about spatial scales is that every BEA area includes parts of several ecological regions. All trade centers in the Basin are located at the boundaries between ecoregions (with the exception of the Tri-Cities which is an artifact of Federal projects). This suggests the hypothesis—untested here—that spheres of economic activity will tend to exist where they can draw from several different ecological regions; that the diversity of ecosystem outputs provided by having access to several ecoregions provides economic advantages. This interweaving of economic and ecologic areas reinforces the notion that regions should be defined differently depending on whether one is answering a question about economic activity or about what Federal lands can supply to best meet society's needs.

Map 6.1— Bureau of Economic Analysis economic areas of the Basin.

Map 6.2— Ecological Reporting Units of the Basin.

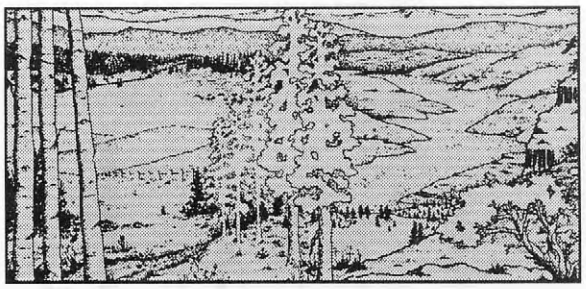
General Findings

Regarding the role of FS and BLM management in maintaining community stability, we find little evidence that agency management succeeds in maintaining community stability through timber harvest levels. The isolation and lack of economic diversity of certain communities make them sensitive to changes in interest rates, labor productivity, consumer preferences, and national business cycles—all factors over which the FS and BLM have little influence. The Basin contains 539 census-recognized places, of which 66 were defined by the FS in 1987 as timber dependent. Today only 29 of these exhibit characteristics suggesting heightened sensitivity to Federal timber sales (see section on "Community Stability and Timber Dependency").

For the entire Basin, we find that current FS and BLM activities have little impact on its economy. It has a large, diverse economy of 1.5 million jobs. The past two decades have seen rapid population growth and the evolution from a mature, resource-based economy to a diverse economy oriented toward the technology, transportation, and service sectors. We expect the economic growth in the Basin to continue, especially in the finance, insurance, real estate, transportation, agricultural services and service sectors. The manufacturing, agriculture, and government sectors are expected to decline over the next 50 years (see "Economic Growth" section).

We had data which allowed us to include range, recreation, timber, and the existence of unroaded areas in our economic efficiency analysis. Range provides 0.4 percent of the net benefit of FS and BLM lands in the Basin, recreation provides 41.2 percent, timber provides 11.5 percent, and the existence of unroaded areas provides 46.9 percent. Changes in society, particularly population growth and aging, will shift the relative importance of these activities over time. We expect that by the year 2045, recreation will be providing 52.9 percent of the value of benefits to society. Motor viewing (pleasure driving) will be the highest value activity in the Basin, followed by day use and trail use. The relative importance of timber will have fallen to 5.4 percent (see "Economics of Ecosystem Management" section). Roads and access to riparian areas are an aspect of recreation supply common to what will be the most highly valued activities on FS and BLM lands over the next 50 years.

Considerable revenues could be raised by charging recreation fees. If the formula for calculating payments to counties were revised to reflect the recreation value of these lands, their revenues could double or triple.



OVERVIEW

This section describes the human and economic context of BLM and FS lands within the Basin. It describes federal, private, and tribal landownership patterns within the Basin. It also characterizes the people who live in the Basin and their economies. The evolution of economic and demographic characteristics in the Basin are described together since the two are inextricably linked.

Demographic and Economic Trends[2]

Current Picture

The land—The FS and BLM manage slightly more than half (53%) of the lands in the Basin; the second largest category is private ownership (38%) (fig. 6.1). Minor portions are owned by State and other Federal agencies (5%), and the tribes (4%). The highest percentage of FS and BLM landownership and lowest percentages of private landownership are found in the Central Idaho Mountains Ecological Reporting Unit (ERU) (81% and 14% respectively) and the Northern Great Basin ERU (73% and 21% respectively). At the other extreme the Columbia Plateau ERU is predominantly private landownership (12% FS or BLM and 76% private). The Snake Headwaters ERU has the highest percentage of National Park and other wilderness (11%). Significant percentages of tribal lands are found in the Northern Glaciated Mountains (17%), Northern Cascades (12%), and Southern Cascades (9%). All other ERUs more closely resemble the overall Basin ownership patterns.

The percent of the land base in different ownerships helps to identify ERUs whose ecosystem integrity is directly affected by BLM and FS land management policies. The amount of private land in each ERU is important because the amount of timber harvesting and cattle grazing on FS- and BLM-administered land affects the amount of production which occurs on private land. The two are inversely related; that is, through market signals decreases in grazing or harvesting from FS- and BLM-administered lands encourage increased production from private lands— in either the short or long term. Nonmarket outputs (outputs not traded in markets) desired by society are often best produced from public lands because public management can internalize and directly control for their production levels. Without government regulations and incentives, privately owned lands may not produce nonmarket outputs.

Among the forested ERUs, the FS and the BLM have greatest potential influence on the ecosystem integrity of the Central Idaho Mountains where they manage 81 percent of the land base (see fig. 6.1). The FS and BLM have the least potential influence in the Northern Glaciated Mountains (FS and BLM manage 39%); and private management has its greatest influence in the Upper

[2] This section was written by Amy L. Horne, based on the background report prepared by McGinnis and Christensen [1996].

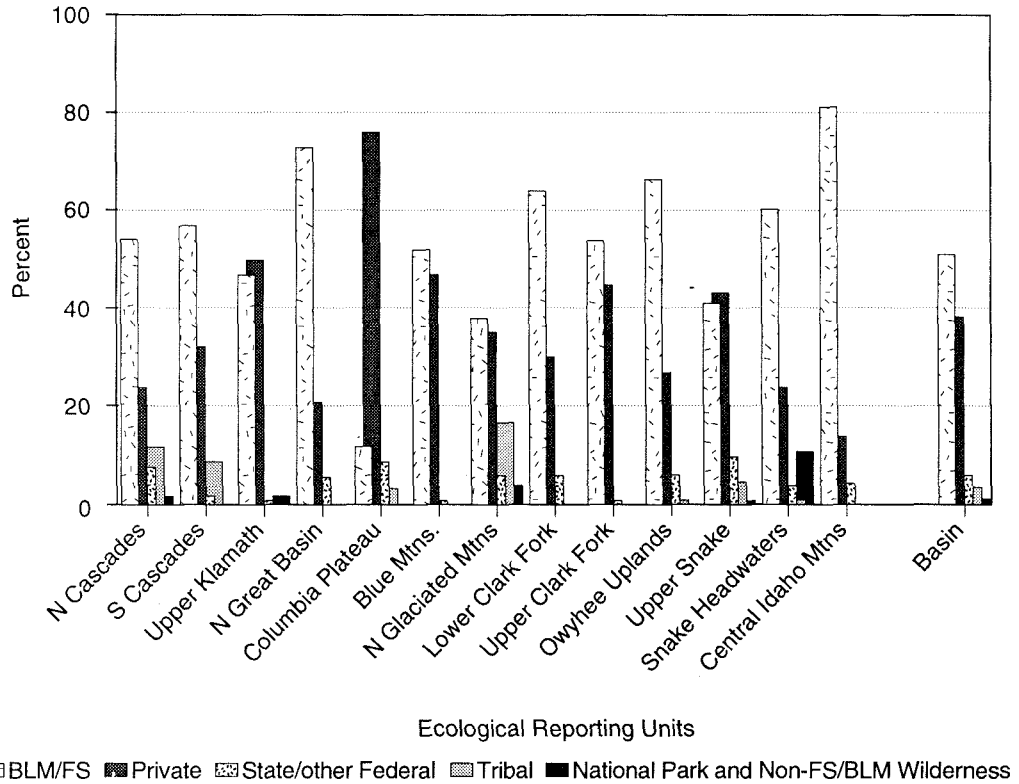


Figure 6.1— Land ownership patterns in the Basin and by Ecological Reporting Unit; categories are BLM and FS, National Park and other wilderness (not FS or BLM), other Federal and State, Tribal, and Private, 1995.

Klamath (50% private). Among the nonforested ERUs, the FS and BLM have the greatest potential influence in the Northern Great Basin (73% FS and BLM, 21% private), and the least in the Columbia Plateau (12% FS and BLM, 76% private).

The people—In a nation that has become largely urban, the Basin is strikingly rural. It accounted for 1.2 percent of the population of the United States in 1990. Over 77 percent of the U.S. population lives in urban areas; in the 13 western states[3] the percentage is even higher (84.6%) (Krannich and others 1994). By contrast, only 31 percent of the population in the Basin lives in urban areas, none of which contains more than one million people; only six of the 100 counties are considered metropolitan (McGinnis and Christensen 1996).[4] Sixty counties are in the most rural category defined by the Census Bureau: non-metropolitan and neither adjacent to a metropolitan county nor containing a community of at least 10,000 people; these 60 counties account for less than 25 percent of the Basin population.

Population density on non-public lands within the Basin is less than one-third of the U.S. average: on average, 20 people dwell in one square mile within

[3] The West Census region includes Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming (Campbell 1994).

[4] The Census Bureau defines a metropolitan county as one in a metropolitan statistical area (MSA). An MSA has a population of at least 100,000 and includes a large population center of at least 50,000 and adjacent communities that are economically and socially integrated with it. The metropolitan counties in the Basin are: Benton, Franklin, Spokane, and Yakima Counties (Washington), and Ada and Canyon Counties (Idaho) (McGinnis and Christensen 1996).

the Basin as opposed to 70 people per square mile for the Nation. Including Federal lands drops population density to 11 people per square mile. Sixty-two percent of the population lives within the Basin in communities of less than 10,000 people, in unincorporated places, or in open countryside—much higher than the 43 percent average for the United States (fig. 6.2). These averaged population densities mask tremendous variation across the Basin, from less than one person per one-square-mile in Harney County, Oregon, to as high as 338 people per one-square-mile in Ada County, Idaho.

People living in the Basin are similar to other people in the United States in age structure, educational attainment, occupational distribution, and sources of income, although variation exists across the Basin. The Basin has a slightly higher percentage of people under the age of 18 than the U.S. average (28.9 versus 25.6 %) and a lower percentage of people in the prime wage-earning years of 25 to 49 (36.0 versus 38.0%). Forty-eight percent of those people living in the Basin have achieved at least some level of higher education compared with 45 percent in the United States as a whole, suggesting it has a high quality workforce. The racial and ethnic composition of the Basin, however, is quite different from the rest of the country. Generally, the Basin has a higher percentage of Caucasians than the United States (91.7 versus 80.3 %); it also has a greater proportion of Native Americans (2.4 versus 0.8 %) and a smaller proportion of African-Americans (0.6 versus 12.1%), Hispanics (6.7 versus 9.0 %), and Asians (1.1 versus 2.9 %).

The economy—Overall, the economies of the four states making up the bulk of the Basin (Idaho, Montana, Oregon, and Washington) are doing well. In 1990 their economies comprised 3.6 percent of the national economy. Washington State's economy was larger than the sum of the other three (U.S. Department of Commerce

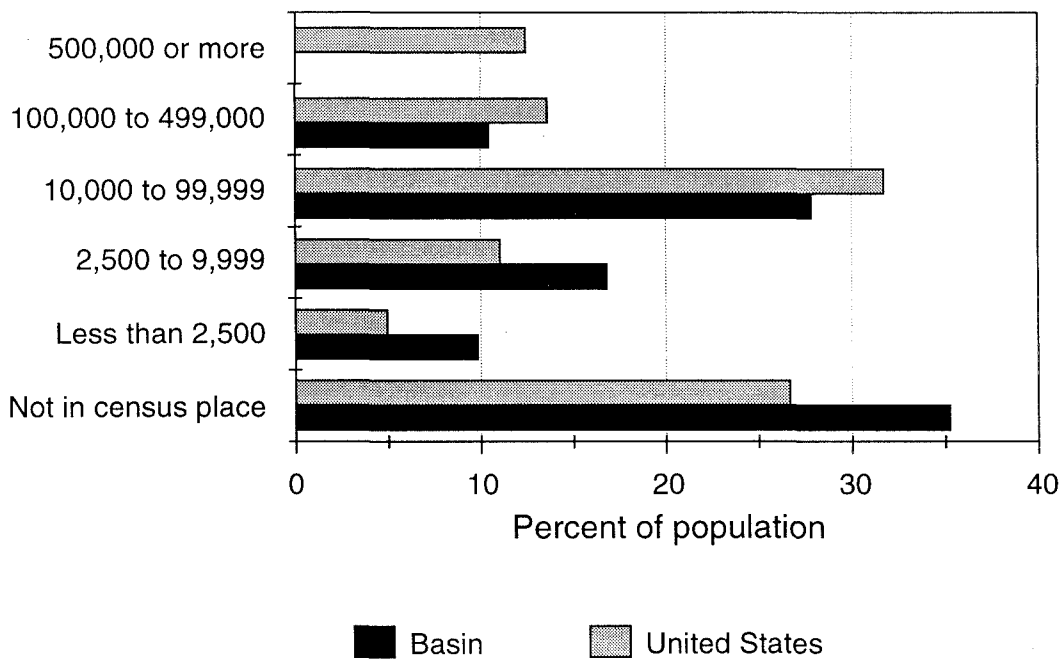


Figure 6.2— Population distribution among places of different sizes; United States and the Basin, 1990.

1993). Washington is the only one of the four states with higher per capita income than the U.S. average, but in all four states per capita income is growing faster than the U.S. rate (table 6.1). Similarly, "earnings per job" are increasing in Montana, Oregon, and Washington faster than in the United States; only Idaho has a smaller percent change. Poverty rate and percent change is lower than the U.S. average in Idaho, Oregon, and Washington, but not Montana. Unemployment rates in Idaho and Montana are lower than the U.S. average and decreasing at a faster rate. In Oregon and Washington the reverse is true: unemployment rates are higher than the national average and falling at a slower rate.

The six metropolitan counties in the Basin have been the center of its economic growth, with higher rates of growth in total employment, total personal income, and non-farm labor income, and a greater ability to weather national recessions than other counties. They tend to have lower per capita incomes than their counterparts throughout the United States; this gap has been widening since 1980. Some economists believe this indicates that amenities are attracting surplus labor, as has been found elsewhere (Treyz 1993, Power 1996); alternatively, these smaller metropolitan areas lack the highest paying jobs. Earnings per job in metropolitan areas of Idaho (primarily Boise) are increasing at a faster rate than the national average. Poverty rates in Washington's metropolitan counties are increasing at a faster rate, though the levels are still lower than the national numbers.

The non-metropolitan counties in the Basin have even better economic indicators than metropolitan counties. Per capita income is higher than the national average in all four states, although Montana's growth rate is lower than the national average. Earnings per job in non-metropolitan counties are higher than the national average everywhere except Montana.

Economic Strengths of the Basin

The Basin's economy is small relative to the United States; it accounted for only 1 percent of U.S. employment in 1995. We characterized the economic strengths of the Basin by identifying those economic activities within it that have a higher percentage of employment than the benchmark economy of the United States (Weimer and Hoyt 1948). Data showing the percentage employment in various economic sectors (see table 6.2) suggest that the traditional notion that manufacturing is the driving sector of the Northwest economy is too narrow (for example see Beuter 1995). Not surprisingly, economic strengths of the Basin include agriculture and agricultural services. Mining and manufacturing, are less important to the Basin's economy than to the Nation's. Basin-wide, including both public and private lands, timber and wood products [Standard Industrial Classification (SIC) 24] account for 2.6 percent of the jobs, cattle grazing accounts for 1.0 percent of the jobs, and mining accounts for 0.4 percent of the jobs (fig. 6.3). The percentage of jobs attributable to recreation is not shown here because the BEA does not define it as an industry. In the discussion of recreation below, we calculate that 14.6 percent of jobs in the Basin is attributable to recreation.

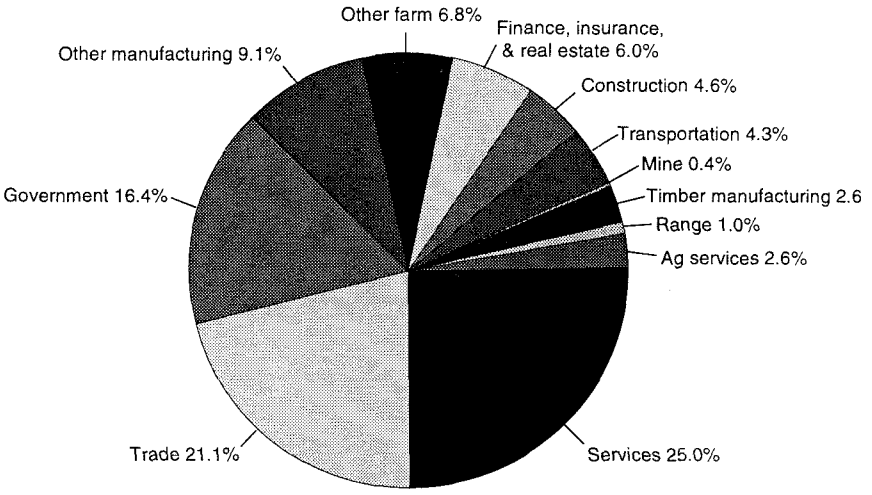


Figure 6.3— Employment in the Basin; distribution among economic activities, 1995.

Table 6.1— Current economic indicators for the United States, Idaho, Montana, Oregon, and Washington; totals, metropolitan and non-metropolitan counties, and current and percent change from previous year or decade.

Category	United States		Idaho		Montana		Oregon		Washington	
	Datum	Percent change	Datum	Percent change	Datum	Percent change	Datum	Percent change	Datum	Percent change
Total										
Per capita income[1]	$20,105	4.9	$17,512	5.0	$17,376	6.2	$18,605	5	$21,289	6
Earnings per job	$26,531	5.6	$23,216	5.4	$20,700	7.5	$23,916	5.7	$26,910	7.3
Poverty rate[2]	13.8%	11.3	13.3%	5.1	16.1%	30.8	12.4%	16.6	10.9%	11
Unemployment rate[3]	6.8%	-8.1	5.6%	-9.7	5.0%	-18	7.2%	-2.7	7.5%	1.4
Metropolitan Counties										
Per capita income	$21,247	4.7	$20,114	5.3	$19,154	4.7	$19,619	5	$22,084	6
Earnings per job	$27,944	5.7	$25,379	6.1	$22,561	5.8	$25,113	5.7	$27,844	7.4
Poverty rate	12.1%	6.1	10.7%	5.1	12.7%	30.8	11.3%	16.6	10.0%	11
Unemployment rate	6.7%	-6.9	4.3%	-10.4	4.3%	-18.9	6.5%	-4.4	7.0%	0
Non-Metropolitan Counties										
Per capita income	$15,682	6.2	$16,377	4.7	$16,817	6.8	$16,236	5.1	$17,400	5.7
Earnings per job	$20,085	5.5	$22,087	4.9	$20,058	8.3	$20,690	5.7	$21,431	6.6
Poverty rate	17.1%	8.2	14.3%	5.1	17.1%	30.8	15.0%	16.6	15.6%	11
Unemployment rate	7.4%	-7.5	6.2%	-10.1	5.3%	-15.9	8.9%	-1.1	10.3%	3

Source: U.S. Department of Agriculture Economic Research Service, August 1, 1995 AUTOFAX State Fact Sheets.

[1]Income and earnings figures are 1992 with change 1991-92, for U.S., Oregon, and Washington; Idaho and Montana are 1993 figures with change 1992-93.

[2]Poverty rates for all are 1990 data, with change 1980-90.

[3]Unemployment figures are 1993, with change 1992-93, for U.S., Oregon, and Washington; Idaho and Montana are 1994 figures, with change 1993-94.

Table 6.2— Employment in economic sectors of the United States, the Basin, and Bureau of Economic Analysis (BEA) regions for 1995; asterisks indicate values above the national average.

Industry	United States	Basin Average	Tri-Cities	Spokane	Missoula	Idaho Falls	Twin Falls	Boise	Pendleton	Redmond-Bend[1]	Butte
	Percent										
Agriculture services	1.14	2.56*	4.41*	1.13	1.92*	2.69*	4.72*	2.53*	2.63*	2.13*	0.92
Mining	0.66	0.45	0.23	0.61	0.64	0.83*	0.26	0.38	0.00	0.00	1.47*
Construction	5.20	4.65	4.21	4.55	5.40*	5.38*	5.37*	5.09	3.48	4.58	3.48
Manufacturing	14.11	11.71	11.29	11.20	11.53	9.59	11.66	12.55	14.96*	16.04*	4.40
SIC 24[2]	0.57[3]	2.52*	1.00*	2.79*	4.98*	0.51	0.50	2.32*	2.65*	5.54*	2.35*
Transportation	4.76	4.30	3.34	4.30	5.67*	3.72	4.72	4.88*	4.53	3.76	6.04*
Trade	21.49	21.14	21.11	22.10*	21.41	21.93*	21.10	20.38	18.97	20.70	20.33
FIRE[4]	7.53	6.00	4.64	6.65	6.22	5.52	5.64	7.71*	4.53	5.48	6.78
Services	28.38	25.02	23.21	26.79	27.36	27.24	21.36	24.17	20.86	23.65	31.68*
Government (all)	14.57	16.39*	14.60	18.76*	15.00*	15.79*	11.01	16.34*	17.81*	15.14*	23.08*
State & local	10.44	12.18*	11.92	14.04	10.52	11.79	9.04	10.32	13.38	11.05	18.50*
Federal	4.13	4.21*	2.68	4.72*	4.48*	4.00	1.97	6.02*	4.43*	4.09	4.58*
Farm employment	2.16	7.78*	12.96*	3.92*	4.85*	7.31*	14.15*	5.98*	12.22*	8.51*	1.83

Note: Farm employment is calculated as the difference between total employment and covered employment. Because it is calculated as a difference it includes rounding errors.

[1]Redmond-Bend is the portion of the Portland-Salem BEA region that is inside the Basin.

[2]Sources for lumber and wood-products manufacturing (SIC 24) employment.

[3]1990 data (Beuter 1995).

[4]Financial, insurance, and real estate industries.

A more complex story emerges by looking at individual BEA regions (see map 6.1) within the Basin. Agriculture is an economic strength in every region except the Butte BEA region. Mining in the Butte BEA region is double the national average, and it is important in the Idaho Falls BEA region as well. Manufacturing is a strong activity only in the Pendleton and Redmond-Bend BEA regions, and forest products and food processing are important components of both. The importance of trade in each BEA region (except the Pendleton region) mirrors the Nation. The same can be said about the service sector except that there is more variability around the Basin. In the Boise BEA region, finance, insurance, and real estate (FIRE) are important activities. In several BEA regions construction and transportation are strong parts of the economy. The percentage of jobs supported by recreation is highest in the Idaho Falls (30%), Missoula (31%), and Redmond-Bend (25%) BEA regions (see the "Recreation" section for more information).

Historical Perspective

Populations in the sparsely settled lands east of the Cascade Range grew rapidly between 1890 and 1920, then stabilized or declined due to restructuring of agriculture and shifts in economic opportunities (Robbins and Wolf 1994). Between 1960 and 1990, population in the western quadrant of the United States had the fastest growth rate (88.2 % versus 39 % for the Nation), increasing its percent of the U.S. population from 15.6 to 21.2 percent. Much of the growth in the western states during this period occurred outside the Basin; however, the population of the Basin still grew faster than the population of the United States. Since the 1960s the population growth in the Basin has been highest in those counties adjacent to protected, usually Federal, lands (Rudzitis 1995). Some economists conclude from this that areas with high amenity values attract new businesses and skilled labor (Power 1996).

Business cycles in the Basin generally mirror those of the total U.S. economy (see table 6.3), with corresponding periods and similar rates of expansion and decline. In certain periods, the effects of national business cycles on demographics and economics within the Basin have shown departures from the norm. The Basin's economy fared better than that of the United States during the generally prosperous decade of the 1970s. Population growth out-paced even that of the 13 western states and, on average, census locations grew rapidly regardless of size. The Basin's prosperity was associated with a national "rural renaissance" that ran counter to the general trend of increasing urbanization. This renaissance was driven by decentralization of manufacturing and services for health and education, reduction in the rate of people leaving agriculture, increased residential sprawl of metropolitan commuters, modernization of rural communities and roads, and increased preference for small town life (McGinnis and Christensen 1996).

During the 1970s total employment in the Basin grew faster than for the United States and showed little effect from the national 1974-1975 recession. Non-farm labor income, an indication of the response of a regional economy to national business cycles, grew faster than the U.S. economy during expansions and did not slow down as much as the U.S. economy during the recession. Although per capita income grew more slowly than the national rate, this effect was counterbalanced by growth in employment. Consequently, the buying power of the Basin's economy increased relative to that of the United States: total personal income (the product of employment and per capita income) grew by 70.9 percent versus 64.4 percent for the United States.

The slower than average per capita income growth in the Basin during the 1970s can be interpreted several ways: there may have been structural shifts in the Basin's economy leading to a smaller proportion of high-paying jobs, or the Basin may have had an abundant labor supply that enabled businesses to attract sufficient labor without raising

Table 6.3—Population, gross national product, and income figures for the United States, 1929-1994 and projections to 2040.

Year	Population		Gross national product		Disposable personal income		Per capita disposable personal income	
	Millions	Annual rate of change	Billion 1982 dollars	Annual rate of change	Billion 1982 dollars	Annual rate of change	1982 dollars	Annual rate of change
1929	121.8	--	709.6	--	498.6	--	4,091	--
1933	125.7	0.8	498.5	-8.4	370.8	-7.3	2,950	-7.8
1940	132.1	0.8	772.9	7.9	530.7	6.2	4,017	5.4
1945	139.9	1.1	1,354.8	-1.9	739.5	-1.3	5,285	-2.4
1950	151.7	1.7	1,203.7	8.5	791.8	7.1	5,220	6.2
1955	165.3	1.8	1,494.9	5.6	944.5	5.6	5,714	3.8
1960	180.8	2.1	1,665.3	2.2	1,091.1	2.2	6,036	0.1
1965	194.3	1.3	2,087.6	5.8	1,365.7	5.8	7,027	4.5
1970	205.1	1.2	2,416.2	-0 .3	1,668.1	4.3	8,134	3.1
1975	216.0	1.0	2,865.0	-1.3	1,931.7	1.9	8,944	0.9
1976	218.0	0.9	2,826.7	5.3	2,001.0	3.6	9,175	2.6
1977	220.3	1.0	2,958.6	4.7	2,066.6	3.3	9,381	2.2
1978	222.6	1.1	3,115.2	5.3	2,167.1	4.9	9,735	3.8
1979	225.1	1.1	3,192.4	2.5	2,202.6	2.1	9,829	1.0
1980	227.7	1.2	3,187.1	- 0.2	2,214.3	0.1	9,723	1.1
1981	230.1	1.0	3,248.8	1.9	2,248.6	1.5	9,773	0.5
1982	232.4	1.0	3,166.0	-2.5	2,261.5	0.6	9,732	- 0.4
1983	234.8	1.0	3,279.1	3.6	2,331.9	3.1	9,930	2.0
1984	237.1	0.9	3,501.4	6.8	2,469.8	5.9	10,419	4.9
1985	239.3	1.0	3,607.5	3.0	2,542.2	2.9	10,622	1.9
1986	241.6	1.0	3,713.3	2.9	2,645.1	4.0	10,947	3.1
1987	243.9	1.0	3,804.4	2.5	2,704.0	2.2	11,134	1.7
1988	246.3	1.0	3,954.2	3.9	2,798.3	3.5	11,418	2.6
1989	248.8	1.0	4,054.2	2.5	2,848.1	1.8	11,512	0.8
1990	251.5	1.1	4,103.9	1.2	2,897.1	1.7	11,591	0.7
1991	252.7	0.5	4,079.0	0.1	2,908.6	0.4	11,510	0.1
1992	255.5	1.1	4,172.6	2.3	2,998.7	3.1	11,737	2.0
1993	258.1	1.0	4,302.7	3.1	3,044.8	1.5	11,788	0.4
1994	260.6	1.0	4,476.8	4.0	3,152.7	3.5	12,080	2.5
Projections								
2000	272.0	0.8	5,383	2.6	3,580.7	2.1	13,164	1.4
2010	291.0	0.7	7,031	2.7	4,503.0	2.3	15,474	1.6
2020	307.0	0.5	9,166	2.7	5,697.7	2.4	18,559	1.8
2030	318.0	0.4	11,957	2.7	7,259.5	2.5	22,829	2.1
2040	327.0	0.3	15,627	2.7	9,313.3	2.5	28,481	2.2

Source: Council of Economic Advisors (1995); WEFA (1991).

wages. Some economists argue that the latter can happen when a region offers a high quality of life such that people are willing to work for less in exchange for the amenities of living there (Whitelaw and Niemi 1994). The demographic effects of amenity-driven migrations on regional growth have been modeled for at least 40 years.[5] In the Basin, public lands are a dominant provider of amenities; recent survey evidence suggests that these amenities do provide an incentive for economic growth.[6]

In the 1980s the Basin's economy had a different response to national business cycles. The 1980-1982 recession disproportionately affected commodity markets such as agriculture and timber, putting the Basin's economy in a deep recession from which it recovered at a rate slower than that of the United States. All the demographic and economic indicators—total employment, per capita income, total personal income—grew more slowly than for the United States. Population in the Basin still grew by 6 percent, but included a 9 percent rate of natural increase (births minus deaths) offset by a 3 percent rate of out-migration. The age structure of the Basin changed markedly with a 27.6 percent increase in the 65-and-older age group, primarily due to the aging of the resident population rather than to migration.

The different ways in which population can change, natural increase, in-migration, or out-migration, have important consequences for regional economies. Natural increase has long-term, slowly felt impacts since expenditures associated with household formation are delayed for 20 years. Migration has an immediate effect on the tax base and the demand for goods and services associated with household formation. Thus shifts in net migration, in or out of the Basin, have a greater impact on rates of economic growth than natural increase.

A shift toward net in-migration occurred in the late 1980s, and population growth continues to be an economic and demographic hallmark of the region today (Sommers and others 1995). Between 1990 and 1992, States in the study area were some of the fastest growing in the Nation: Nevada (11.1%), Idaho (5.9%), Washington (5.7%), and Oregon (4.6%) all grew well above the U.S. rate of 2.6 percent. Since 1990, the population in the Basin has been growing faster than the national average for all degrees of urbanization; small metropolitan counties grew the fastest at 6.3 percent, non-metropolitan counties adjacent to metropolitan ones had the next fastest rates of growth at 5.8 percent. Recent evidence indicates that renewed growth in non-metropolitan areas may be part of a new national trend. This may explain why the U.S. recession of 1990-1991 had little impact on the Basin; during this period, nonfarm labor income in the Basin grew faster than it had during the national expansion between 1983 and 1989.

Associated with recent population growth in Idaho, Montana, Nevada, Oregon, and Washington is the evolution from "a mature resource-based economy to one that is becoming a major player in advanced technology, retail, and transportation services" (Sommers and others 1995). The information age has restructured the economies of these states leading to more rapid expansion in non-manufacturing than manufacturing sectors. Construction and real estate businesses, because they are associated with the population growth, have been robust. The gaming sector, casinos and the like, has also shown explosive growth. The producer-services sector, which includes finance, engineering, management, law, advertising, computer programming, building maintenance, and guard services, has also grown rapidly.

[5] Power, Thomas Michael. 1995. Memo to Tom Quigley, Science Integration Team Leader, Interior Columbia Basin Ecosystem Management Project, July 5, 1995. 3 p. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar, Walla Walla, WA 99362.

[6] Rudzitis, G.; Watrous, C.; and Johansen, H. 1995. [Manuscript]. Attitudinal survey of Upper Columbia River Basin residents. Moscow, ID: University of Idaho Department of Geography. [not paged].

In contrast, the forest products sector in the Northwest economy (see table 6.2), continues to decline. Market watchers expect more changes and downsizing to be involved in reaching new levels of equilibrium harvest (Sommers and others 1995). On the other hand, some components of the forest-products sector have been growing rapidly, particularly manufactured housing, millwork production, and the paper sector.

Differences Among Non-metropolitan Counties

Because one of the policy questions relevant to the ICBEMP deals with economic growth in non-metropolitan counties, we wanted to learn whether there are any structural characteristics of counties which exhibit greater economic growth or resiliency. A typology of non-metropolitan counties developed by the Economic Research Service (ERS) (initially in 1979, and updated with three new categories in 1989) has six categories of economic specialization based on the derivation of income:[7] farming, manufacturing, mining, government,[8] services, and nonspecialized (counties that fell into no other group)(Cook and Mizer 1994). The typology also has five policy categories: retirement,[9] Federal land,[10] commuting,[11] transfers-dependent,[12] and persistent poverty.[13]

We added a sixth policy category—recreation counties[14] (Johnson and Beale 1995)—because in the Basin, over 80 percent of recreation value on public lands is derived from BLM- and FS-administered lands and their management has important implications for economic development.

One question concerns the likelihood that a county's economy will resemble its current structure in ten years. We wondered whether the likelihood of change could be correlated with the predominant economic activity: for example whether farming counties are more likely to evolve into something else than manufacturing counties. In the 1989 typology, about one-third of the counties in the Basin were classified in the same categories as in 1979, changes in one-third may be due to the new categories or changes in definition, and the remaining third experienced real changes in the composition of their economies (table 6.4) (McGinnis and Horne 1995). The farming category was the most common and most stable among Basin counties. The manufacturing and retirement categories lost the most counties in both percentage and absolute terms. The farming and the nonspecialized categories gained the largest number of counties. Of the 14 nonspecialized counties in the 1989 typology, five had been in a specialized economic group in 1979 but strengthening of other sectors diminished the importance of the formerly dominant sector (see McGinnis 1996).

Many county economies ceased to be dominated by manufacturing because of losses in wood products or minerals processing. For example, Gem, Idaho, Grant, and Harney Counties in Oregon, and Klickitat County, Washington changed from manufacturing- to farming-dominant, while Idaho and Nez Perce Counties in Idaho, Klamath County in Oregon, and Stevens County in

[7] Service activities contributed a weighted average of at least 50 percent of labor and proprietor income 1987-1989. Service activities include private, personal, and agricultural services, wholesale and retail trade, finance and insurance, transportation, and public utilities.

[8] Government includes federal, state, and local offices; military installations; public educational and health facilities; prisons; transit, housing, port, customs, airport and other special purpose authorities; public housing; and units that manage public resources (forests, rangeland, and parks).

[9] Retirement counties had 1970-1980 net in-migration rates of people aged 60 and over that were at least 15 percent of expected population for this age group in 1980.

[10] Federal counties had at least 33 percent of the land area in Federal ownership in 1977.

[11] At least 40 percent of workers commuted to jobs outside the county in 1990.

[12] At least 25 percent of total personal income was accounted for by federal, state, and local transfer payments 1987-1989.

[13] Persistent poverty counties had per capita personal income in the lowest quantile in 1950, 1959, 1969, and 1979.

[14] Recreation counties were defined using several income, employment, and noneconomic indicators--such as percent seasonal housing. They include places that specialize in recreation unrelated to outdoor activities, such as gaming.

Table 6.4—Typology of non-metropolitan counties in the Basin; change in number of counties within each economic or policy category between 1979 and 1989.

Economic or policy group	Number of counties 1979	Number of counties 1989	Number of counties in same category
Metro	5	6	5
Economic Groups			
Farming	31	35	29
Manufacturing	19	12	9
Mining	4	6	3
Government	11	10	7
Services	NA	17	NA
Nonspecialized-unclassified	6	14	3/9[1]
Policy Groups			
Retirement	16	7	5
Federal lands	65	64	61
Commuting	NA	5	NA
Transfers	NA	6	NA
Persistent poverty	0	1	0
Recreation	NA	18	NA

NA= "Not Applicable" since this group was not defined in the 1979 typology.
[1]Three of these counties were unclassified in 1979, but six others did not qualify for any economic group in 1979.

Washington became nonspecialized. Bonner County in Idaho and Jefferson County in Oregon came into the manufacturing group because of increases in wood products income. Note that the instability of the manufacturing county group was evident prior to the 1991 Judge Dwyer[15] decision (enjoining FS timber sales until a management plan for northern spotted owl habitat was developed) and was largely influenced by forces other than FS or BLM policy. The large drop in retirement counties appears related to the juxtaposition of high in-migration during the 1970s and slow population growth during the 1980s, making it difficult to meet the criteria of having retirement age in-migration be 15 percent of the expected retirement-age population. One retirement county became metropolitan (Canyon County, Idaho).

We examined trends in various economic indicators to see whether particular groups have shown consistent patterns (figs. 6.4 and 6.5). Of the economic groups, the services-dependent counties have consistently shown the highest rates of economic and population growth since 1970. This group includes counties with trade-center towns (Idaho Falls, Twin Falls, and Missoula), and growing recreation and tourism economies (Sun Valley, Kalispell, Jackson Hole, and Elko). Since the early 1980s this economic group has had the highest per capita income. Its employment and total personal income growth rebounded much faster after the early 1980s recession than the other economic groups. This was the only economic group having net in-migration between 1980 and 1990.

[15] *Seattle Audubon Society v. Evans*, 771 F. Supp. 1081 (W.D. Wash) 1991.



Figure 6.4— Rate of population change in the Basin counties according to economic typology, average annual percent change, 1970-1992.

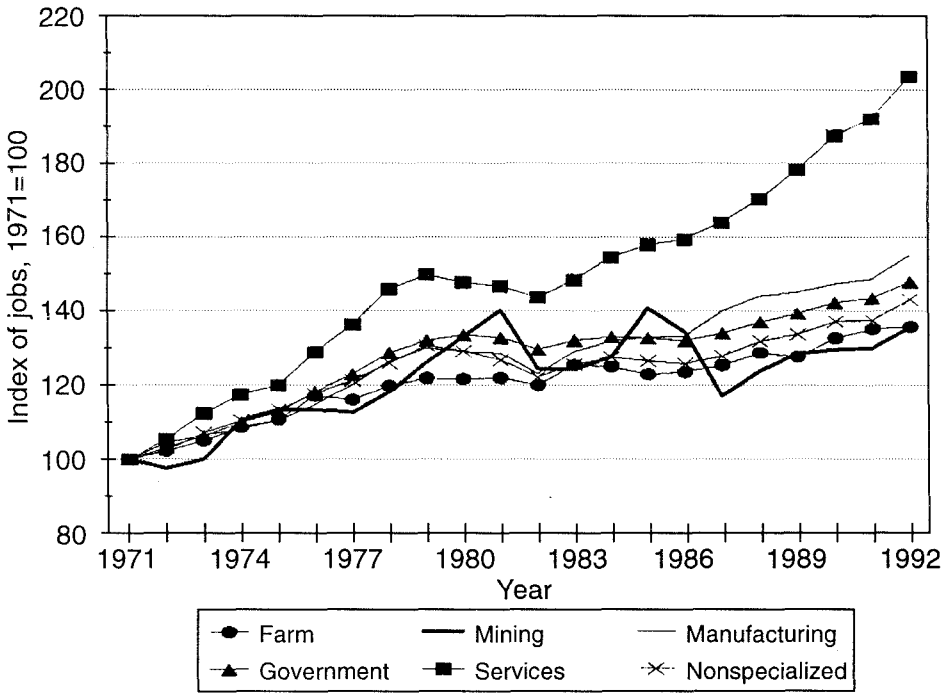


Figure 6.5— Employment growth in the Basin counties within each category of economic typology, 1971-1992.

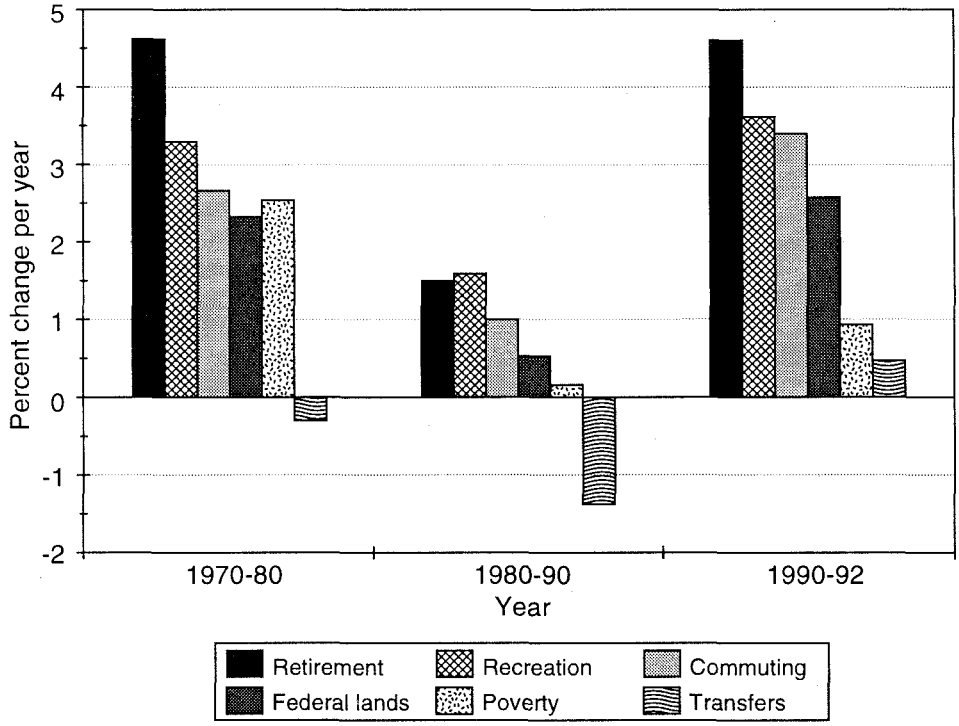


Figure 6.6— Rate of population change in the Basin counties within each category of policy typology, average annual percent change, 1970-1992.

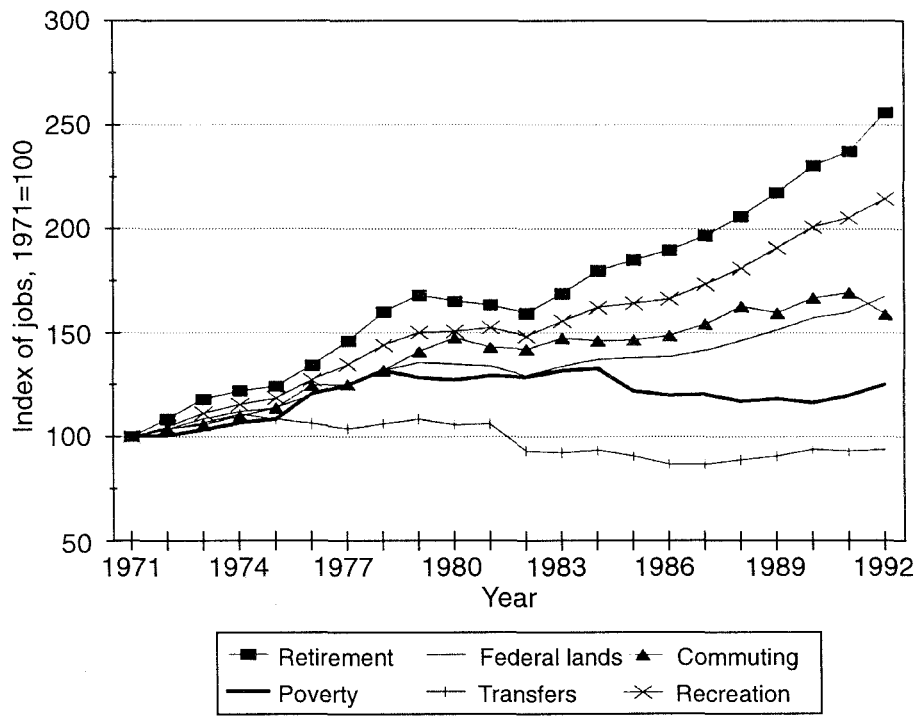


Figure 6.7— Annual change in employment in the Basin counties, within each category of policy typology, 1971-1992.

The mining counties have had the most volatile economies in the past 25 years. They fared well in the 1970s, but in the 1980s suffered population losses and very slow rates of job growth. The fluctuations in the mining sector were clearly evident as total personal income declined by 20 percent in the mid-1980s. Per capita income tends to be cyclical (though not in step with national business cycles), but the average salary is now the highest among the non-metropolitan groups in the Basin.

Farming counties posted lower growth rates than the Basin average during the 1970s and the 1980s and also exhibited greater volatility in per capita income than other non-metropolitan counties. The government, manufacturing, and nonspecialized counties tended to follow similar patterns of fast economic growth in the 1970s (though slower than the services, recreation, and retirement groups), very slow growth following the early 1980s recession, and renewed growth late in the decade.

The manufacturing group has had the lowest per capita income of the economic groups but the second highest salary per job. This seeming incongruity can be explained by differing labor force participation rates, age and family structures, and commuting patterns (McGinnis and Horne 1995). Most of the economic and policy groups show salary per job tracking the Basin average for non-metropolitan counties and following the trend of declining real average salaries since the mid-1970s. The government group is the exception with significantly lower average salary than the other groups since 1970.

Among the policy groups, recreation and retirement counties have shown consistently high rates of growth in population, total employment, and total personal income over the last 20 years (figs. 6.6 and 6.7). They were the only two groups showing substantial net in-migration in the 1980s. Between 1990 and 1992, retirement counties continued to have the highest rates of population growth among the non-metropolitan counties, followed closely by recreation and commuting counties.

The recreation counties have consistently had the highest per capita income of the policy groups. A comparison of recreation and manufacturing counties found this is in part because residents of recreation counties derive more income from non-salary sources such as investments and transfers than residents of manufacturing counties (fig. 6.8). This supports arguments by some economists that recreation counties attract people with high property income and wealthy retirees. But residents of recreation counties also have higher employment earnings per capita despite having lower average earnings per job (McGinnis and Horne 1995). This seeming contradiction stems in part from residents of recreation counties having fewer dependents per wage earner (which would increase per capita earnings) than those of manufacturing counties. It is also due to differences in how the two numbers are calculated; earnings per capita are calculated by county of residence, and earnings per job are calculated by county of employment—thus

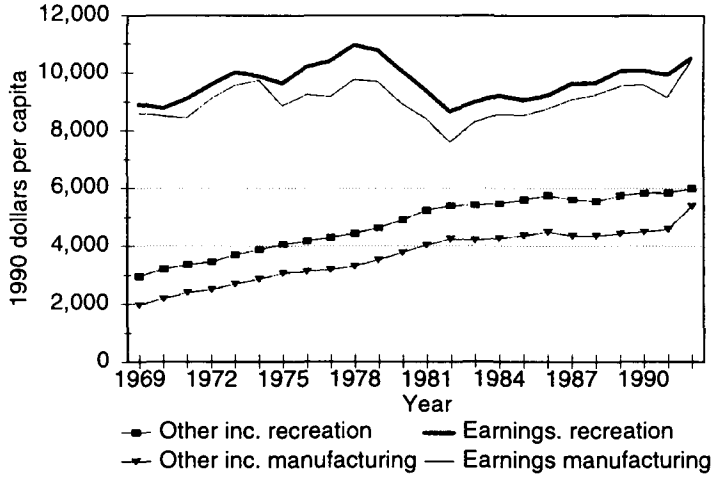


Figure 6.8— A comparison of per capita income in recreation and manufacturing counties within the Basin, divided into income from earnings and other (property and transfers).

people who commute between counties can skew the results. In both recreation and manufacturing counties the net effect of commuting is to remove income, but the impact per capita is greater in manufacturing counties.

In contrast to growth in the rest of the Basin, counties dependent on transfer payments experienced 20 years of sluggish growth and population losses. Three of the six transfers-dependent counties experienced closures of mines or smelters in the 1980s. These counties show the typical pattern of out-migration of working-age population following economic collapse and with it an increase in the importance of transfers among the remaining, primarily older, population.

Outlook

The U. S. population is expected to continue to grow, albeit at a declining rate, over the next 50 years (Marcin 1993). The population will become older, more affluent, more educated, and more racially and culturally diverse. The gross national product is expected to grow at an average rate of 2.7 percent over the next half century, and growth in per capita disposable income is expected to increase in line with general aging (see table 6.3). The economy is expected to evolve toward information-based technologies and service, and away from agriculture and forestry (Marcin 1993).

We expect the general economic growth of the past five decades in the Basin to continue. One implication of this is steady growth in per capita income and sustained in-migration in parts of the Basin. By the year 2040, the Basin population is expected to increase in size from between 407,000 (14%) and 3.6 million (108%).[16]

[16] The 407,000 figure represents the lowest projection available and was derived by distributing projections in national employment and earnings by industry down to states and counties based on historical growth rates (U.S. Department of Commerce 1992). The 3.6 million figure was derived from U.S. Census projections of rates of natural increase and migration patterns similar to recent trends (McCool and Haynes 1996).

Demographic trends are likely to have significant impacts on the Basin—primarily in changing its rural nature but also in what society will want from its public lands. Increased residential development adjacent to public lands will increase pressures to control fires and to modify some forest practices. The types of people attracted to the Basin may be more interested in ecological issues and passive-use values than traditional extractive industries. Retirees may increase the demand for bird-watching, walking, and picnicking. Improvements in transportation and telecommunication systems may attract population and business to the Basin's small metropolitan areas.

All these factors suggest increased stresses and conflict over land-use in the Basin. Residential developments tend to be located on private lands adjacent to public lands, often in riparian areas. These developments will detract from scenic vistas and could further impair functioning of riparian ecosystems. Allocation of water between agriculture, residential, and instream-use may become increasingly controversial.

By the year 2040 the BEA expects economic sectors in the Basin to exhibit differential growth rates but no change in rank. Using population projections by McCool and Haynes (1996) and BEA employment projections (U.S. Department of Commerce 1990, 1992), we found greatest growth in the service sector (including health, business, educational, and legal services) which is expected to increase by 456,000 jobs by the year 2040. The average wage rate in the service sector currently is $18,185 per year, placing it eighth out of 11 sectors. Other sectors in which employment is expected to grow are trade (314,000 new jobs); government (186,000 jobs, 75% of which will be at state and local levels); and manufacturing (148,000 jobs). The agricultural services sector, which includes farm operators and managers, nursery workers, tree planters, and inspectors of agricultural products, is expected to increase by

60,000 jobs by the year 2040. The average wage rate in this sector is the lowest of all sectors ($11,300 per year) and is expected to remain lowest in 2040. On a percentage basis, the fastest rate of job growth will be in the service sector, followed by agricultural services, trade, and FIRE (finance, insurance and real estate).

The BEA projections show declines in the percentage of jobs in the Basin in (in decreasing order) farming, government, and manufacturing sectors. The durable goods manufacturing sector, which includes timber and plywood, is expected to decline in percentage of jobs by the year 2040. Average wage per job is highest in the manufacturing sector ($27,500 per year) and is expected to remain so. The nondurable goods sector, which includes paper production, is also expected to decline in percentage of jobs by the year 2040. This is also a high wage sector; the nominal average wage is currently $23,000 per year. The farming sector is expected to remain one of the smallest employment sectors. Average wage is the second to lowest in this sector after agricultural services ($12,000 per year). The government sector will decline by 0.03 percent per year to the year 2040. Wage rates are modest in this sector, averaging $19,000 per year.

Trends in Resource Allocation Priorities

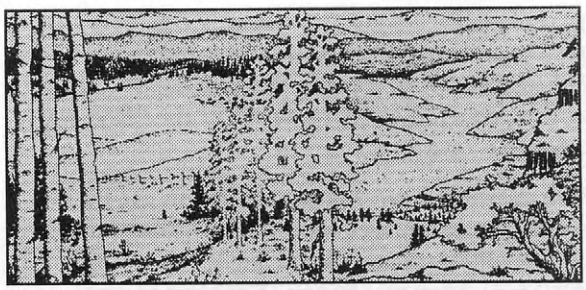
The Social Assessment (following chapter) discusses the history of the Basin and the laws pertaining to the management and development of natural resources. From an economic perspective there are two lessons to be learned from the laws, policies, and regulations that guide Federal land stewardship. First, these laws, policies, and regulations document shifting public expectations about goods, services, and conditions derived from or found on public lands. Second, these laws, policies, and regulations have served to dictate resource allocation in those cases where markets either do not exist or where society has elected to intervene in markets (for example to lower prices).

The first lesson involves understanding that shifts in Federal policy through time have played their part in creating the political, legal, and ecologic conundrum faced by society, and its land managers, today. These shifts reflect changing societal views about what it wants from these lands. This discussion is evidence that society's priorities have changed over time—and by inference, will continue to do so.

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RESOURCE CHARACTERIZATION

In this section we address specific resources relevant to FS and BLM administration, such as fish, minerals, range, recreation, special forest and range products, timber, and water, and include any available projections of supply and demand for each resource. The information presented in this section forms the basis for the economics of ecosystem management section at the end of this document that examines how different management directions might affect the bundles of goods, functions, and conditions produced by these ecosystems.

We have attempted to make the discussions of each resource group as consistent as possible. The differences in the detail of discussion for each resource are unavoidable and reflect many things. For example, a substantial amount of economic data are available for timber, but such information is virtually non-existent for special forest and range products (for example, floral greens, mushrooms, and huckleberries). For some resources, data were available for scattered locations but not consistently across the Basin. Unevenness in definition and methodology in data collection, between states for example, made it impossible to synthesize some information. Differences in the economic behavior of the resources exist—timber markets are well understood, recreation is largely not a market good, fisheries are a classic example of common goods. These differences result not only in uneven data, but in different traditions within the economic discipline of characterizing and evaluating resource questions.

Fish[17]

Understanding the economic systems relating to fisheries in the Basin is important because they are one of the resources the Charter specifies the ICBEMP to address. This section t orld in which fish populations are too low to support much commercial fishing but the consumptive and non-consump tive recreational value of the fish is substantial.

The Columbia River fishery story illustrates two important economic lessons. First, it demonstrates that a resource can be used at a rate that leads to its depletion. The same incentives for overuse are currently at work on under- or unpriced resources on BLM- and FS-administered lands. The second lesson is that economies are dynamic. Economic activities that dominate a society can disappear because of resource depletion, changes in technology, or changes in taste. Likewise, economic activities of minor importance today may become dominant activities in the future.

The Basin currently supports multiple fisheries enjoyed by American Indians and recreational and commercial interests. Today, in terms of total economic value, recreational fishing is more important than commercial fishing, and much of it takes place on public lands and waters. Recreational uses of fish are diverse and

[17] This section was written by Amy L. Horne based on Fluharty (1995).

pervasive, including fisheries for anadromous, resident, warmwater, and coldwater species; ice fishing; and fish viewing (recreational fishing will be covered in more detail in the "Recreation" section).

Fish spawned, reared, and cultured in the Basin contribute to in-river commercial fishing below Bonneville Dam and mixed stock fisheries off Alaska, California, Oregon, Washington and British Columbia, Canada. Commercial fishing above Bonneville Dam is currently far below historical levels and primarily reserved for the tribes by treaty (a small non-treaty fishery for white sturgeon exists). The tribes have commercial fisheries for steelhead, sturgeon, shad, and walleye and severely limited harvests of chinook and coho salmon. Compensation to the tribes for impacts of the dams on fisheries has reached a total of $90 million (nominal dollars) and can be expected to continue.

Altogether, the value of commercial fish harvests from the Basin is estimated at 12 million dollars per year, 93 percent of which is attributable to salmon, 5 percent to steelhead, and the balance to white sturgeon, shad, and walleye (table 6.5) (Fluharty 1995). A conservative estimate is that this results in between 600 and 1,200 direct jobs. More realistic estimates of lower income and less-than-full-time work would make this number higher (Fluharty 1995). On the other hand, the number of jobs may be overestimated because it is based on a 13-year average that includes a steadily downward trend since 1988; the 1995 value of the commercial fishery will probably be much below that. Today's commercial fishing values are lower than they would be if the fishery had been managed for strong stocks instead of for restricted catches (Fluharty 1995).

There are many resident native and non-native fish that contribute to fish values in the Basin. Some introduced species—both warm and

Table 6.5—Value of commercial fish stocks of the Basin, average annual in 1993 dollars, 1980 to present.

Species	Treaty commercial fishery in zone 6[1]	Non-treaty Columbia River landings	Estimated annual average value of Basin salmon caught in commercial ocean fisheries[2]	Total
	Thousand 1993 dollars			
Chinook	2,119	3,632	4,820	10,571
Coho	27	244	--	271
Sockeye[3]	71	42	--	113
Steelhead	495	--	--	495
White Sturgeon	270	24	--	294
Shad	1	40	--	41
Walleye	2	--	--	2
Total	2,985	3,982	4,820	11,787

Source: Fluharty 1995.

[1] Zone 6 is the mainstem of the Columbia River between the Bonneville and Chief Joseph Dams.

[2] 1987-1991.

[3] No commercial sockeye salmon fishery has taken place since 1988.

coldwater fish—provide recreational activity but at the same time compete for habitat or directly prey on native resident species (Fluharty 1995). Recreation industries are evolving around some of these introduced species but in general they have received little management attention.

Historical Perspective

The history of fish in the Basin, and their economic significance, falls into three time periods. The first period is before significant commercial harvest began in 1860, when fishing was conducted primarily by Native Americans. The second period, from 1860 to 1980, is characterized by steadily dropping salmon populations, overfishing of some species, dam construction and operation, and loss of habitat; during this period the proportion of salmon caught by tribal members nearly went to zero while non-tribal commercial harvests climbed to near 100 percent. The third period, from 1980 to the present, is defined by a movement toward parity in the distribution of the shrinking salmon harvest within the Basin between tribal and non-tribal peoples, and the initiation of Basin-wide plans aimed at improving the salmon situation (fig. 6.9).

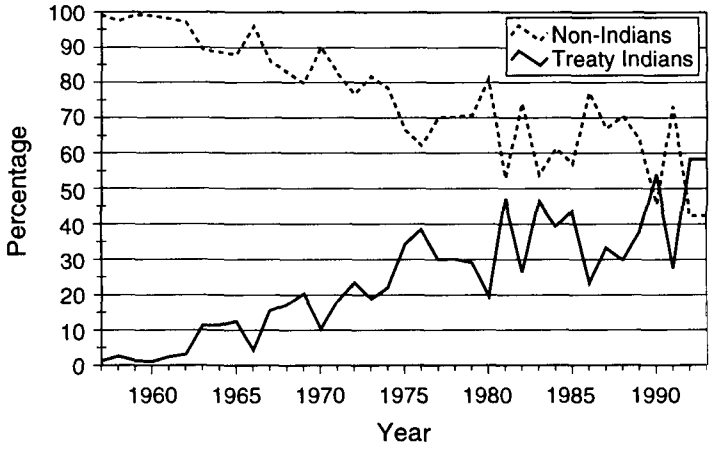


Figure 6.9— Distribution of Columbia River commercial landings of salmon and steelhead between tribal and non-tribal peoples, 1957-1993.

Between 1860 and 1980 the numbers of fish caught by Native Americans dropped precipitously from pre-commercial levels. In the mid-Columbia River[18] numerous conflicts occurred between tribal and non-tribal fisheries. Non-tribal fishwheel operators decreased tribal catch by occupying the best sites for harvesting salmon and by harvesting fish before tribes could. Dams and other habitat loss further diminished tribal fisheries, so that by 1958 their catch had dropped to only a few thousand fish.

With the treaty-fishing zone being located upstream from Bonneville Dam, and most of the fishery occurring below the Dam or in the ocean, questions about the meaning of the treaty language regarding the share of the harvest accruing to tribes were raised. In the Belloni and Boldt judicial decisions (*Sohappy v. Smith* 1969, *United States v. State of Washington* 1974), it was determined that fishing "in common" meant that fisheries management should ensure the harvests were split evenly (50% to 50%) between treaty and non-treaty fishing entities. These decisions helped set the stage for a new era of fisheries-management with vastly different allocation parameters and brought tribes to the fisheries management negotiation table for the first time.

Commercial fishing started on the lower reaches of the Columbia River and gradually expanded toward the ocean and upstream as competition for fish increased. Commercial harvest of Columbia River salmon increased rapidly after 1866 when new canning technology made it possible to process and ship salmon to distant markets (fig. 6.10). Harvest pressures intensified as new types of gear were developed. Harvests in the Pacific Ocean commenced in the late 1910s and early 1920s, putting tremendous pressures

[18] "Mid-Columbia River" is used here to refer to the main stem of the Columbia between the Bonneville and Chief Joseph Dams; "Lower Columbia River" refers to the river and its tributaries downstream of Bonneville Dam; "Upper Columbia River" refers to the mainstem east and north of Chief Joseph Dam.

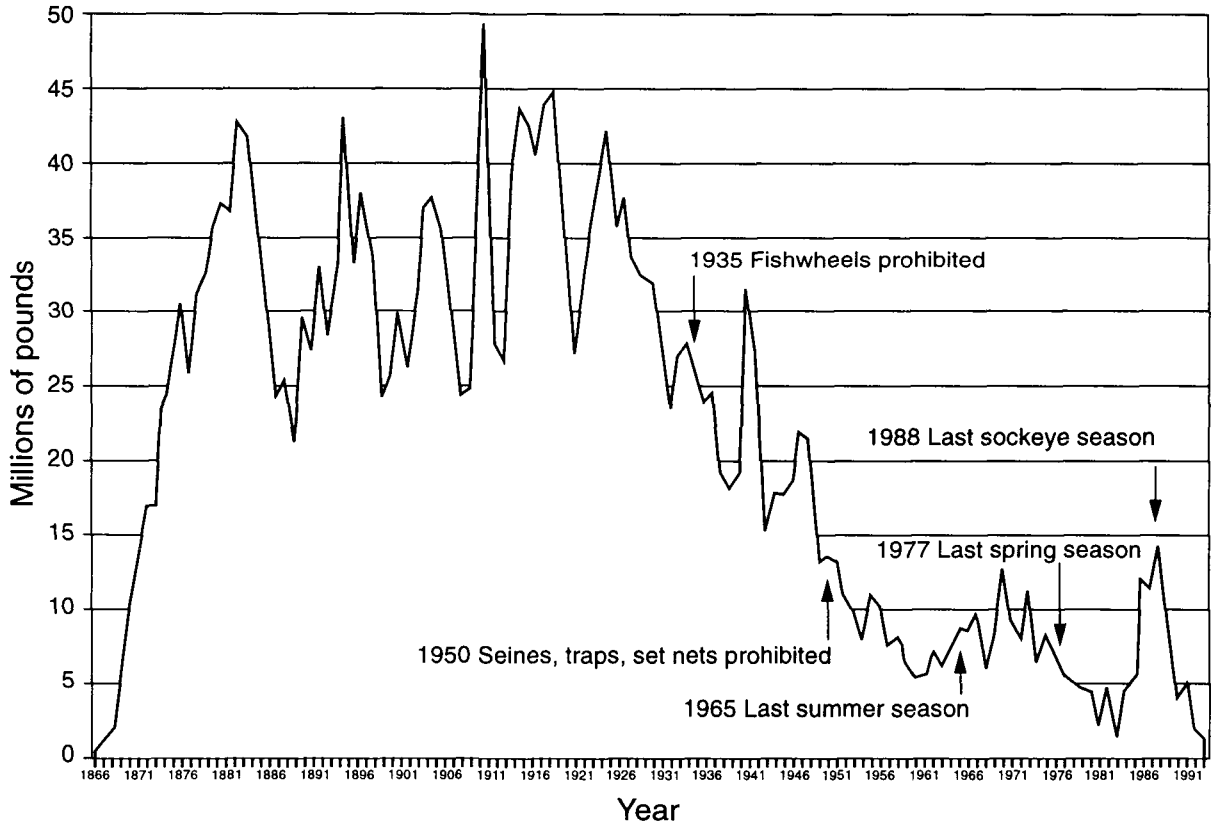


Figure 6.10— Annual commercial landings of salmon and steelhead from the Columbia River, in millions of pounds, 1866-1993.

on salmon populations spawning in the Basin. The Columbia River chinook salmon was the almost exclusive target species in the early salmon fisheries because of its abundance and value. With the decline in the chinook numbers, the fishery simply began to focus on other species. Total harvest of all salmon species fluctuated between 24 and 49 million pounds per year between 1880 and 1930, averaging 33.9 million pounds (Smith 1979). Salmon harvest from the Columbia River system dropped to about 23.8 million pounds annually in the 1940s; about 10.9 million pounds in the 1950s and to 1.2 million pounds by the early 1980s.

Before the development of the dams, distribution of in-river production of all species of salmon is estimated to have been 23 percent below the Bonneville Dam and 77 percent above (Lee 1993). By the late 1970s the production above Bonneville Dam (including hatchery production) had dropped to 42 percent, while salmon production below Bonneville Dam represented 58 percent.

Commercial catches of sturgeon began in 1884 and rose rapidly to 5.5 million pounds per year in the 1890s. Thereafter, sturgeon harvest dropped precipitously; in roughly a decade sturgeon was eliminated as a significant commercial species. The combination of high demand and value combined with the sturgeon's slow reproduction and growth rates required careful management—which the sturgeon did not receive. Subsequent construction of dams on the Columbia River severely restricted the movements of the large, old fish, hampering their ability to reproduce.

Shad were introduced into the Columbia River by 1876 (Wydoski and Whitney 1979). Dam construction on the mainstem of the Columbia River since the 1930s has benefited the shad by removing

Celilo Falls as a natural barrier and by creating the slower waters of the reservoirs. Shad have now extended their range to the Priest Rapids Dam on the Columbia River and into Idaho's Snake River. Since 1938, shad have supported a fishery ranging in size from 150,000 to 1.5 million pounds per year. The value of shad is low relative to other seafood because of low demand and high abundance. Management of this species is difficult because the fishery coincides with the higher value summer chinook salmon.

Another commercial fishery in the Basin is trout culture (Glude 1988). For over 100 years the Thousand Springs area of Idaho's Hagerman Valley has dominated the United States production of commercial rainbow trout with some 14 companies, 30 farms, and 16 fee-fishing pond operations.

Recreational demand for improved salmon and trout fishing in the Columbia River system has been a main factor driving restrictions on commercial gear and catch limits on the Columbia River, particularly after World War II (Smith 1974). Recreational catch grew from an insignificant amount at the turn of the century to a major component of the in-river fishery. Recreational fishing occurs throughout the range of salmonids in the Columbia River basin, but predominantly below the Bonneville Dam where fish quality is highest.

Chief targets for recreational fisheries in the Basin have been chinook, coho, and steelhead salmon. Rainbow, bull, and cutthroat trout have been the main native species taken along with the introduced brown trout (Ames 1966). Sturgeon sport fisheries are now strictly regulated to control harvests especially in Idaho and Montana; most recreational sturgeon fishing is now below Bonneville Dam. As opportunities for traditional sport fisheries have declined some fishing enthusiasts have shifted to catching introduced warm water species such as shad or walleye. Reservoirs and irrigation facilities have improved habitat for these species at the expense of native salmon and trout species preferred by more traditional Basin fishing enthusiasts.

Hatchery salmon production has not lived up to expectations, but it does supply a considerable proportion of the salmon caught in the Columbia River and the Pacific Ocean. The scale and cost of the hatchery operations by tribes, states, power companies, and federal agencies has been large. Between 1938 and 1975, approximately $400 million was spent on fish passage facilities at dams, hatcheries, and spawning channels. A series of 21 hatcheries, 86 fish ladders, and spawning-habitat restoration projects were initiated in 1949, which cost an additional total of $84 million by 1975 (Smith 1979).

The value of the recreational salmon and steelhead fishing supported by the Basin was about $9.7 million per year (1987-1991). Fish caught in the Columbia River represented 81 percent of this value and the rest were caught in the Pacific Ocean off the United States (Alaska, Washington, Oregon, and California) and Canada. Three-quarters of this value ($7.3 million) was contributed by recreational steelhead fishing in the Columbia River. Most of the rest of the value lies in recreational fishing for fall chinook caught either below Bonneville Dam or in the Pacific Ocean.

Future Fish Valuation Issues

Future economic values of fish in the Basin depend on demographic trends, social preferences, outcomes of a variety of public policy debates, and biogeophysical events and trends. As the population in the Pacific Northwest region continues to grow more people will participate in fishing in the Basin.

If there are continuing losses of salmonids, the relative importance of other species is likely to increase. Coldwater fishing opportunities are notable in the Basin, particularly in headwater streams supporting native trout but also in lakes and streams where introduced coldwater species and hatchery stocks constitute the bulk of the fish. Warmwater species are also likely to play an increasing role in providing recreational opportunities.

Pumping ground water in Idaho's Snake River Valley may also pose a threat to riparian ecosystems and fish. A number of rivers are over-subscribed for water withdrawals, leaving little for fish at the requisite time. It remains to be seen whether resolution of water rights issues on a state-by-state basis will benefit fish and wildlife. Without such consideration, fish are likely to have an increasingly difficult time, and so will their commercial, tribal, and recreational usage.

Minerals[19]

Three major components of the mining industry in the Basin are covered in this section, metallic minerals, phosphate, and aggregates (sand, gravel, and crushed stone), each of which has distinct economic characteristics. This section begins with a description of minerals activity in the Basin. For metallic minerals and phosphate, activity is minor in spatial scale but significant in national and international commodity markets. Aggregate mining is more widely distributed throughout the Basin and lower in value; aggregates are primarily traded in local markets and used to construct buildings and infrastructure associated with human populations. Although mining is important to jobs and income in a few communities in the Basin, when compared with a large, diverse, and growing economy it represents only a minor share of gross state product (GSP). Effects of past metal mining are discussed after mineral activities. Mining for metals has caused wide-spread and long-term environmental hazards in some parts of the Basin (most notably the Clark Fork River and Smelterville in Kellogg, Idaho).

The future of minerals activity in the Basin is addressed in the last section. The distribution of activity relating to mineral exploration and development is dependent on the locations of deposits, which are restricted to specific geographic areas for metals, minerals, and phosphate, but are more widely dispersed for aggregates. Whether activity will occur in the future will depend on a number of factors including the minerals present and their grade, global prices, technology, and access. Most of these factors, except for access, will not be affected by BLM or FS policy or regulation.

[19] This section was written by Michael Zientek and Tom Frost, U.S. Geological Survey, based in part on a background report prepared for the ICBEMP by the U.S. Bureau of Mines.

Overview of Recent Minerals Production

The mineral industry in the Basin is localized in a few counties; consequently, its contribution to regional employment is small. Within the industry, however, the types and values of minerals produced play an important role in national and global spheres (tables 6.6 and 6.7). Phosphate deposits in Caribou County, Idaho, primarily in the Snake Headwaters Ecological Reporting Unit (ERU), account for 4 percent of the world's phosphate production and over 12 percent of the national output. Gold production in Montana, Idaho, and Washington accounts for 11 percent of national and 1.5 percent of world production. Silver production in Idaho and Montana represents 30 percent of the Nation's and 4 percent of the world's silver production. Similar comparisons for lead, copper, and zinc cannot be made because the data are combined or withheld for confidentiality.

Two mining districts in the Basin, Butte (Upper Clark Fork ERU) and Coeur d'Alene (Lower Clark Fork ERU), contain world-class deposits that have contributed an important share of the Nation's copper and silver production (table 6.8). Mineral deposits of such size are quite uncommon and can significantly affect the world supply of minerals (Singer 1995). The Coeur d'Alene and Butte mining districts have contributed more than 90 percent of all the base-metal and silver produced in the Basin. Mines in the Coeur d'Alene district consistently rank among the top ten for silver and lead production in the country. The three largest hardrock gold-producing districts, Butte, Republic, and Boise Basin (in the Upper Clark Fork, Northern Glaciated Mountains, Central Idaho Mountains ERUs, respectively), are responsible for over 38 percent of the total production from the Basin. Historically, several deposits have been among the top 20 deposits in the United States for gold, zinc, and copper production.

Table 6.6—Selected minerals production in the world, the United States, four northwest states, and Nevada;[1] importance of Basin minerals production at international and national scales.

Commodity	World production	United States production	U.S. Percentage of world production	World rank	World reserve base	U.S. reserve base	U.S. percentage of base	World rank
	..... Metric tons				..... Metric tons			
Phosphate	147,000,000	48,096,000	33	1	34,000,000,000	444,000,000	13	2
Gold	2,110	290	14	2	51,000	4,770	—	—
Silver	14,723	1,848	13	2	420,000	72,000	17	1
Copper	88,000,000	1,631,000	19	2	590,000,000	90,000,000	15	2
Lead	3,260,000	477,000	15	2	130,000,000	22,000,000	17	2
Zinc	7,282,000	547,000	8	5	330,000,000	50,000,000	15	3
Molybdenum	112,224	53,364	48	1	12,000,000	5,350,000	45	1

Commodity	Washington production	Oregon production	Idaho production	Montana production	Total	Percentage of world production for 4 NW states	Percentage of U.S. production for 4 NW states	Nevada production	Percentage of world production for Nevada	Percentage of U.S. production for Nevada
Phosphate	NR	NR	5,921,000	C	5,921,000	4.0	12.3	NR	—	—
Gold	9.000	NR	3.348	18.511	31.813	1.5	11.0	177.03	8.4	61
Silver	C	C	337	222	559	3.8	30.2	578.0	3.9	31
Copper	NR	W	C	C	—	—	—	C	—	—
Lead	C	NR	C	C	—	—	—	W	—	—
Zinc	C	751	C	C	—	—	—	W	—	—
Molybdenum	NR	NR	C	C	—	—	—	C	—	—

NR— Production not indicated in state summary.

W—Information withheld to avoid disclosing company proprietary data.

C—Information combined with other commodities and only value of production is reported.

[1]U.S. Bureau of Mines (1993a,b).

Table 6.7—Discovered metal resources in the world, United States, and the Basin; production and resources remaining as of 1995, by metric ton and percent.[1]

	World–total discovered metal	U.S.–total discovered metal	U.S. percentage of world discovered metal	World rank for the U.S.	Basin production of metal	Basin remaining discovered metal	Basin total discovered metal	Basin percentage of world discovered metal	Basin percentage of U.S. discovered metal	Percentage of Basin discovered metal remaining
	Metric tons		Percent		Metric tons			Percent		
Gold	193,476	19,632	10	2	775	984	1,759	0.9	9.0	56
Silver	1,742,114	364,942	21	1	59,601	34,599	94,200	5.4	25.8	37
Copper	1,518,116,406	291,101,318	19	2	11,819,927	31,507,462	43,327,389	2.9	14.9	73
Lead	348,663,289	68,198,613	20	1	1,128,364	1,052,423	8,780,787	2.5	12.9	12
Zinc	712,574,161	130,799,184	18	1	6,107,226	1,304,446	7,411,672	1.0	5.7	18

[1]Data from Singer (1995) and Zientek and others (1995).

Table 6.8—World-class deposits of the Basin; cumulative production of base and precious metals as of 1995.[1]

District	Gold	Silver	Copper	Lead	Zinc	Cobalt	Molybdenum
	Metric tons of metal						
Boise Basin	92	--	--	--	--	--	--
Republic	105	278	--	--	--	--	--
Butte	98	21,281	8,589,762	387,839	2,227,406	--	--
Coeur d'Alene	2	31,263	170,972	7,015,098	3,300,281	--	--
Subtotal	297	52,822	8,760,734	7,402,937	5,527,687	--	--
Basin total	775	59,327	9,398,189	7,728,364	6,107,226	14	49,805

[1]Modified from Zientek and others (1995).

Nonfuel metallic and nonmetal mineral commodities are not distributed uniformly across the Basin, so that while mining is locally important it is only a minor factor in state-wide economic statistics (figs. 6.11 and 6.12). Mineral deposits tend to occur in clusters or belts that reflect the underlying geological processes that controlled their distribution. Occurrences of mineralization are not equally valuable. Even though there are thousands of prospects in the Basin, a few world-class deposits account for most of the production and resource base in the region.

These mineralized terranes and world-class mineral deposits bestow a comparative economic advantage for the exploration and development of these resources in some areas. Twenty of the 100 counties within the Basin accounted for more than 90 percent of the Basin's nonfuel mineral production value over the period 1980 to 1992 (fig. 6.13). The top six counties (Caribou and Shoshone, Idaho; Silver Bow and Lincoln, Montana; Humboldt and Elko, Nevada) account for nearly 70 percent of the mineral production value in the same time period. Only two of these counties (Lincoln, Montana and Shoshone, Idaho), however, are entirely within the Basin. In the top ten mineral producing counties in the Basin, mining employment ranged from 0.63 to 13.22 percent of total employment in 1992 (table 6.9). Being a high wage sector, the percentage of total county earnings from the mining sector is more dramatic, ranging from 1.53 to 36.46 percent, and averaging 16 percent in 1992.

Across the Basin, there are 180 mining and mineral processing sites in operation, 11 under development, and 10 maintained on standby status (fig. 6.14). The value of production from these sites in 1992 was approximately $2.7 billion. These numbers do not include production of aggregate. Only 18 sites, which had a total production value of more than $600 million in 1992, are considered large (table 6.10).

In 1990, the contribution of mining, including aggregates, to the GSP of the Basin economy was estimated to be 4.2 percent. The majority of this contribution was from nonfuel minerals, significantly above the share of nonfuel minerals in the GNP (approximately 1%). Mineral fuels contribute less than one quarter of the mining contribution. The mining sector's contribution to employment in Montana, Idaho, Washington, and Oregon ranged from about 0.1 percent to 1.5 percent of the totals. Mining earnings range from 0.2 percent to 3 percent of the totals for these states.

Metals production is the most important component of nonfuel minerals in the Basin, representing approximately 75 percent of the total value between 1982 and 1990. In contrast, metals production in the Nation only accounted for 37 percent of the value of nonfuels mineral production from 1989 to 1991. Most of the value in the Basin came from the production of gold; also important were silver, copper, molybdenum, magnesium, lead, and zinc. The value produced by each of these metals cannot be reported because of confidentiality.

The total average annual value of nonfuel mineral production in Idaho, Montana, Washington, and Oregon increased between 1959 and 1991 by 35 percent, in real terms, to $1.6 billion. In the 1980s, the value of mineral production decreased by about 7 percent in real terms. This decrease reflects a lengthy and deep recession in the minerals industry which prompted closures of mines in the Coeur d'Alene mining district and reduced production from deposits at Butte. The percentage of mining in the GSPs of Idaho, Montana, Oregon, and Washington has largely declined over time, because other sectors have grown at a faster pace.

Remediation Costs for Past Mining

The U.S. Bureau of Mines estimates that there are nearly 14,000 inactive or abandoned mining sites in the Basin, of which 164 sites have a high potential for environmental hazard. Another 190 sites were classified as having possible potential for environmental hazard. Expenditures required to remediate these sites will contribute significantly to jobs and income in some regional economies, if money is found to pay for remediation.

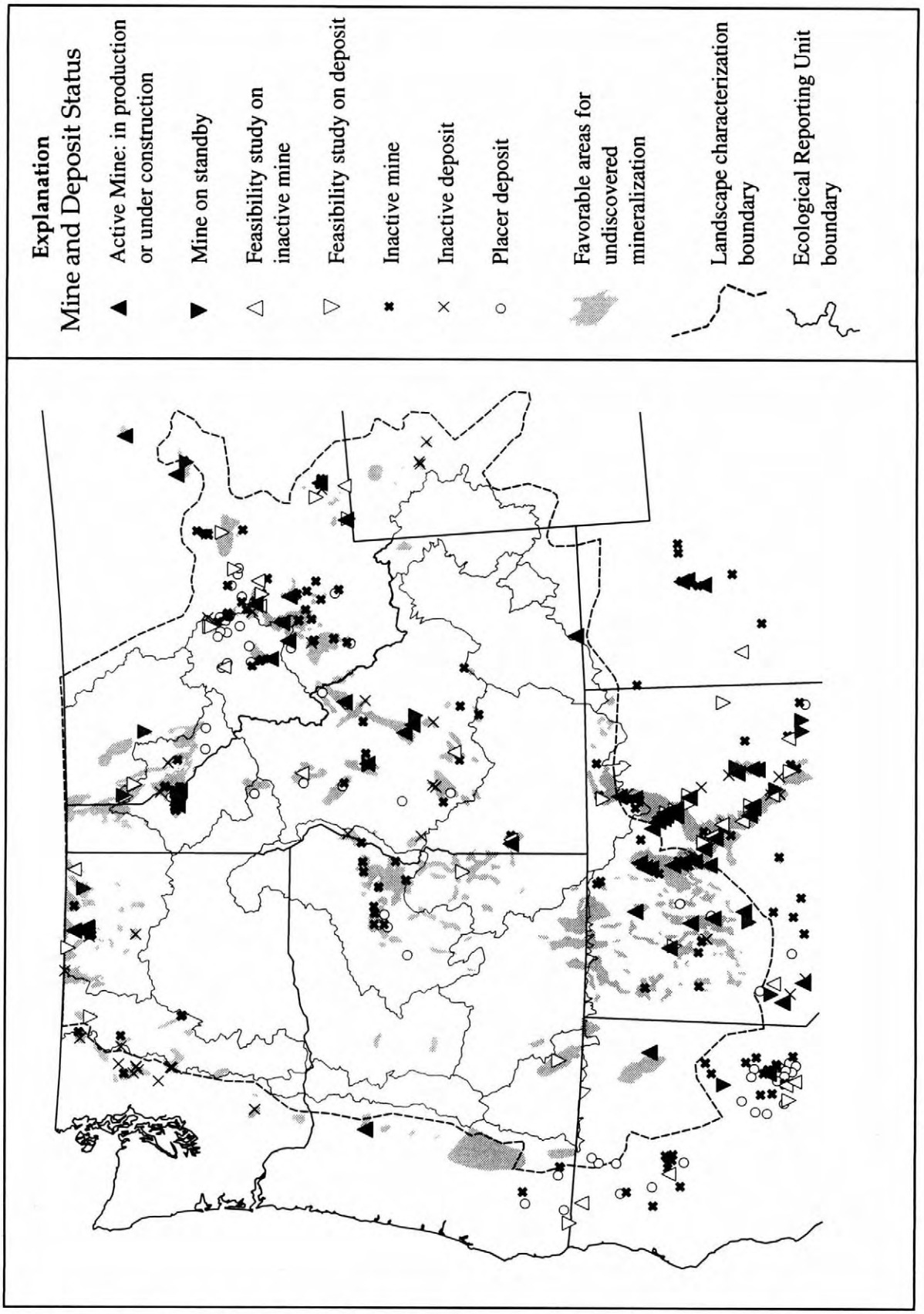


Figure 6.11— Location of mines and mineral deposits in the Basin, by activity status, 1995.

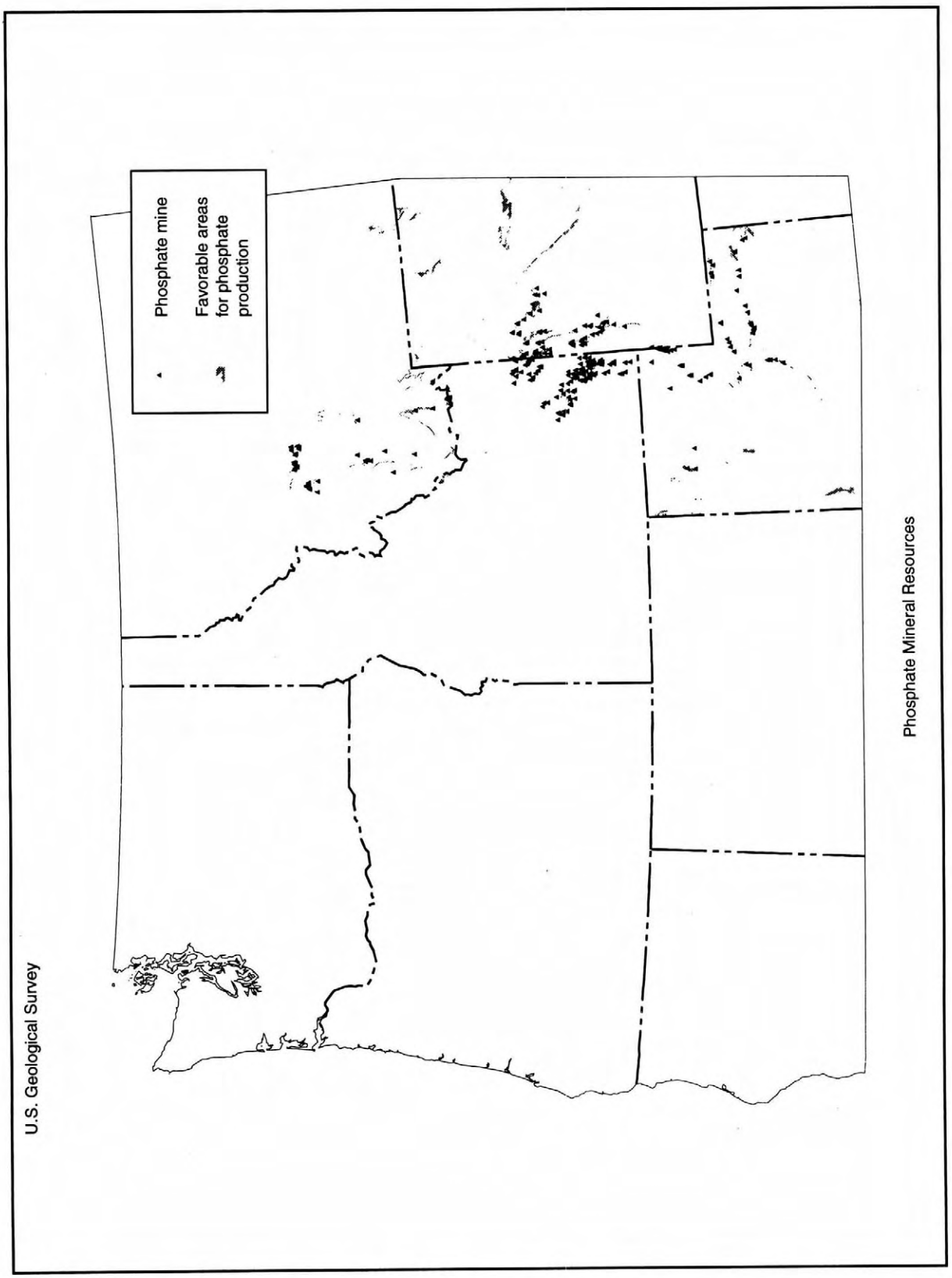


Figure 6.12— Location of phosphate mineral resources in the Basin, 1995.

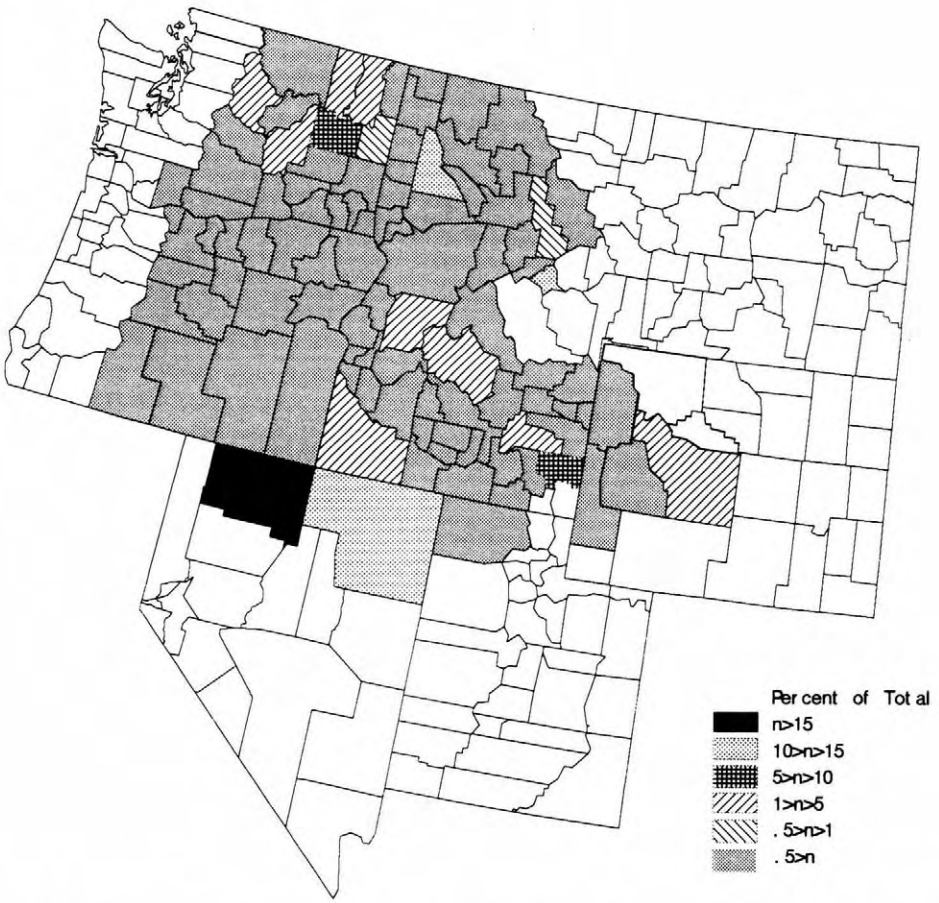


Figure 6.13— Percent of Basin nonfuel mineral production value contributed by each county, average from 1980 to 1992.

Table 6.9—Top ten mineral-producing counties in the Basin; mining employment as a percent of county employment, 1969-1992.

County, State	Year							
	1969	1974	1979	1984	1989	1990	1991	1992
	Percent							
Caribou, ID	7.90	6.22	16.31	16.05	12.06	12.74	12.75	12.32
Custer, ID	7.36	6.37	4.67	21.77	NA	NA	NA	13.22
Owyhee, ID	0.54	0.55	4.89	6.16	NA	NA	NA	4.94
Shoshone, ID	30.63	28.72	27.34	27.96	24.24	23.82	14.89	10.82
Lincoln, MT	NA	NA	NA	NA	5.96	5.74	5.25	4.71
Silver Bow, MT	18.14	19.89	10.54	1.34	NA	NA	NA	3.38
Elko, NV	2.04	2.38	3.05	6.38	6.55	6.89	7.30	7.15
Chelan, WA	0.12	0.09	0.15	0.21	NA	NA	0.66	0.63
Ferry, WA	5.97	4.82	4.53	NA	NA	NA	13.50	12.24
Stevens, WA	3.36	2.18	4.70	1.89	1.21	1.27	1.65	1.30

NA=Not Available.

Source: U.S. Bureau of Mines (1995).

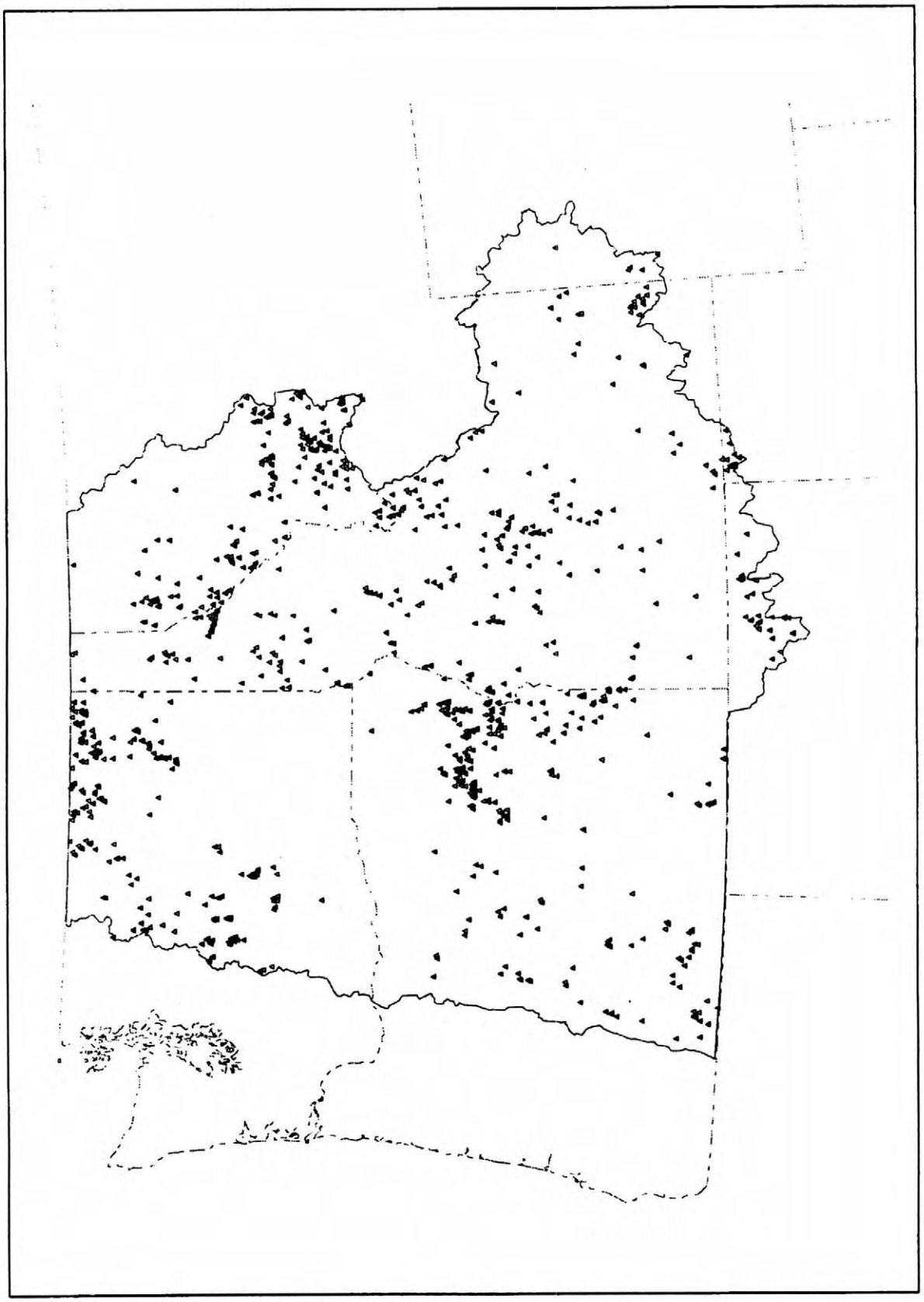


Figure 6.14— Mining and mineral processing sites in operation, under development, or on standby status in the Basin (excluding sand, gravel, and crushed stone sites), 1995.

Table 6.10—Number of mineral sites in the Basin having output greater than $100,000 in 1992, and percentage of Basin mineral output, by commodity, 1992.

Commodity	Sites	Percent of Basin mineral output
Gold and silver	10	58.31
Copper	2	26.09
Diatomite	1	1.95
Limestone	1	1.62
Molybdenum	1	4.72
Phosphate	3	7.32
Total	18	100

Note: Totals may not add to 100 due to rounding.
Source: U.S. Bureau of Mines (1995).

The estimates of the costs to remediate chemical hazards associated with mining are inconsistent, some separated by orders of magnitude. In 1988, the General Accounting Office (GAO) estimated that 424,049 acres of Federal land affected by hardrock mining in 11 western states were unreclaimed. The cost of reclaiming the abandoned 281,581 acres was estimated to be $284 million. The Western Governor's Association Mine Waste Task Force stated the cost of remediation would be $315 million in Idaho, $912 million in Montana (including Superfund sites), and up to $77 million in Oregon. The EPA estimates that it will cost $210 million to mitigate the Bunker Hill Superfund site in Idaho; at least $53 million has been spent so far in remediation efforts in the Clark Fork Basin in Montana.

Future Mineral Development

Discovered metal deposits in the Basin, primarily in the Butte and Coeur d'Alene mining districts, contain significant percentages of the world's discovered resources for copper (3%), lead (2.5%), and zinc (1%). Nationally, deposits in the Basin account for 15 percent of the copper, 13 percent of the lead, and 6 percent of the zinc. Twelve to 73 percent of these discovered resources remain to be produced.

Metallic mineral deposits—The short term is defined as the time it takes to put a mineral deposit into production once it is discovered, about 10 years. Figure 6.14 shows the location and operational status of 141 significant metallic mineral deposits in the Basin. The map reveals historical and current patterns for mineral development in the region as well as where activity may occur in the future. Eighteen metallic mineral deposits are currently undergoing feasibility studies and could be put into production in the next 10 years; in addition, there are 22 deposits in production, under construction, or on standby. Another 14 deposits are not currently economic to mine; summary statistics for these sites are in table 6.11.

Long-term forecasts of minerals activities require probabilistic estimates of new discoveries. Quantitative estimates for undiscovered metallic resources in the Basin were developed by first delineating 97 tracts in which 25 metallic mineral deposits might occur. Within these "permissive" tracts, areas favorable for undiscovered mineralization were delineated when there was indication of mineralization. The final step was to estimate the probability of the number of undiscovered deposits present and to simulate the amount of undiscovered metal. An average of 84 undiscovered deposits was

Table 6.11—Activity status of discovered deposits of base and precious metals in significant mineral deposits in the Basin, 1995.[1]

Resources	Gold	Silver	Copper	Lead	Zinc	Cobalt	Molybdenum
	Metric tons of metal						
Mines in production or under construction	303	4,666	1,282,523	992,322	108,067	--	342,376
Deposits with announced resources that are undergoing feasibility studies	453	17,763	3,834,754	60,101	349,531	--	--
Deposits with announced resources which are not economically feasible	29	963	2,754,601	--	174,000	17,418	1,852,893
Total	785	23,392	7,871,878	1,052,423	631,598	17,418	2,195,269

[1]Modified from Zientek and others (1995).

estimated to be present for all of the 25 deposit types. Statistics summarizing the amount of undiscovered metallic mineral resources are presented in table 6.12.

Economic activity associated with undiscovered metallic mineral deposits has high likelihood in all ERUs except the Southern Cascades, Upper Klamath, and Upper Snake (fig. 6.15). An economic analysis was used to forecast the likelihood of supplying minerals from these undiscovered resources (table 6.12). The economic potential of these resources is estimated as the proportion that could be produced under specified economic and technological conditions. The analysis considered only those deposit types currently thought to be exploration targets.

At current metal prices, about 12 undiscovered deposits are economically feasible. If developed at the same time, these mines could generate annually almost 11,000 jobs, $770 million regional output, and $326 million in income. If prices double, about 33 deposits would become economically feasible to mine. These mines could generate annually about 19,500 jobs, $1.4 billion regional output, and $592 million in income.

Developing a long-term economic forecast for mineral development in the Basin requires combining three pieces of information: the likelihood that undiscovered resources will be developed, inactive mines, and discovered resources that are either undeveloped, on standby, or in development. Whether mineral resources are developed depends on the quality and quantity of the resource, market conditions, improved technology for low-cost extraction and processing techniques, and, to the extent the deposits are on Federal land, Federal land-use policies. The combination of these factors creates much greater uncertainties in the long-term forecast compared with the short-term. The results of the long-term forecast are illustrated in figure 6.16 and table 6.13. The map shows areas whose undiscovered resources are favorable for development activities. It also shows areas of known significant deposits, both producing and undeveloped, around which mineral activity may be expected in the long term. General patterns for minerals activity include:

Table 6.12—Probable quantities of base and precious metal resources remaining undiscovered in the Basin.

	Gold	Silver	Copper	Lead	Zinc	Cobalt	Molybdenum
	Metric tons						
0.95 quantile	822	21,108	5,580,000	120,910	445,050	0	29,670
0.90 quantile	970	27,153	7,240,000	263,900	892,640	0	62,839
0.50 quantile	1,681	66,063	15,100,000	2,721,500	5,681,300	0	389,000
0.10 quantile	2,707	140,960	32,100,000	14,050,000	23,477,000	0	1,459,900
0.05 quantile	3,116	170,320	41,900,000	19,263,000	31,320,000	180,870	1,949,400
Mean	1,790	77,433	18,104,500	5,292,260	9,544,970	33,796	603,923

Potential supply of undiscovered mineral resources. Average amount of undiscovered mineral resources that could be produced under different price assumptions

	Metric tons						
Current metal price	838	21662	4,000,000	3,800,000	6,700,000	--	--
1.5 times current price	1,120	29,434	6,000,000	4,600,000	8,100,000	--	--
2 times current price	1,275	37,324	7,700,000	4,800,000	8,500,000	--	240,000

Source: Personal communication. 1995. Michael Zientek and Tom Frost, geologists. U.S. Geological Survey, Spokane, WA.

- A northeasterly trend of areas that may be favorable for long-term mineral development extends from southeastern Oregon through central Idaho and into southwestern and central Montana. The most economically attractive targets are gold and silver in large, low-grade, bulk mineable deposits, and deposits of copper and cobalt in central Idaho.
- In the western part of the Northern Glaciated Mountains and North Cascades ERUs, underground mining for gold and silver has a long history and will likely continue in the short term. In the long term, more emphasis will be placed on developing bulk-mineable open pit mines.
- A northwesterly trend of areas with considerable base metal resource extends from southwestern Montana through northern Idaho and into northeastern Washington. This includes the Butte and Coeur d'Alene mining districts, which account for the bulk of past production of copper, lead, zinc, and silver in the Basin. It also includes significant copper-silver deposits in northwestern Montana and lead-zinc deposits in northeastern Washington.

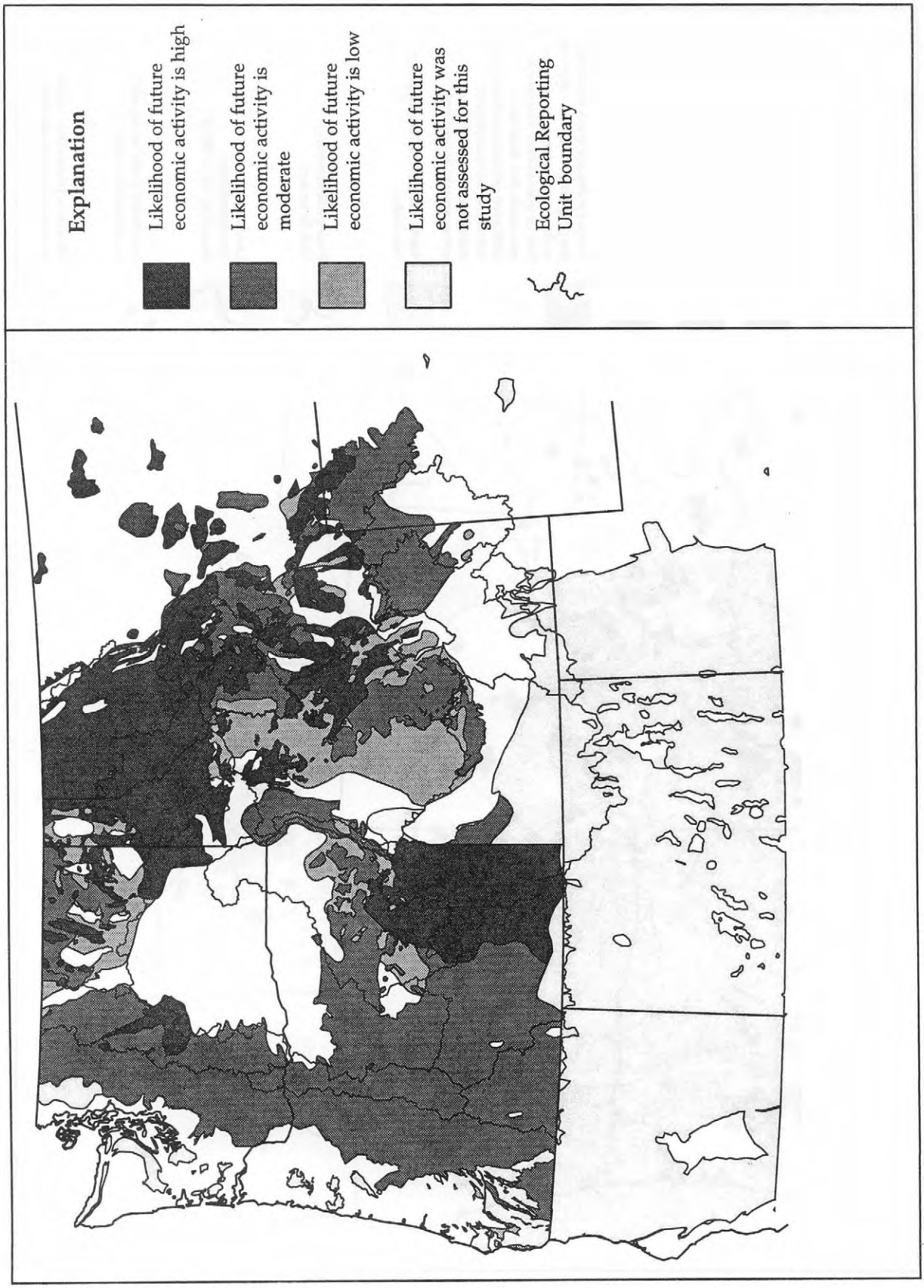


Figure 6.15— Likelihood of economic mining activity in areas of the Basin.

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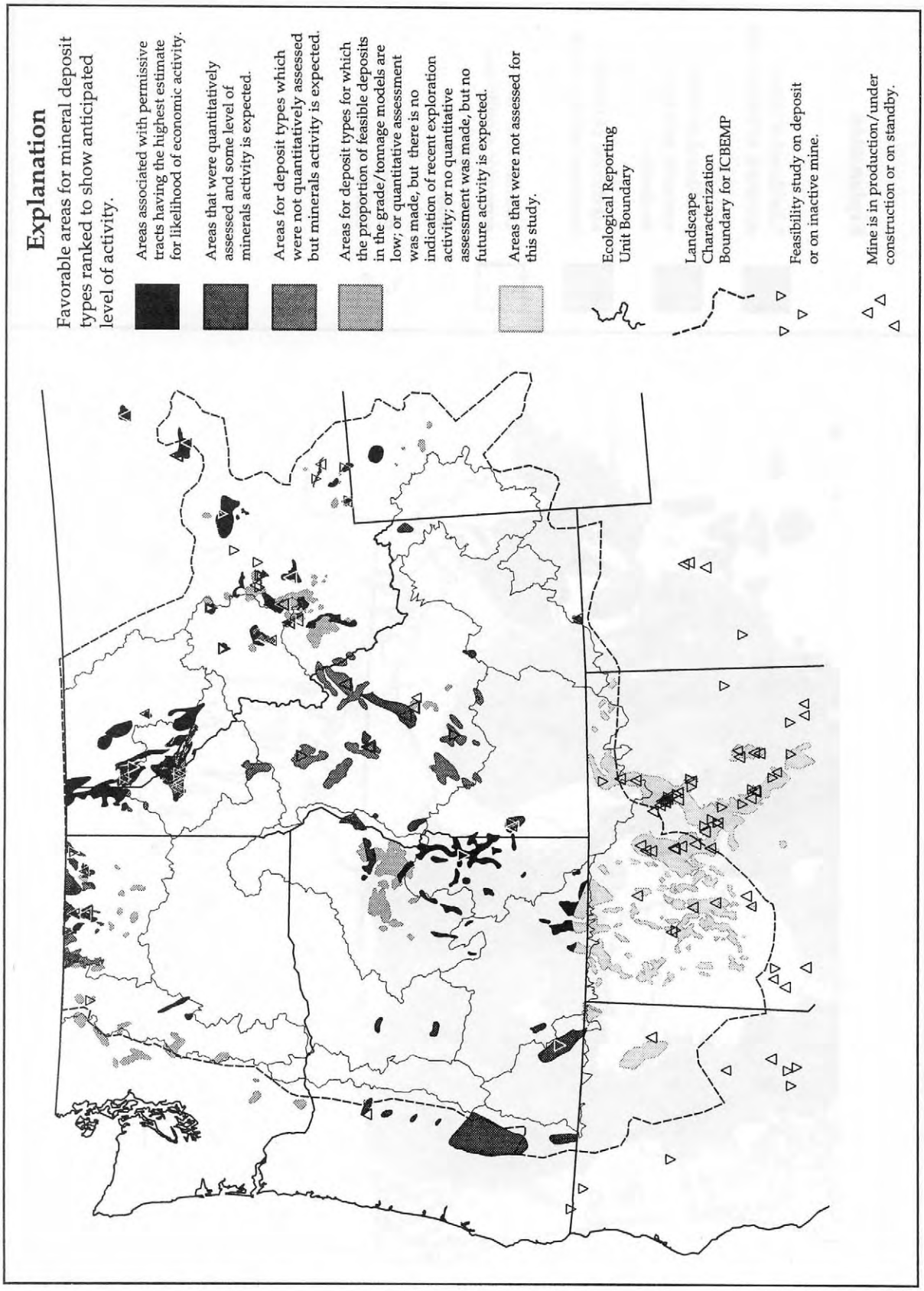


Figure 6.16— Likelihood of base, precious, and ferroalloy metals activity in the Basin.

Table 6.13—Potential metallic mineral and phosphate resources in each Ecological Reporting Unit (ERU) in the Basin.

ERU	Metallic resources -- base and precious metals		Non-metallic resources -- phosphate	
	Short-term	**Long-term**	**Short-term**	**Long-term**
Southern Cascades and Upper Klamath	Southern Cascades: No significant base, precious, or ferroalloy deposits are known. If a discovery were made, it is unlikely that the deposit would be in production in the next 10 years. Upper Klamath: No sites with *significant production were identified;* however, a recently discovered gold deposit is undergoing feasibility studies.	The Southern Cascades, Upper Klamath, and Upper Snake are the only Ecological Reporting Units in which permissive tracts for undiscovered resources with a high likelihood of economic activity do not occur. Favorable areas for undiscovered mineralization occur in the Upper Klamath ERU.	None	None
Snake Headwaters and Upper Snake	Snake Headwaters: No significant base, precious, or ferroalloy deposits are known. If a discovery were made, it is unlikely that the deposit would be in production in the next 10 years. Upper Snake: Minor gold and silver production and resource identified in the Champagne deposit, Butte County, Idaho. However, no other significant deposits of base, precious, or ferroalloy metals were identified. For most of the area, no additional short-term metallic minerals production activity is anticipated.	The Southern Cascades, Upper Klamath, and Upper Snake are the only Ecological Reporting Units in which permissive tracts for undiscovered resources with a high likelihood of economic activity do not occur. Favorable areas for undiscovered mineralization are small proportion of both ERUs (≤ 1 percent).	Phosphate deposits that can be mined by open-pit methods are located mostly in the Snake Headwaters ERU, and in adjacent parts of the Upper Snake ERU. Seven major active open-pit mines in the southeast Idaho phosphate district are the Conda, Henry, Maybe Canyon, Wooley Valley, Enoch Valley, Mountain Fuel, and Smokey Canyon mines.	Large-scale open-pit mining and processing of phosphate ore probably will continue into the long-term future in the Snake Headwaters and Upper Snake ERUs.

Table 6.13 (continued).

ERU	Metallic resources -- base and precious metals		Non-metallic resources -- phosphate	
	Short-term	**Long-term**	**Short-term**	**Long-term**
Northern Great Basin	No significant base, precious, or ferroalloy deposits are known. If a discovery were made, it is unlikely that the deposit would be in production in the next 10 years.	Includes permissive and favorable tracts for undiscovered resources with a high likelihood of economic activity.	None	None
Columbia Plateau	Minor historic gold production from the Pierce City placer deposit in Clearwater County, Idaho. However, no other significant deposits of base, precious, or ferroalloy metals were identified.	Includes permissive tracts for undiscovered resources with a high likelihood of economic activity. Favorable areas for undiscovered resources are a small proportion of the ERU (<1 percent).	None	None
Blue Mountains	Numerous sites with significant historic mineral production of base and precious metals. Essentially all of the identified resources are now associated with the Red Ledge deposit, which is within Hell's Canyon National Recreation Area. Therefore, no short-term minerals activity is anticipated in this region. Exploration around the large number of inactive mines could find extensions to these deposits or develop additional resources based on different mining and beneficiation methodologies. However, no discoveries have been reported that would indicate short-term minerals production.	Includes permissive tracts for undiscovered resources with a high likelihood of economic activity. Favorable areas for undiscovered resources are a significant proportion of the ERU.	None	None

Table 6.13 (continued).

ERU	Metallic resources -- base and precious metals		Non-metallic resources -- phosphate	
	Short-term	**Long-term**	**Short-term**	**Long-term**
Central Idaho Mountains, Lower Clark Fork, Northern Cascades, Northern Glaciated Mountains, Owyhee Uplands, and Upper Clark Fork	Significant past and current production from the following counties: Central Idaho Mountains - Custer Co., Idaho Lower Clark Fork - Shoshone Co., Idaho Northern Cascades - Chelan Co. Wash. Northern Glaciated Mountains - Ferry and Stevens, Cos., Wash. and Lincoln Co., Mont. Owyhee Uplands - Owyhee Co., Idaho and Elko Co., Nevada Upper Clark Fork - Silver Bow Co., Mont. All ERU's contain significant discovered resources of base, precious, and ferroalloy metals and deposits that are currently undergoing feasibility studies.	Includes permissive and favorable tracts for undiscovered resources with a high likelihood of economic activity. Favorable areas for undiscovered resources are a significant proportion of the ERU.	The Montana phosphate district, located in the Upper Clark Fork ERU, is a relatively minor producer of phosphate rock from underground mines. The Centennial underground mine is located on the Idaho-Montana border, near the northern margin of the Upper Snake ERU.	Smaller-scale, underground mining of phosphate ore probably will continue in the Upper Clark Fork ERU.

Metallic mineral deposits will be available for discovery and exploitation for decades to come. Compared with the 775 metric tons of gold that already have been produced from the Basin, estimates of the amount of gold remaining in undiscovered, conventional deposits range from 822 to 3,116 metric tons. Estimates are that at present, 785 metric tons of discovered gold remains to be developed. Estimates for other commodities are summarized in tables 6.11 and 6.12. Conservative measures of the frequency distribution (0.95 and 0.90 quantiles) of copper, zinc, gold, and silver contained in undiscovered deposits in the Basin are comparable to the amount identified in discovered deposits; measures for lead and molybdenum are much lower than the identified resource base. Average values of the frequency distributions for gold, silver, copper, lead, and cobalt contained in undiscovered deposits are two to five times higher than the resources remaining in known deposits; the same measure for zinc is 15 times that in the known resource base.

Phosphate—The Western Phosphate Field underlies an area of about 130,000 square miles in southeastern Idaho, western Montana, western Wyoming, and northern Utah (see fig. 6.12). Although resources in the Western Phosphate Field are vast, the amount that can be economically mined is limited. Phosphate deposits that can be mined by open-pit methods are located mostly in the Snake Headwaters and adjacent parts of the Upper Snake ERUs. Seven major active open-pit mines are in operation in southeastern Idaho. The Montana phosphate district, located in the Upper Clark Fork ERU, is a relatively minor producer of phosphate rock from underground mines. The Centennial underground mine is located on the Idaho-Montana border, near the northern margin of the Upper Snake ERU. Three major phosphate treatment plants are located in Soda Springs, Idaho; two others are located in Pocatello, Idaho. A vanadium-recovery plant is also located in Soda Springs (Bennett and Gillerman 1994).

Large-scale open-pit mining and processing of phosphate ore probably will continue into the long-term future in the Snake Headwaters and Upper Snake ERUs. Smaller-scale, underground mining of phosphate ore probably will continue in the Upper Clark Fork ERU. Reserves of economically exploitable phosphate ore in southeastern Idaho are estimated to be 1 billion metric tons of ore that average 24.5 percent P_2O_5 (Kraus and others 1984). The Montana phosphate district has an estimated resource of 600 million metric tons of ore that average 24 percent P_2O_5. Recent total annual production from southeastern Idaho has averaged 5 million metric tons a year (U.S. Bureau of Mines 1993b). Assuming production continues at similar rates, the known ore represents at least 200 years of future mining and processing. Over time, mining probably will shift to lower-grade and/or deeper ores, as warranted by changing technologies, economic conditions, and competitor activities.

Aggregate—Natural aggregate (sand and gravel, or crushed stone) is used primarily in construction and repair of infrastructure—buildings, roads, bridges, runways, railways, dams, canals, and sewer systems. Aggregates are primarily used in urban areas and transportation routes; markets generally are local in order to minimize transportation costs. The 1980-1992 cumulative value of sand-and-gravel and stone produced in the Basin was $1.3 billion, or 10 percent of the value of the total mineral production of the region.

About 11 tons of stone, sand, and gravel are produced per person per year in the seven states that compose the Basin. If this rate continues and population increases as predicted, total production could rise from 46.4 million tons in 1992 (from 449 operations) to over 100 million tons per year (from about 900 operations) by the year 2050. Deposits of sand and gravel form more slowly than the rate at which they are being depleted in areas of high demand. In the long term, sand and gravel deposits will be depleted or built over in urban areas, and aggregate production will shift toward crushed rock as it has in eastern and midwestern states (Langer and Glanzman 1993).

Range[20]

Cattle grazing has been an important part of the Basin's economy since just after the Civil War (Schwantes 1989). It has also been a lightning rod for debate about the stewardship of public lands both in the Basin and elsewhere in the West. The FS began regulating grazing on National Forest land in 1905 and the passage of the Taylor Grazing Act (1934) extended range regulation to the rest of the public domain.

Starting in the 1970s efforts were made to address concerns of local ranchers, agencies, and the public about inaugurating multi-resource and interdisciplinary management on BLM and FS rangelands (Quigley and others 1989). Reflecting stewardship demands for "more than just grazing" on the public lands, these efforts addressed forage production, livestock use, wildlife habitat and riparian enhancement, environmental quality, rural community stability, and development of diverse and healthy rural economies.

Critics of cattle management on western public lands state that public agencies have become captive to the livestock industry, that current use levels are eroding public lands, encouraging exotic plants, displacing native plant and animal species, and that agencies charge fees that are far below market values (Ferguson and Ferguson 1983). These and other critics have called for wholesale changes in management of the public range, tighter Federal controls, and reduced grazing. Karl Hess, Jr. (1992, 1995) provides another viewpoint and argues that public range stewardship should employ market incentives rather than rely on government policies, laws, and regulations.

This section briefly characterizes the role of livestock in the Basin and the nine BEA regions and evaluates livestock dependence on forage on lands managed by the FS and BLM. It also provides background information on grazing and on Federal rangelands in the western United States. Finally, this section examines contempory economic issues and the current projections of livestock production.

Western Range Overview

The productivity of western rangelands is extremely variable; the better desert sites in Oregon and Washington produce up to 250 pounds of forage per acre, while grasslands may produce up to 5,000 pounds per acre (Joyce 1989). Rangeland condition has changed dramatically throughout the western states since Europeans first appeared. Misuse and overuse caused range conditions to be most degraded around the turn of the century; range condition has been improving in most areas since the 1930s (Joyce 1989).

In 1987, 57 percent of the 22.0 million acres of Oregon rangeland was Federally owned (12.6 million acres) and 43 percent of the acreage was non-Federal (9.4 million acres). Washington rangeland was 25 percent Federal (1.9 million acres) and 75 percent non-Federal (5.6 million acres). We do not have similar data for the other individual states in the Basin, but in the eight states of the Rocky Mountain region (Montana, Idaho, Wyoming, Utah, Nevada, Colorado, Arizona, New Mexico), 336 million acres (of a land base of 553 million acres) is rangeland. Of the 336 million acres, about half (167.4 million acres) is federally owned. The BLM administers 125.5 million acres; the FS 33.5 million acres; and other Federal agencies 8.4 million acres.

According to the *Rangeland Reform '94 Draft EIS* (U.S. Department of Interior 1994a), there are about 26,900 permits to graze livestock on Federal rangelands held by 22,350 livestock operators nationwide. In the 11 western states in which Federal rangeland is concentrated,[21] permittees

[20] This section was written by Christopher E. DeForest, based in part on the background work of Leslie Frewing-Runyon, Economist, Bureau of Land Management, Oregon State Office, Portland, OR.

[21] These 11 western states are Oregon, Washington, California, Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, and New Mexico.

and lessees make up 22 percent of total beef producers. Beef cattle producers with Federal permits make up about 3 percent of the 907,000 producers in the 48 contiguous states. Permitted use on Federal lands makes up about 7 percent of beef cattle forage and about 2 percent of the total feed consumed by beef cattle in the 48 contiguous states. As for sheep, the roughly 4,600 sheep producers with Federal permits make up about 19 percent of total sheep producers in the 11 states in which Federal rangeland is concentrated.

Dependency on Federal Forage

A perennial question is to what extent ranchers are dependent on Federal forage. In this document, "dependency" is defined as the portion of total feed consumed by livestock provided by permitted use of FS and BLM lands. Total feed requirements were calculated assuming a cow needs 12 animal unit months (AUMs) per year and a sheep needs 2.4 AUMs. An AUM is the amount of forage required to sustain one cow, five sheep, or five goats for one month; forage includes grazed forage, hay, crop residue, silage, or grain. The lack of consistent, region-wide, county-level data required us to assume that cattle and sheep inventories reported by the Census of Agriculture are within a single county for the whole year. This would not be the case if Federal pastures are in a different county than the associated base ranch. Another complication is that many operators have multiple land holdings and permits, and may transfer livestock to other counties or states in the winter.

The dependency of the livestock industry on BLM and FS forage varies from 1 to 11.9 percent of total forage among the BEA regions, with an average of 7 percent (table 6.14). These percentages reflect the dependency of the livestock industry on BLM and FS forage. The numbers would be higher if they included only those operators holding Federal permits or reflected the seasonal importance of Federal forage (see below). Cattle dependent on BLM and FS AUMs average 2 percent of total agricultural sales across the Basin. (We discuss the livestock industry relative to agriculture because it is a part of that sector.) BEA regions in which cattle sales represent higher than the average percent are Redmond-Bend (2.7%), Idaho Falls (2.9%), and Boise (5.4%).

Seven counties in the Basin had over 30 percent dependency on FS and BLM AUMs: Skamania, Washington (48%); Camas, Idaho (39%); Humboldt and Elko, Nevada (38% each); Custer and Clark, Idaho (36 and 34%, respectively); and Chelan, Washington (33%). Of the 100 counties in the Basin, 67 counties had under 10 percent dependence on FS and BLM forage. On average, one cow or one sheep got 3 percent of its feed from FS or BLM permit lands. Only five of the counties with over 10 percent dependence on Federal grazing were large producers of cattle and calves (over $25 million). Most of the counties identified as highly dependent on Federal forage had small sales of cattle and calves, suggesting that the livestock industry in those counties may be marginal.

Using annual AUM data obscures the seasonal nature of shifting cattle or sheep between pastures during the year. Much of the public rangeland is at higher elevations and is traditionally used for spring or summer grazing while the richer private lands lie fallow or are used to grow winter feed. The degree of seasonality for BLM- and FS-administered lands and other Federal lands varies widely between states (table 6.15). Although the BLM, FS, and other Federal lands are grazed mostly in the spring and summer, they also receive considerable use in the fall and winter. Thus the seasonal availability of some types of rangeland may constrain livestock production more than numbers of permitted AUMs.

This estimate can be calculated from assumptions about the seasonal pattern herd size and extent of substitute feed during different grazing seasons. By assuming the average seasonal pattern shown in table 6.15, a constant annual herd size, and that

Table 6.14—Importance of agriculture and grazing (a component of agriculture) to Bureau of Economic Analysis (BEA) on Bureau of Land Management (BLM) and Forest Service (FS) land to economies of the Basin, by BEA region.

BEA region	Agriculture labor income as percent of total labor income	Value of agricultural products sold ($millions)	Cattle-calf sales as percent of total agricultural product sales	Dependency on FS-BLM Animal Unit Months (AUMs)	Percent of total agricultural sales dependent on FS-BLM AUMs
	Percent	1992 dollars	Percent	Percent	Percent
Tri-Cities	12.3	2,196	22.3	1.4	0.3
Spokane	3.0	646	14.5	2.5	0.3
Missoula	0.7	117	48.1	1.0	0.5
Idaho Falls	7.8	852	25.6	11.2	2.9
Twin Falls	17.2	962	30.1	6.1	1.8
Boise	4.5	1,098	45.4	11.9	5.4
Pendleton	9.5	780	30.0	6.6	2.0
Redmond-Bend	5.0	388	30.1	9.1	2.7
Butte	0.4	57	76.2	2.4	1.8
Total Basin	6.6	7,096	28.8	7.0	2.0

Source: Frewing-Runyon (1995).

Federal feed losses could only be offset by 10 percent during the spring and summer periods critical to dependent ranching operations, each reduction in Federal AUMs affects ranching operations by an additional 20 percent, which corresponds to a factor of 1.2.

It is often argued that private herd sizes are limited by availability of spring and summer Federal forage. This argument assumes that livestock operations would not be able to find alternative feed sources if the Federal grazing program were reduced. While this might be true in the short run, in the long run operators may adjust to reduced Federal range permits in a number of ways depending on relative costs. Adjustments might include shifting the timing and use of their base property, changing herd size, or buying additional feed. Another adjustment might be to change the type of operation from "cow/calf" to "stocker/feeder."

Permit Issues

There are a number of issues that surround the permit system used in Federal range management. These issues are a central focus of the Rangeland Reform EIS (U.S. Department of Interior 1994b) and those results are used in this section to describe some of the permittee issues. One side note, the Rangeland Reform EIS reports 1992 dependency levels for permitted cattle and sheep herds, by state (table 6.16). Their definition of dependency is different from ours and represents the dependency of only those ranchers who hold Federal grazing permits; it excludes the majority of ranchers who have no access to Federal forage. This accounts for the difference from the much lower figures reported in table 6.15.

A basic characterization of the holders of FS or BLM grazing permits are that, on average, they had much bigger operations and were more profitable per cow and per ranch than non-permittees (tables 6.17 and 6.18) (U.S. Department of Interior

Table 6.15—Seasonality of grazing allotments, by state, on Bureau of Land Management (BLM), Forest Service (FS) and other Federal[1] land, 1994.

State	Spring		Summer		Fall		Winter		Not Seasonal[2]		Total
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number
Idaho	1,870	29	1,801	28	1,038	16	697	11	981	15	6,387
Montana	189	42	211	47	38	9	0	0	9	2	447
Nevada	86	21	126	31	108	26	22	5	70	17	412
Oregon	1,579	30	1,286	24	1,099	21	375	7	958	18	5,297
Washington	283	25	329	30	304	27	18	2	177	16	1,111
Wyoming	112	28	151	38	126	32	7	2	4	1	400
Total	4,119	29	3,904	28	2,713	19	1,119	8	2,199	16	14,054

[1] "Other federal" category includes Agricultural Research Service, Department of Defense, Army Corps of Engineers, Department of Energy, Bureau of Reclamation, U.S. Fish and Wildlife Service, and National Park Service.

[2] "Not Seasonal" indicates allotment where season of use was not recorded.

Table 6.16—Average dependency of Federal grazing permittees on Federal forage, by State, percent of total cattle and sheep, 1992.

State	Number of permittees	Cattle dependent	Sheep dependent
		Percent	
Idaho	3,675	23	35
Montana	4,710	11	35
Nevada	930	36	43
Oregon	1,790	23	27
Washington	450	13	0
Wyoming	2,940	23	29

Source: U.S. Department of Interior (1994a).

1994a). Federal grazing permittee per-cow costs and receipts were significantly lower than for non-permittees. Non-permittee cash expenses were $106 per cow higher than permittee costs (31%); permittee cash receipts were $65 lower than non-permittee cash receipts (13%). The lower expenses were due chiefly to lower costs for feed; capital expenditures per cow were also lower (U.S. Department of Interior 1994a). Federal permittees also averaged almost nine times as many sheep as non-permittees (112 sheep versus 13 sheep). Permit acreage and AUMs are skewed heavily toward the largest permit holders (U.S. General Accounting Office 1992, 1993). The 1,000 largest BLM permit holders (out of 22,058 permits, covering 163.3 million acres in 16 western states) had 50.3 percent of the AUMs in 1991, while the 1,000 smallest had 0.04 percent. For FS land, the 1,000 largest permittees (of 8,206 in FS Regions 1 to 6) controlled 63 percent of the AUMs while the 1,000 smallest had 0.3 percent. The bulk of the benefits from the subsidized Federal program went to a small number of individuals, corporations, and partnerships.

Table 6.17—Cow-calf production cash costs and returns for Federal grazing permittees and non-permittees in ten western and Great Plains states, 1990.

Item	Non-permittees	Permittees	Non-permittees	Permittees
	..... Dollars per ranch		..... Dollars per cow	
Cash receipts	46,205	95,502	496	431
Cash expenses:				
Feeder cattle	(4,446)	(1,152)	(48)	(5)
Forest Service-Bureau of Land Management pasture	NA	(2,768)	NA	(13)
Other public pasture	(521)	(625)	(6)	(3)
Total other feed costs	(16,635)	(27,050)	(179)	(122)
Other variable cash expenses	(8,338)	(21,920)	(90)	(102)
Total variable cash expenses	(29,921)	(53,515)	(321)	(245)
Total fixed cash expenses	(12,057)	(22,227)	(129)	(100)
Total cash expenses	(41,977)	(75,742)	(451)	(345)
Cash receipts less cash expenses	4,228	19,760	45	86
Capital expenditures	(11,462)	(18,446)	(123)	(83)
Total, cash expenses and capital replacement	(53,439)	94,188	574	(428)
Net cash returns	(7,234)	1,314	(78)	(3)

Source: U.S. Department of Interior (1994a).
NA = Not applicable.

Table 6.18—Comparison of Federal grazing permittees and non-permittees ranch and herd size, 1990.

	Number of ranches in sample	Average herd size	Percent of operations with:		
			Fewer than 100 cows	100-499 cows	500 or more cows
Permittees	6,678	221	33.9	56.9	9.2
Non-permittees	49,658	93	61.6	35.1	3.3

Source: U.S. Department of Interior (1994a).

A 1986 General Accounting Office report found that about 76 percent of the permittees with grazing permits on BLM-administered lands were individuals, but that they accounted for only 54 percent of the AUMs. Another 11 percent were corporations that controlled 29 percent of the AUMs from BLM forage. Another 8 percent of the permittees were partnerships that held 7 percent of the AUMs. The same report found that small herds (under 100 animals) accounted for half the permits but only 10 percent of the AUMs; while large herds (500+ animals) accounted for 15 percent of the permits and 58 percent of the AUMs.

Having a Federal grazing permit allows the holder to graze livestock on Federal lands, typically at below-market rates. Permits also confer value in two other ways; "as a general rule, all else being equal, a ranch with a Federal grazing permit is worth more than a ranch without a permit" (U.S. Department of Interior 1994a). One hidden value has to do with transferability of grazing permits. When a ranch with a BLM or FS permit is sold, the permit is usually reissued to the new owners, provided they agree to meet regulatory requirements and the terms and conditions of the permit. As a matter of law, the issuance of grazing permits creates no right, title, or interest in the Federal lands. However, as a matter of practice, because grazing permits are usually reissued to the new owner, they attach value to the base property. The value of the permit at least partly reflects the capitalized value of the subsidy, the difference between the Federal grazing fee and the competitive market rate that could be charged for Federal forage (U.S. Department of Interior 1994a). Correspondingly, changes in Federal grazing fees or the terms of the permit can be expected to alter this *de facto* value that accrues to holders of Federal grazing permits.

The second implicit value of Federal grazing permits involves fluctuations in base ranch values due to changes in the grazing program or the specific grazing permit. According to the *Rangeland Reform Draft EIS* (U.S. Department of Interior 1994a), because permit values are associated with the privilege (not a right) to graze on Federal lands, permit changes that result in a reduction in base ranch value are not compensable. A change in base ranch value may show up as a change in market value if sold, or in the amount that a bank will loan to an operation.

Setting grazing fees for FS- and BLM-administered lands below commercial values is controversial. In 1989, BLM charged its operators $1.81 per AUM; comparable commercial values for forage were $8.49 per AUM (GAO 1990, cited in Cubbage and others 1993). Supporters of the current fee structure note that Federal grazing allotments typically require the permittee to install and maintain fencing and develop water for the livestock, whereas other land owners may include these items in their higher fees. The House report (U.S. House Committee on Natural Resources 1994) asserted that grazing fees are too low, not just by comparison with private grazing permits, but because they increase base ranch values and some can be subleased at a profit.

Half of the value of fees paid to the BLM by grazing permittees go into a Range Betterment Fund. The House report (U.S. House Committee on Natural Resources 1994) concluded that the grazing permittees appear to receive the benefits of most of the fees paid into this fund. Further, both the FS and BLM pay a portion of the grazing receipts to the states, which reallocate the money to counties. The House report (U.S. House Committee on Natural Resources 1994) questions the propriety of channeling these funds back into local grazing advisory boards controlled by ranchers.

The costs associated with managing public rangelands are another perennial issue. *The Rangeland Reform Draft EIS* (U.S. Department of Interior 1994a) tallies national data for BLM and FS rangeland management and rangeland improvement costs for 1993. Nongrazing expenses were costs associated with activities that preserved rangeland, such as monitoring rangeland condition and preventing trespass. All other expenses in the rangeland program were used for managing

Table 6.19—Program costs of managing public rangeland, 1993.

Category	Livestock grazing expenses		Nongrazing expenses[1]	Rangeland program costs	
	Total (Thousand Dollars)	Cost per AUM (Dollars)	Total (Thousand Dollars)	Total (Thousand Dollars)	Cost per AUM (Dollars)
Rangeland management	52,683	3.23	24,362	77,045	4.72
Rangeland improvements	12,456	0.76	4,535	16,991	1.04
Totals	65,139	3.99	28,897	94,036	5.76

Source: U.S. Department of Interior (1994a).

[1] Nongrazing expenses are for activities that preserve rangeland, such as monitoring rangeland condition and preventing trespass. All other expenses in the rangeland program are for managing livestock grazing.

livestock grazing (table 6.19). The EIS (U.S. Department of Interior 1994a) reported that the BLM and the FS spent an average of $3.99 per animal unit month (AUM) of forage grazed by livestock on lands they administered; and that in 1993, the grazing fee was $1.86 per AUM.

Projections of Livestock Production

As part of the 1989 Resources Planning Act (RPA) process, the FS projected that national livestock production would increase steadily from 1986 to 2040, but that grazing supplied by permits on public lands would increase by less than 1 percent (Joyce 1989). On a national level, during the same time period, cattle herd inventories were expected to increase by 56 percent between 1986 and 2040, to approximately 55 million animals. Breeding ewe inventories were projected to more than double to 18 million. These projected increases were driven by an increasing domestic population, and to a limited extent, by increasing per capita consumption and international trade. Most of the increased demand for cattle and sheep was expected to be met on private lands. AUMs from FS lands were projected to increase over the period in FS Region 1 by 3 percent, have no change in Region 4, and decrease in Region 6 by 1 percent. BLM AUMs were projected to stay at current levels.

Different projections were made in the *Rangeland Reform '94 Draft Environmental Impact Statement* (U.S. Department of Interior 1994a). It found that historically, forage consumption by livestock has been decreasing on both BLM- and FS-administered rangelands in response to agency decisions about carrying capacity and resource protection and to operator decisions for business or personal reasons. These decreases of 6 percent per decade (BLM) and 8 percent per decade (FS) were projected to continue regardless of changes in the Federal grazing programs. Under the *Rangeland Reform '94 Draft EIS* (U.S. Department of Interior 1994a) "No Action Alternative," representing continuation of current management practices, decreases of 18 percent in livestock forage authorized by the BLM and 19 percent by the FS were projected over the 20-year analysis period. Factors contributing to the anticipated declines included stocking rate reductions from recognition of continuing resource damage and a declining economic feasibility of livestock grazing, as well as from implementation of recovery plans for Federally-listed threatened and endangered species. Under the *Rangeland Reform '94 Draft EIS* "Proposed Action" (U.S. Department of Interior 1994a), decreases in AUMs authorized are projected to be slightly greater over the next 20 years: 20 and 21 percent below current authorizations for the BLM and FS, respectively.

Recreation[22]

In this section we discuss the rapid rise in demand for recreation in the Basin since World War II and the amount of recreation occurring on BLM and FS lands in the Basin today. To understand distribution of benefits from these lands we discuss characteristics of the people who recreate in the Basin. The total public supply of recreational settings is also characterized, and the portion of those settings managed by the FS and BLM is noted. We use willingness-to-pay concepts to assess the recreation value of all public lands and the part contributed by these two agencies. The roles of recreation in regional economies and agency budgets are also discussed. Finally, we describe an approach for predicting trends in recreation activity and ways in which management can affect both the quantity and quality of recreation.

Publicly owned lands[23] in the Basin provide significant recreation benefits to people living there, other residents of the seven states of the Northwest (the "greater Northwest"),[24] residents of the other 43 states, and citizens from other countries. Over 200 million recreation activity days per year were made to Federal lands in the Basin between 1991 and 1993, representing a minimum of $1.2 billion in willingness-to-pay benefits and supporting 220,000 jobs. Fishing provides the greatest willingness-to-pay benefits of any recreation activity ($293 million), followed by day use[25] activities ($251 million), winter sports ($230 million) and hunting ($146 million). Hunting, motor viewing, and day use activities support the greatest number of jobs (49,000; 40,000; and 34,000, respectively).

Historical Trends in Recreation

After the advent of transcontinental railroads, accounts of remarkable recreational fishing in the streams and lakes of the Basin attracted travelers (Craig and Hacker 1940). In the early twentieth century, recreational use of public lands in the Basin was limited by distance from population centers; railroads brought some visitors but access to the core of the forest reserves was inhibited by lack of trails. The Agricultural Appropriations Act of 1915 was the first significant Congressional recognition of recreation as a legitimate use of the national forests (Cubbage and others 1993). Visitation to Federal lands increased rapidly through the 1920s with the advent of the automobile.

Since World War II, there has been a steady increase in recreation activity in the West and the Basin, spurred by Depression-era public works development of trails and landmark lodges. Between 1945 and the early 1970s, recreation activity on public lands grew more than 10 percent per year driven by rapid population growth, increased affluence, improvements in cars and interstate highways, decreased gasoline prices, increased air travel, and the decline of the average workweek to 40 hours and 5 days (Walsh 1986). Land management agencies responded to this increase in recreation activity by developing resource and visitor management programs.

In the 1980s major changes occurred in the national recreation scene. Participation in many activities outpaced the projections in the report by the U.S. Outdoor Recreation Resources Review Commission (1962), largely because population grew faster than expected but also because technology spawned new activities (mountain biking, wind surfing, jet skiing) and made camping more feasible (Cordell and others 1990). Since 1980, recreation visitor days on FS-administered lands in the Basin have increased 2.3 percent per year; at

[22] This section was written by Amy L. Horne, based in part on a 1995 background report by Amy Molitor and Natalie Bolon. On file with: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management; Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar, Walla Walla, WA 99362.

[23] This assessment is only of recreation occurring on publicly owned lands because of the difficulty of surveying activity on private lands. Given the incomplete survey the estimates of recreation value and activity in the assessment area are understated.

[24] The "greater Northwest" is defined as those parts of Idaho, Montana, Oregon, Utah, Washington, and Wyoming lying outside the Basin plus Elko and Humboldt Counties, Nevada.

[25] Day use activities are defined as picnicking, family gatherings, swimming, collecting berries and firewood, and visiting interpretive centers, museums, historic or prehistoric sites.

these growth rates recreation use will double every 31 years. Visitation to National Park lands in the study area has increased 4.3 percent annually since 1984.

Wilderness designation, accelerated by the 1964 passage of the Wilderness Act, is one indication that society wants management of certain lands to be different than that of others. There is a range of opinions on how much wilderness is enough, depending on whether one regards public land wilderness as "locked up resources" or as "the last refuges." Oregon, Washington, Idaho, and Montana have each had a portion of their national forests designated as wilderness. A second round of wilderness designation has succeeded in Washington and Oregon, but attempts to designate more wilderness in Idaho and Montana have been stalled in Congress for the past decade.

Competing uses for Federal resources have caused disagreements over stewardship. The FS and BLM increasingly mediate conflicts among recreation users (for example, rafters versus jet boaters, snowmobilers versus cross-country skiers), and between recreationists and resource extractors. Increases in the recreational collection of nontimber forest products, such as mushrooms and huckleberries, and non-consumptive uses such as bird-watching further complicate the stewardship task of balancing competing demands.

Amount of Recreation Activity

Over 200 million recreation activity days per year were made to Federal lands in the Basin for selected activities (table 6.20). Day use and motor viewing[26] account for 45 percent of the recreation activity days occurring in the Basin. Camping (25 million activity days), fishing (18 million), trail use,[27] and hunting (16 million each) are the next most popular recreation activities in the Basin. One quarter of this activity occurs in the Central Idaho Mountain ERU; other ERUs in which significant recreation activity occurs include the Northern Glaciated Mountains, Lower Clark Fork, Northern Cascades, Southern Cascades, and Blue Mountains.

Who Participates in Recreation

The Basin is an important vacation spot for people from different parts of the country.[28] We used lifestyle data (Claritas 1994) that match or can serve as proxies for the 12 classes of recreation activities that occur on publicly owned lands: sightseeing is a proxy for motor-viewing, birdwatching is a proxy for wildlife viewing, hiking and horseback riding are part of trail use, downhill and cross-country skiing are included in winter sports. We divided the data into three spatial units: (1) the Basin, defined by the nine BEA regions, (2) the greater Northwest, defined as people living outside the Basin but in the seven Northwest states, and (3) U.S. residents living outside the greater Northwest.

In 1993, 149,024 people living in the Basin took vacation trips of more than one day's duration in Idaho, Montana, Oregon, Washington, or Wyoming (Claritas 1994). For people living in the greater Northwest, 410,548 per year took a vacation in these five states. Over 6.5 million people living outside the greater Northwest took vacations in this five-state region. While these numbers pertain to whole states and not solely to the Basin, they do reflect the demand for vacations in the region by people living in different parts of the country.

People living in the nine BEA regions are more likely to participate in certain recreational activities than the U.S. population (table 6.21). For freshwater fishing, for example, a higher percentage of people living in the Basin participate than the U.S. average (18.57% versus 15.17%); the

[26] Motor viewing includes sightseeing from automobiles and pleasure driving.

[27] Trail use includes biking, day hiking, horseback riding, backpacking, and walking.

[28] To examine the question of who participates in recreation in the Basin we used a marketing database (Claritas Corporation 1994) that estimates the number of adults in each census tract likely to participate in a given activity based on census data, purchasing information, and surveys.

Table 6.20—Recreation activity days in the Basin, by activity and Ecological Reporting Unit (ERU 1-13), averaged 1991-1993.

Activity	ERU 1	ERU 2	ERU 3	ERU 4	ERU 5	ERU 6	ERU 7
	Activity days						
Trail use	2,215,467	1,052,879	252,476	204,648	661,633	1,346,378	2,279,461
Camping	2,838,089	1,628,728	904,477	683,951	872,307	2,580,500	3,648,963
Hunting	436,590	504,206	120,455	330,435	791,075	4,519,573	2,347,280
Fishing	135,664	1,368,209	137,894	406,263	2,725,315	1,531,059	2,955,824
Nonmotor boating	64,574	839,377	50,900	100,618	360,887	103,829	191,698
Viewing wildlife	119,154	1,314,081	48,313	111,811	934,597	435,531	2,498,405
Day use	2,234,015	3,623,842	1,757,594	701,225	3,434,809	3,185,049	11,818,900
Motor boating	95,699	73,817	87,884	190,470	55,449	246,517	3,037,015
Motor viewing	6,762,177	3,804,620	290,988	838,391	1,377,152	1,794,295	5,689,239
ORV use	446,160	93,947	17,464	116,022	79,135	191,414	383,089
Winter sports	846,252	1,237,132	62,672	128,128	137,742	1,027,098	391,823
Snowmobiling	214,450	104,562	36,185	32,506	43,272	165,547	263,901
Total	16,408,29	15,645,400	3,767,302	3,844,469	11,473,373	14,126,789	35,505,598

Activity	ERU 8	ERU 9	ERU 10	ERU 11	ERU 12	ERU 13	Total
	Activity days						
Trail use	1,388,763	836,826	462,287	365,376	1,269,016	3,722,663	16,107,875
Camping	2,327,797	1,048,789	1,010,427	620,646	1,095,613	5,873,383	25,133,670
Hunting	2,165,185	1,756,524	1,209,796	511,300	560,193	3,827,434	16,080,047
Fishing	1,273,397	735,649	1,323,905	618,765	613,250	4,133,381	17,985,574
Nonmotor boating	122,398	97,336	26,382	25,483	412,936	945,152	3,341,572
Viewing wildlife	287,645	1,023,643	134,763	147,888	118,661	663,071	7,837,562
Day use	4,907,052	2,399,166	737,851	1,309,595	2,466,031	13,473,143	52,048,273
Motor boating	822,936	349,219	818,016	150,138	219,673	2,307,145	8,453,979
Motor viewing	3,729,659	1,566,640	970,497	737,126	1,824,727	13,006,164	42,391,674
ORV use	546,683	253,747	288,540	279,888	198,951	1,855,628	4,750,668
Winter sports	369,865	324,242	535,814	443,151	918,432	2,890,309	9,312,661
Snowmobiling	263,240	346,520	47,767	55,035	388,358	852,936	2,814,279
Total	18,204,622	10,738,299	7,566,045	5,264,391	10,085,842	53,600,409	206,230,832

ERU 1 = Northern Cascades; ERU 2 = Southern Cascades; ERU 3 = Upper Klamath; ERU 4 = Northern Great Basin; ERU 5 = Columbia Plateau; ERU 6 = Blue Mountains; ERU 7 = Northern Glaciated Mountains; ERU 8 = Lower Clark Fork; ERU 9 = Upper Clark Fork; ERU 10 = Owyhee Uplands; ERU 11 = Upper Snake; ERU 12 = Snake Headwaters; ERU 13 = Central Idaho Mountains

Table 6.21—Participation rates in recreation activities in the United States, greater northwest, the Basin, and the Basin Bureau of Economic Analysis (BEA) regions, 1993.

Region	All Terrain Vehicles	Back-packing-hiking	Bird watching	Cross country skiing	Downhill skiing	Fresh-water fishing	Horse-back riding	Hunting rifle	Hunting shotgun	Motor boating	Sight seeing	Snow-mobiling
	Percent											
United States	1.75	6.00	4.11	1.79	3.80	15.17	3.14	4.76	4.66	6.48	21.13	1.23
Greater Northwest	2.04	6.46	4.42	1.88	3.97	16.25	3.46	3.89	5.38	7.14	21.95	1.35
Basin	2.65	6.18	4.79	1.92	3.60	18.57	3.91	4.82	6.79	7.67	21.44	1.66
BEA regions												
Tri-Cities	2.56	5.76	4.42	1.67	3.35	17.68	4.16	4.67	6.57	7.41	21.07	1.66
Spokane	2.25	6.08	4.52	1.86	3.63	16.98	3.28	4.24	5.86	7.09	20.67	1.44
Missoula	2.75	6.08	5.00	1.88	3.47	19.48	3.52	4.80	7.09	7.19	19.40	1.60
Idaho Falls	2.62	6.42	4.98	2.03	4.06	18.29	3.80	4.98	6.70	8.00	22.10	1.72
Twin Falls	3.28	5.63	4.77	1.81	2.79	19.93	4.65	5.52	7.92	7.91	19.92	1.92
Boise	2.44	6.42	4.47	1.85	3.90	18.03	3.96	4.59	6.37	7.58	22.19	1.47
Redmond-Bend	2.96	5.66	4.64	1.79	3.02	18.84	4.18	5.33	7.36	7.80	20.29	1.80
Pendleton	2.88	5.70	4.96	2.00	3.05	19.27	3.92	5.11	7.42	7.64	20.03	1.76
Butte	2.52	6.29	4.92	2.08	3.37	18.62	3.42	4.28	6.62	7.08	20.43	1.51

Source: Claritas Corporation (1994).

higher participation for this sport is particularly significant given its universal popularity. Driving all-terrain vehicles, birdwatching, horseback riding, hunting with a shotgun, motorboating, and snowmobiling are all activities residents of the Basin and the greater Northwest are more likely to enjoy than the average U.S. citizen. Backpacking, cross-country skiing, and hunting with a rifle are more popular in most parts of the Basin than in the United States. Greater differences in participation rates exist between people who live in rural areas and those in urban areas, inside or outside of the Basin, than income levels or occupations; this is particularly true for freshwater fishing in which participation rates among rural residents are 10 percent higher than those in urban areas (Claritas 1994). Income level makes virtually no difference in whether someone participates in fishing. Farmers, blue-collar workers, professionals and managers all have similar rates of participation in fishing.

Supply of Recreational Settings

The western United States offers greater recreational opportunities than the eastern United States for certain types of settings, especially those in remote, wilderness, or backcountry areas (Cordell and others 1990). Land-based opportunities are 5 to 15 times greater in the West than in the East; FS and BLM lands provide most of the remote backcountry settings. At the national level, opportunities for remote backcountry and roaded natural settings have been decreasing at 0.9 percent and 0.7 percent per year respectively, while developed recreational opportunities have been increasing 0.6 percent per year. Seventy percent of the unroaded areas of 200,000 acres or greater in the United States (except Alaska) lie in the Basin (fig. 6.17).

The supply of recreational opportunities on Federal lands can be described by the number of acres of various "Recreational Opportunity Spectrum" (ROS) classes. We use three classes: primitive/semi-primitive, roaded natural, and rural/urban. "Primitive/semi-primitive" lands are natural-appearing, of moderate to large size, and have road densities less than 1.7 miles per square mile. "Roaded natural" areas have moderate evidence of human activity that is generally in harmony with the natural environment and have higher road densities between 1.7 and 4.6 miles per square mile. "Rural/urban" settings are substantially modified from the natural environment, with a moderate to high density of visitors, and road densities greater than 4.6 miles per square mile. In the Basin, many of the Federal acres in this category are ski areas.

About 60 percent of the Federal lands in the Basin fall into the roaded natural category; 40 percent are primitive/semi-primitive and less than 1 percent is rural/urban. The FS and BLM manage over 90 percent of the Federal acres available for recreation in almost every ERU and ROS class in the Basin (table 6.22). Almost one-third of the primitive/semi-primitive ROS acres lie in the Central Idaho Mountains ERU; other ERUs with substantial amounts of this ROS class include Northern Glaciated Mountains, Owyhee Uplands, Blue Mountains, and Snake Headwaters. The Southern Cascades and Upper Klamath ERUs

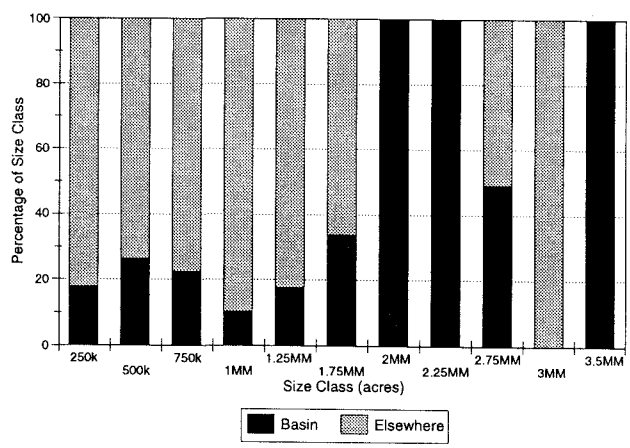


Figure 6.17— Contribution of large unroaded areas in the Basin to supply in contiguous United States, by size of unroaded area.

Table 6.22—Supply of recreational opportunities on Federal land in the Basin; acres and percentage managed by Bureau of Land Management (BLM) and Forest Service (FS), overall and within each Basin Ecological Reporting Unit (ERU) by combined Recreation Opportunity Spectrum (ROS) class, 1995.

Ecological Reporting Unit (#)	ROS combined class					
	Primitive/Semi-primitive		Roaded natural		Rural/urban	
	Acres	Percent	Acres	Percent	Acres	Percent
Northern Cascades (1)	2,073,679	91.26	1,551,382	95.71	58,812	99.89
Southern Cascades (2)	424,782	99.25	1,542,463	98.70	1,858	100.00
Upper Klamath (3)	215,750	93.15	1,750,932	90.30	1,917	73.66
Northern Great Basin (4)	2,015,596	99.06	5,538,392	99.71	17,694	96.78
Columbia Plateau (5)	948,459	66.54	2,498,284	91.51	43,720	9.72
Blue Mountains (6)	2,468,990	99.58	4,001,988	99.70	8,329	92.71
Northern Glaciated Mountains (7)	3,880,995	77.00	3,908,036	93.19	13,066	96.48
Lower Clark Fork (8)	1,336,008	98.62	2,978,974	100.00	10,953	100.00
Upper Clark Fork (9)	1,410,313	100.00	1,615,809	99.73	6,561	100.00
Owyhee Uplands (10)	3,247,570	98.12	7,925,540	98.31	17,523	92.52
Upper Snake (11)	892,485	93.01	2,413,857	97.96	1,617	78.67
Snake Headwaters (12)	2,277,987	97.86	1,722,256	98.97	1,915	66.74
Central Idaho Mountains (13)	9,086,858	97.09	7,524,897	99.94	9,265	96.47
Total	30,279,474	93.79	44,972,809	97.84	193,230	77.08

have few primitive/semi-primitive recreation settings, especially given their proximity to population centers. In the roaded natural ROS settings, Owyhee Uplands and Central Idaho Mountains each account for nearly 8 million acres; the Northern Great Basin, Blue Mountains, Northern Glaciated Mountains, and Lower Clark Fork also have significant amounts of roaded natural settings.

Roaded natural settings provide for 74 percent of all activity days. They offer over 68 percent of all activity days for all types of recreation except trail use and camping (table 6.23). Trail use occurs predominantly in primitive/semi-primitive areas (56%). About half of camping occurs in roaded natural areas, and 26 percent each occurs in primitive/semi-primitive or rural/urban. About 24 percent of winter sports occur in rural/urban settings.

Willingness-to-pay for Recreation on Public Lands in the Basin

Willingness-to-pay for recreation on Federal lands in the Basin is at least $1.2 billion per year. Values vary greatly between ERUs reflecting in part the unique set of recreation advantages offered by each. For example, the Central Idaho Mountain ERU accounts for nearly one-quarter of all recreational benefits from Federal lands in the Basin (table 6.24). Other ERUs with high recreational values include the Northern Glaciated Mountains, the Southern Cascades, the Blue Mountains, and the Lower Clark Fork. Differences between regions reflect differences in numbers of visits, the types of activities occurring in them, and willingness-to-pay associated with each activity.

Table 6.23—Distribution of recreation activities in the Basin between Recreation Opportunity Spectrum (ROS) classes, 1995.

Activity	ROS Class		
	Primitive/Semi-primitive	Roaded natural	Rural/urban
	Percent		
Camping	26.10	48.13	25.77
Day use	10.19	73.81	16.00
Fishing	13.84	80.93	5.22
Hunting	21.88	75.19	2.93
Motor boating	14.23	70.08	15.69
Motor viewing	6.27	87.48	6.25
Nonmotor boating	7.84	84.86	7.30
Off-road vechicles	20.03	75.46	4.51
Snowmobiling	14.55	81.19	4.26
Trail use	56.12	36.64	7.24
Viewing wildlife	13.85	78.30	7.85
Winter sports	8.05	67.87	24.08
Total Recreation Activities	13.67	74.10	12.23

Note: Percents may not add to 100 due to rounding.

To some extent these differences are distorted by differences in size. Some ERUs have high value by virtue of being large. This makes the high values of the smaller ERUs, for example Southern Cascades and Lower Clark Fork, more striking. Lands administered by the FS and BLM provided $1.0 billion (83%) of the recreation benefits in the Basin (table 6.24). These data probably underestimate total value (and overestimate the percent contribution of FS and BLM lands) because only 77 percent of the surveyed management units provided usable data, and no activity occurring on private land is included. The values of the Snake Headwaters and Columbia Plateau ERUs are understated because of missing data from the Army Corps of Engineers and Yellowstone and Grand Teton National Parks.

Fluharty (1995) found the value of recreational fishing supported by salmon spawned and reared in the Basin to be about $9.7 million per year (1987-1991). Fish caught in the Columbia River represent 81 percent of this value and the rest were caught in the ocean off Alaska, Canada, Washington, Oregon and California. Three-quarters of this value ($7.3 million) is contributed by recreational steelhead fishing in the Columbia River. Most of the rest of the value lies in the recreational fishing for fall chinook caught outside the Basin.

Solely within the Basin, fishing is the recreational activity providing the greatest willingness-to-pay benefits, nearly $300 million (table 6.25). Day use is another highly valued activity ($250 million per year), about half of which occurs on FS- and BLM-administered lands. Winter sports like downhill and cross-country skiing also provide

Table 6.24—Average annual willingness-to-pay for recreation in the Basin, by Basin Ecological Reporting Unit (ERU) and Recreation Opportunity Spectrum (ROS) class, for all Federal lands and Forest Service- and Bureau of Land Management-administered lands (FS-BLM), 1991-1993.

ERU (#)	Total primitive/ semi-primitive	Total roaded natural	Total rural-urban	Total all ROS	FS-BLM primitive/ semi-primitive	FS-BLM roaded natural	FS-BLM rural-urban	FS-BLM all ROS
	Dollars							
Northern Cascades (1)	26,978,850	3,737,607	15,904,995	80,259,452	26,865,466	37,103,446	15,904,995	79,873,907
Southern Cascades (2)	18,649,939	67,766,903	25,903,310	112,320,152	13,774,702	67,766,903	25,903,310	107,444,916
Upper Klamath (3)	2,425,663	10,644,091	3,181,744	16,251,498	1,364,742	6,263,284	3,042,627	10,670,653
Northern Great Basin (4)	3,491,075	24,584,854	3,634,166	31,710,094	3,491,075	15,324,613	3,634,166	22,449,853
Columbia Plateau (5)	10,160,089	62,846,343	7,222,769	80,229,201	10,160,089	61,610,006	4,642,389	76,412,484
Blue Mountains (6)	28,597,221	47,230,780	27,132,669	102,960,670	28,597,221	47,230,780	27,132,669	102,960,670
Northern Glaciated Mountains (7)	73,817,529	71,331,354	13,891,382	159,040,265	30,227,070	55,147,190	12,898,454	98,272,714
Lower Clark Fork (8)	24,453,094	46,542,728	17,530,370	88,526,191	15,185,252	46,542,728	17,530,370	79,258,350
Upper Clark Fork (9)	24,341,749	25,860,987	8,179,374	58,382,110	24,341,749	22,159,182	8,179,374	54,680,304
Owyhee Uplands (10)	16,421,095	48,326,626	6,808,928	71,556,649	13,043,557	36,593,859	3,874,948	53,512,365
Upper Snake (11)	5,146,426	25,237,539	2,812,933	33,196,898	5,104,240	24,021,957	1,978,651	31,104,849
Snake Headwaters (12)	18,974,684	31,219,886	11,112,609	61,307,179	18,320,523	31,059,621	11,112,609	60,492,753
Central Idaho Mountains (13)	88,300,798	145,384,501	43,621,238	275,306,537	88,300,798	144,811,461	41,549,707	274,661,965
All ERUs	341,758,212	644,352,199	184,936,486	1,171,046,898	278,776,484	5,956,350,314	177,384,269	1,051,795,783

Table 6.25—Contribution of recreation activity on all Federal, Forest Service and Bureau of Land Management-administered lands (FS-BLM) to recreation net economic benefits in the Basin, 1991-1993.

Activity	Net economic benefit		
	All Federal lands	FS-BLM	FS-BLM percent of all Federal lands
	..... Dollars		.... Percent ....
Camping	91,789,117	75,419,530	82.17
Day use	251,064,000	130,047,740	51.80
Fishing	292,826,010	252,719,032	86.30
Hunting	146,276,740	141,046,516	96.42
Motor boating	7,609,776	5,231,747	68.75
Motor viewing	77,235,245	75,361,696	97.57
Nonmotor boating	10,614,219	10,556,444	99.20
ORV use	6,631,702	6,631,702	100.00
Snowmobiling	4,899,530	4,898,282	99.97
Trail use	84,008,335	77,413,949	92.15
Viewing wildlife	65,489,031	43,045,469	65.73
Winter sports	230,543,527	229,423,677	99.51
Total	1,269,014,282	1,051,795,783	82.88

substantial benefits ($230 million per year), and take place predominantly on FS- and BLM-administered lands. Hunting ($146 million/year) and camping ($75 million/year) are other high value activities. Snowmobiling and off-road vehicle (ORV) use are lower value activities because of lower participation rates, but the FS- and BLM-administered lands provide almost all the suitable settings.

Our assumption that each ERU has unique recreation value is borne out when we calculate recreation value per unit land area (table 6.26). Current value reflects aspects of both recreation supply and demand: the natural character of the area, road networks, wilderness allocation, distance from population centers, and the age and income characteristics of those populations. The ERUs that currently have highest recreation value are the Southern Cascades, Lower Clark Fork, Central Idaho Mountains, Northern Cascades, and Upper Clark Fork. Each ERU has a unique mix and relative value of recreation activities. Some ecological units show distinct advantages in providing certain recreation activities; for example, the Southern Cascades and Central Idaho Mountains are highly valued areas for fishing.

Contribution of Recreation to Regional Economies

In Idaho, Oregon, and Washington, tourism is one of the three most important generators of outside income (Nolan 1993). In the past few years, Montana's economy has been driven largely by an influx of new residents and the strength of the tourism sector (Sommers and others 1995). Montana's wildlands play an important role in its

Table 6.26— Net economic value (willingness-to-pay) of current recreation activities on FS and BLM administered lands, by Ecological Reporting Unit (ERU).

Activity	ERU 1	ERU 2	ERU 3	ERU 4	ERU 5	ERU 6	ERU 7	ERU 8	ERU 9	ERU 10	ERU 11	ERU 12	ERU 13	Average by Activity
	Dollars per acre (in 1994 dollars)													
Fishing	1.22	23.57	2.05	2.26	6.58	6.02	3.34	7.57	5.16	2.50	2.88	3.71	8.07	5.18
Hunting	3.22	6.96	1.44	1.48	1.47	5.59	4.44	15.56	14.29	2.86	2.82	4.03	8.90	4.97
Day use	4.20	12.80	1.58	0.80	0.68	3.02	2.35	6.89	3.50	0.29	0.71	3.13	6.08	2.77
Winter sports	5.43	14.88	0.31	0.50	0.24	3.29	1.35	2.24	2.31	1.10	2.11	5.68	5.78	2.65
Camping	5.87	6.33	2.80	0.86	0.48	2.53	1.52	3.44	1.83	0.49	0.64	1.41	2.78	1.81
Trail use	9.28	5.40	0.72	0.34	0.48	1.85	1.24	2.84	2.03	0.32	0.58	2.62	2.51	1.72
Motor viewing	5.09	5.44	0.36	0.39	0.19	0.68	1.01	2.33	1.14	0.17	0.29	0.92	2.25	0.98
Viewing wildlife	0.60	12.24	0.39	0.34	0.32	1.07	0.46	0.82	0.98	0.13	0.64	0.68	1.26	0.88
Motor boating	0.04	0.19	0.23	0.11	0.02	0.06	0.12	0.41	0.17	0.38	0.10	0.32	0.77	0.25
Nonmotor boating	0.05	1.21	0.06	0.05	0.07	0.04	0.21	0.27	0.25	0.03	0.04	0.77	0.52	0.21
Off-road vehicle use	0.34	0.14	0.02	0.06	0.02	0.07	0.07	0.33	0.18	0.05	0.11	0.11	0.31	0.12
Snow mobiling	0.16	0.15	0.04	0.02	0.01	0.06	0.05	0.16	0.25	0.01	0.02	0.20	0.14	0.07
Total by ERU	35.49	89.28	10.00	7.19	10.56	24.29	16.18	42.87	32.09	8.32	10.95	23.58	39.37	21.62

ERU 1 = Northern Cascades; ERU 2 = Southern Cascades; ERU 3 = Upper Klamath; ERU 4 = Northern Great Basin; ERU 5 = Columbia Plateau; ERU 6 = Blue Mountains; ERU 7 = Northern Glaciated Mountains; ERU 8 = Lower Clark Fork; ERU 9 = Upper Clark Fork; ERU 10 = Owyhee Uplands; ERU 11 = Upper Snake; ERU 12 = Snake Headwaters; ERU 13 = Central Idaho Mountains

tourism sector. Although only about one-quarter of non-resident visitors engaged in wildland-based activities, they accounted for half of the economic impact associated with non-resident travel in Montana (Moisey and Yuan 1992).

We calculated jobs associated with recreation activity by multiplying the number of recreation activity days by the response coefficients (listed in appendix 6-B) for residents under the column for "jobs, direct effects."[30] Throughout the Basin, recreation supports nearly 220,000 jobs. The percentage of the job force supported by recreation is above that of the Basin in the Idaho Falls, Missoula, and Redmond-Bend BEA regions (table 6.27). In the Pendleton BEA region, another area with high recreation use, the percentage of jobs supported by recreation is equal to that of the Basin; the lower levels of day use and motor viewing reduce the importance of recreation in Pendleton relative to Redmond-Bend. Other BEA regions have higher than average recreation jobs focused around specific activities; fishing, motor boating, and winter sports contribute to jobs in the Boise region; hunting, snowmobiling and viewing wildlife are significant to the Butte region. While significant numbers of jobs are supported by recreation in the Spokane and Tri-Cities BEA areas (34,608 and 18,640 respectively), the economies are so large that recreation jobs do not form part of the base.

Fluharty (1995) found that:

> *In the Basin much of the recreational [fishing] activity takes place on public lands and waters. Free access for fishing tends to equate with low value to users and land managers alike, however, access is only one part of the equation. Purchases of food, equipment, lodging, transportation, licenses and other accouterments of recreational fishing add up to significant expenditures. In some areas, whole towns, resorts, businesses and individuals are highly dependent on sale of services to people who participate in recreational fishing.... The economic values of recreational fishing are significant, diverse, and pervasive in the Basin.*

He estimates that 56 percent of these fishing expenditures occur in eastern Washington, 20 percent each in Idaho and eastern Oregon, and 4 percent in Montana. The Basin portions of each state attract fishing enthusiasts from other parts of the same state. Within the Basin about 70 percent of the fishing activity is generated by residents and 30 percent by non-residents. Great variation in attraction to non-residents exists across the Basin, however, with fishing participation in eastern Washington being only 8 percent non-resident while in Montana non-resident participation is 52 percent.

Fish viewing, part of wildlife viewing, results in $80 million per year in expenditures (Fluharty 1995). This activity includes viewing salmon spawning in rivers and streams, viewing stations at dams and fish ladders (these account for millions of visits per year), fish hatcheries, and fish festivals.

Recreation in Agency Budgets

The fees collected by state and Federal agencies from recreational visitors are much less than either agency costs or benefits provided. Low recreation fees are the result of policy decisions and legal restrictions. In addition, revenues from special use permits are only 1 percent of the net economic benefit provided by Federal lands in the Basin ($12.8 million collected in 1993) (table 6.28). This policy decision underprices recreation experiences on public land, resulting in agency revenues hardly covering the costs of roads, trails, facilities, maintenance, and education. One argument for this policy is equity; it enables all Americans to recreate on Federal lands regardless of their wealth. However, a consequence is that people treat recreational settings as a common good, causing the classic tragedy of over-use. (There are cases,

[30] The recreation response coefficients were calculated by Greg Alward, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Land Management Planning, Fort Collins, CO.

Table 6.27—Percentage of employment supported by recreation activities for the Basin and Basin Bureau of Economic Analysis (BEA) regions, 1991-1993.

Recreation Activity	Boise	Butte	Idaho Falls	Missoula	Pendleton	Redmond-Bend	Spokane	Tri-Cities	Twin Falls	Total Basin
	Percent									
Camping	.70	.53	1.47	1.69	1.06	1.28	.52	.50	.56	.82
Day use	1.49	1.66	4.51	6.26	2.13	3.84	1.70	.81	1.41	2.28
Fishing	1.04	.61	1.70	1.97	1.56	1.99	.65	.24	.92	1.01
Hunting	3.25	5.24	5.49	9.26	4.12	2.88	2.36	.78	2.80	3.27
Motor boating	.35	.23	.54	1.16	.11	.12	.27	.08	.27	.31
Motor viewing	2.16	1.53	5.64	5.03	1.65	3.85	1.81	2.20	1.70	2.69
Nonmotor boating	1.27	.82	5.19	1.71	1.35	7.61	.91	.36	.77	1.89
Off-road vehicles	.06	.04	.14	.09	.03	.03	.04	.03	.07	.05
Snowmobiling	.33	.83	1.42	1.01	.34	.34	.28	.19	.26	.46
Trail use	.57	.63	1.71	1.64	.85	1.03	.49	.58	.47	.79
Viewing wildlife	.06	.31	.10	.57	.16	.45	.09	.05	.05	.15
Winter sports	.94	.44	2.66	.76	1.11	1.63	.42	.41	.96	.91
Total	12.22	12.86	30.57	31.15	14.48	25.05	9.55	6.23	10.24	14.64
Number jobs	92,023	7,022	44,329	34,049	13,745	30,607	34,608	18,640	7,817	219,839

Table 6.28—Federal revenues from recreation special use permits in the Basin, by agency, 1994.

Management Agency	Revenues
	1993 dollars
Bureau of Land Management	317,431
Forest Service	5,260,356
National Park Service	2,490,466
Fish and Wildlife Service	12,825
Corps of Engineers	33,556
Oregon Parks and Recreation	1,953,933
Idaho State Agencies	2,700,905
Total	12,768,792

however, where permit systems are implemented to avoid over-use.) Also the lack of recreation fees, equivalent to prices, means that the agencies do not receive revenues that reflect the value of the recreation opportunities they provide, and hence have little incentive to provide them. Further, low rate schedules have been criticized for being inconsistent between agencies and for giving special advantages to large concessionaires (U.S. House Committee on Natural Resources 1994).

Predicting Recreation Trends

Population growth and the proportion of that population having a degree of affluence are the most significant factors contributing to increases in recreation activity (English and others 1993). The significant population increases expected for the Basin, the greater Northwest, and the rest of the United States over the next 50 years indicate major increases in recreation activity on FS- and BLM-administered lands in the Basin. These factors plus the percentage of people in the age range in which they are most likely to engage in physically demanding recreation activities, the price of recreation, availability of suitable recreational opportunities, as well as opportunities for substitute activities, capture most of what determines recreation demand.

We estimate future recreation demand using population projections for each county in the seven states in which the Basin is located. Number of people, population age structure, and income level are characteristics used to predict the number of trips for each activity. Regression coefficients are taken from the RPA and modified by regionally specific data (English and others 1993, Hospodarsky 1987, Hospodarsky and Lee 1989).

Age structure influences recreation activity because older people tend to travel further for recreation, stay in developed campgrounds, and stay longer than younger people (Cordell and others 1990). Younger people (age 18-34) are more likely to undertake more physically demanding activities such as skiing, backpacking, and mountain biking. Age, however, has little influence on participation rates in the more popular activities such as fishing, motor viewing, viewing wildlife, or picnicking.

We assume here that age will have the same effect on recreation activity in the future as it has in the past, but evidence exists that age-related participation rates can rise. Today older people have higher participation rates in more physically demanding sports such as downhill skiing, camping, hiking and backpacking than people the same age did 40 years ago (English and Cordell 1985). College education is also correlated with higher participation rates in active recreation, and the proportion of college-educated people in the population is increasing (Marcin 1993). This means that older age groups will tend to be more educated than people in those age groups today, suggesting their participation rates in active recreation will be higher.

Other studies have found differences in recreation participation by racial and ethnic groups and urban or rural residence (Dwyer 1994). These factors may shift recreation preferences somewhat; racial and ethnic groups are a small but growing proportion of the population and the U.S. population is expected to become more urban over the next 50 years. These factors are not included in the demand model because we do not know how differences in preference translate into numbers of trips for recreational activities. This omission probably makes little difference because percentage changes in racial and ethnic groups are expected to be small relative to total population.

In our treatment, the primary factor affecting supply of recreational opportunities is the number of acres in the three Recreation Opportunity Spectrum (ROS) classes. These were determined using output from CRBSUM regarding road density and vegetation pattern class. We assumed no change in ROS classification for lands in the Basin not administered by the FS or BLM, nor for any recreation locations lying outside the study area. The effect of changes in ROS supply is weighted by distance from population centers: thus changes in ROS acres on the Mt. Hood

National Forest (close to the Portland metropolitan area) will affect recreation activity more heavily than changes on the BLM Vale District. The model solves for demand and supply simultaneously and can be used to predict changes in visitation resulting from different scenarios or alternatives.

Other factors may also affect the quality and quantity of recreation activities in the Basin. Crowds of people may be the most significant factor limiting participation (Crocker 1985). Disturbances caused by insects, diseases, and fires also reduce recreation benefits in proportion with the severity of the disturbance; recreation value recovers as the forest recovers (Flowers and others 1985, Leuschner and Young 1978). Insect outbreaks have mixed effects on activities associated with fish and wildlife. Some fish and wildlife populations may be enhanced by increased dead wood in streams and forest stands, more vertical stratification, and more insect availability; some populations may be harmed by loss of cover, increased stream temperatures, and increased fire hazard (Gottschalk 1990).

Forest management activities can either enhance or detract from the quality of recreational experiences. Positive effects result from management that encourages diverse plant communities and stands having greater average tree diameters and higher trees per acre (Shaw 1977). Negative effects result from residual stands having low tree densities or small tree diameters (Walsh and others 1988). Management that degrades scenic quality or reduces the abundance and catchability of fish diminishes recreation benefits (Hueth and others 1988). Those silvicultural practices having positive, or avoiding negative, effects on recreation value are more likely to gain public approval of agency management activities than are others.

The issue of roads is complex. Roads can provide access for certain popular recreation activities but can permanently reduce wild, backcountry areas. Roads can reduce fish populations and catch rates, that affect the value of that site as a tribal or sport fishery. For example, erosion following logging and road building on the Salmon River caused the capitalized value of the fishery to drop from over $200 million to $14 million (Hueth and others 1988, Rice 1989). Roadless areas have recreation value in their own right; residents of Colorado and Utah reported household willingness-to-pay for wilderness ranging from $52 per year for 2.7 million acres to $92 per year for 16.2 million acres (Vincent and others 1995). Hiking is more highly valued in unroaded areas, while cross-country skiing is valued more highly in roaded areas (Walsh and others 1984b).

The reaction of recreationists toward critical habitat designation depends on its extent and location. Since riparian zones tend to be more important for recreation than upland areas, critical habitat designation for salmon in the Basin may cause extensive, unmitigatable recreation losses especially to boaters and anglers (Haynes and others 1992). The closing of certain areas in Montana to protect bald eagle populations is viewed favorably, while closings to protect grizzly bears are not (Bradford 1994, Frost 1985, Vincent 1989).

Nationally, the greatest shortages in recreational opportunities are for primitive camping, backpacking, hiking, horseback riding, nature study, and wildlife observation (Cordell and others 1990). These are recreational settings for which the Basin public lands have a comparative advantage that, if maintained, will increase in value.

In the future, recreation demands for the public lands in the Basin will continue to increase. The Basin offers more recreational opportunities, especially in undeveloped and remote settings for land-, snow-, and water-based activities, than other regions in the country. The relative importance of recreation opportunities in the Basin will increase over time. As more people travel to the Basin for vacations, recreation will become an increasingly important export.

Special Forest and Range Products[30]

This section reviews the little information available about the special forest and range products industry in the Basin. It identifies the species of the greatest economic value, employment opportunities, and the future direction of the industry.

The collection of forest and range plants east of the Cascade crest for commercial processing and trade is a small but growing industry. Between 85 and 90 percent of the special forest and range products industry currently takes place west of the crest of the Cascade Range (westside), generating hundreds of millions of dollars in product sales (Schlosser and Blatner, in press). During the past few years the industry has been expanding from the west of the Cascade Range to that area east of the crest (eastside). However, it will take at least a decade before the industry in the Basin begins to approach the economic maturity seen in its westside counterpart. Historically, collection of wild products has decreased as techniques for cultivation or synthesis have been developed. This has been the case for the Pacific yew, because Taxol, a drug used in cancer treatment, can now be produced without yew bark.

The issue of tribal use should not be confused with this discussion; the entire dimension of tribal use of plants and animals is discussed in the Social Assessment chapter. Competition over many of the special forest and range products is a key issue for the tribes, particularly given the growing commercialization of many species in recent years.[31]

Economic information pertaining to the special forest and range products industry is difficult to obtain because data on jobs and harvest values are not regularly reported and many of the transactions are on an unrecorded cash basis. Most of the information available here has been provided by two surveys: a 1989 survey of the floral greens and Christmas-ornamentals processors on the westside (but not the eastside) of the Cascade crest, and a 1992 survey of wild edible mushroom processors in Washington, Oregon, and Idaho (Schlosser and Blatner, in press; Schlosser and others 1991).

Total sales of special forest and range products in the Pacific Northwest range between $172 and $180 million (table 6.29). About 85 percent of the total sales value is derived from products collected on the westside; four-fifths of the westside total sales is derived from sales of floral greens and Christmas ornamentals. Even though many of the same or similar plants grow on both sides of the Cascade Range, harvest on the eastside of the Cascades is minor compared to harvest on the westside. This difference is primarily due to the lack of harvesters and industry infrastructure. The wild, edible mushroom industry is probably the most valuable special forest and range product activity in the Basin. Harvesting and processing of huckleberries may generate as much as $10 million in annual sales. (In table 6.29, huckleberries are included in the category named "other edibles and medicinals.")

The number of people working in the special forest and range product industry in the Basin is unknown. There are probably thousands of mushroom harvesters and perhaps a similar number of harvesters of baby's breath and huckleberries. In 1992 some 1,500 people harvested Pacific yew, but these jobs are expected to disappear shortly.

In the special forest and range product industry as a whole, about 70 percent of the jobs involve harvesting. These are frequently low paying, seasonal jobs with no medical or retirement benefits. Something close to full-time employment can be had by shifting from product to product throughout the seasons. The number of jobs may be overestimated due to double-counting of people working on more than one special forest or range product (Schlosser and Blatner, in press).

[30] This section was written by Amy L. Horne based on a background report prepared by William E. Schlosser and Keith A. Blatner (in press). On file with: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

[31] Personal communication. 1995. R. Hanes, Bureau of Land Management, Portland, OR.

Table 6.29—Value of special forest and range products collected east and west of the Cascade crest in Oregon and Washington, 1989.

Item	East	West	Total
	Dollars		
Floral greens & Christmas ornamentals	7,425,000	121,075,000	128,500,000
Wild mushrooms	11,800,000	26,800,000	41,100,000
Other edibles and medicinals	NA	NA	2 -10 million
Total	greater than 19-29 million	greater than 148 million	greater than 172-180 million

NA = information not available.
Source: Schlosser and Blatner (1997).

Processing jobs, which account for 30 percent of employment in the special forest or range product industry, and marketing jobs are the best paying jobs in the industry. Most facilities that process special forest and range products for market are concentrated west of the Cascade Range and are larger and more established than processing facilities located in the Basin. They typically deal with more than one product line, switching throughout the year as resource supplies and product demands dictate.

Timber[32]

Timber supply and demand are determined by the simultaneous interaction of global, national, regional, and local consumers, producers, and landowners. The purpose of this section is to present one perspective of future timber supplies that accounts for the impacts of recent changes in the direction of forest management. This perspective is taken from the *1993 RPA Timber Assessment Update* (Haynes and others 1995).[33] There are four parts to this perspective: (1) a broad overview of prospective timber demands; (2) the associated trends in timber supplies; (3) an overview of past, present, and future forest products production, harvests, and stumpage prices in the Basin; and (4) a discussion of two general issues: the effects of increased salvage logging, and future employment prospects for the forest sector in the Basin.

Future trends in the timber market, like all projections, are dependent on the underlying assumptions. These assumptions include trends in broad economic indicators such as population, gross national product, disposable income, and per capita disposable income (see table 6.3). There are also specific assumptions about housing starts, timberland area, shifts in land management intensity and growth rates of various forest types, and broad assumptions about the role of technological advances in creating demand for new products and increasing labor productivity. (These and other assumptions are described in detail in Haynes 1990, Haynes and others 1995.) A notable assumption included in this discussion is the unexpected recent increase in the use of recycled fiber. In the late 1980s, projections were for recycling rates to increase 33 percent over the next 50 years; instead recycling rates increased 67 percent between 1989 and 1994 in response to forest products industry initiatives and waste management concerns and are now expected to improve by another 30 percent by the year 2040.

[32] This section was written by Richard W. Haynes.

[33] The FS is required by the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 to prepare a renewable resource assessment. The purpose of this RPA assessment is to analyze the timber resource situation to provide indications of the future cost and availability of timber products to meet the Nation's demands. The analysis also identifies developing resource situations that may be judged desirable to change, and it identifies developing opportunities that may stimulate both private and public investments.

Prospective Timber Demands

Timber demands can be projected using expected trends in per capita consumption. Economic theories of natural resource use often assume that resource use increases as population and income grow (Cliff 1973). Facts point to a different reality. In spite of a steady increase in per capita income, per capita consumption of all forest products in the United States has varied over the past decades, from 80 cubic feet in 1950 to a low of 54.1 cubic feet in 1970, to a high of 82.8 cubic feet in 1986, back down to 74 cubic feet in 1991. Perhaps more important has been the change in the composition of product consumption. Per capita consumption of solid wood products has fallen, although in recent years it has rebounded as Americans have spent more to repair and alter existing housing units. Per capita fiber consumption has increased 45 percent over the past four decades with most of the growth taking place in the 1950s and 1960s. Finally, fuelwood consumption, which fell by 82 percent between 1950 and 1970, rose rapidly in the 1970s. By the late 1980s it had once again matched the 1950 level.

Recent research in the United States suggests that per capita wood product consumption will decline slightly over the next 50 years (Haynes 1990; Haynes and others 1995; U.S. Department of Agriculture, Forest Service 1988). This view of the future places less reliance on solid wood products manufactured from logs and greater reliance on engineered and reconstituted products for structural applications. It assumes a greater use of recycled fiber and greater demand for nontimber commodities and noncommodity benefits (such as some recreation activities) from forests. In spite of this, total roundwood consumption in the United States is expected to grow 0.7 percent per year to 26.5 billion cubic feet by the year 2040. This is about the same rate of change as expected for U.S. population growth.

The largest demand increases (in terms of roundwood) are for sawlogs and pulpwood. The faster growth in the demand for roundwood, in terms of percentage, is in miscellaneous products (including oriented strand board) and fuelwood. Softwood demand is primarily for sawlogs and pulpwood, but the largest parts of hardwood demand are for fuelwood and pulpwood, with hardwood sawlogs a close third.

Prospective Timber Supplies

In spite of increasing environmental regulations, timber harvests during the next 50 years are expected to grow from 18.1 to 25.3 billion board feet or 0.7 percent per year. Harvests will increase slightly faster than demand as U.S. production partially replaces imports of Canadian lumber and newsprint.

Softwood timber harvest has increased by more than 60 percent over the last four decades. It is projected to increase an additional 35 percent (0.6% per year) to 14.6 billion cubic feet by the year 2040. Slowing domestic demand, increased use of recycled fiber, and increasing use of hardwoods account for this slower projected growth in demand for softwood timber. The Pacific Northwest and the South are expected to remain the two most important timber producing regions in the United States.

Hardwood harvests have nearly doubled over the past four decades and are expected to increase at about 0.9 percent per year throughout the next 50 years. In the near term, increases are a function of substitution of hardwoods for softwoods in paper and paperboard production. The rapid increase in the use of recycled fiber in paper and paperboard production has been holding down the growth in harvests since 1988 and will continue to do so until the year 2000.

The proportion of softwood harvest coming from public timber lands peaked in the late 1960s at 30 percent of total softwood harvest. In 1991, harvests on public lands accounted for 23 percent of the total harvest: 17 percent from lands administered by the FS and 6 percent from an assortment of other federal, state and local agencies. Because harvesting on Federal lands declined in the early

1990s, the proportion of harvest occurring on public land is estimated to have been 17 percent in 1995. The reduction in Federal harvests has also decreased the percentage of the national timber harvest occurring in western states from 55 percent to 45 percent, while the percentage of the national timber harvest occurring in eastern states has increased from 45 percent to 55 percent.

Prospective Price Trends

Price trends for forest products differ sharply between the solid wood and paper sectors. For solid wood products such as softwood lumber, we expect real price increases to be roughly 0.7 percent per year. For paper and paperboard, the expected long-term trend is for no change in constant real prices. Both trends are consistent with past price behavior.

Real stumpage price inflation over the next two decades is expected to follow the long-term trend growth (2.5% per year). Stumpage prices are expected to increase in the next 15 years as the transition from harvesting natural stands to harvesting managed stands is completed and as harvests on public lands are reduced in the western United States. In the long term prices will stabilize, reflecting a balance between supply and demand in both the stumpage and wood product markets. Increasing use and availability of recycled fiber may restrict price increases in the 1990s. Pulpwood prices may also experience growth but only after the year 2010.

The Basin

Against this background of prospective national trends in the forest sector, timber harvest levels in the Basin have been declining since the early 1960s as a proportion of total U.S. harvest (table 6.30). Currently, they account for 10 percent of total U.S. harvest. Timber harvests in the Basin have declined by roughly 7 percent since 1986 and are expected to decline by another 7 percent by the end of the decade. Public harvests currently account for 46 percent of the total harvest and the forest industry ownership is larger than the other private ownership. Current projections for lumber and plywood production (table 6.30) between the years 1991 to 2000 are for a drop in lumber production of 800 million board feet and an increase in structural panel production of roughly 500 million square feet (Haynes and others 1995).

Stumpage price trends for the Eastside and UCRB EIS areas from 1943 to 1993 are shown in figure 6.18. Price volatility increased beginning in the 1970s because stumpage prices were being pushed up by increased competition among buyers, first in the lower Basin and then in the 1980s in the upper Basin. Stumpage prices are expected to increase in the near term as a consequence of cumulative Federal land management planning decisions and actions to protect the northern spotted owl, marbled murrelet, and anadromous fish species. Real (inflation-adjusted) stumpage prices in 1995 are on average 118 percent higher than 1989 levels in eastern Oregon and Washington. Over the next two to five decades prices are expected to stabilize, reflecting a balance between supply and demand in both the stumpage and wood product markets.

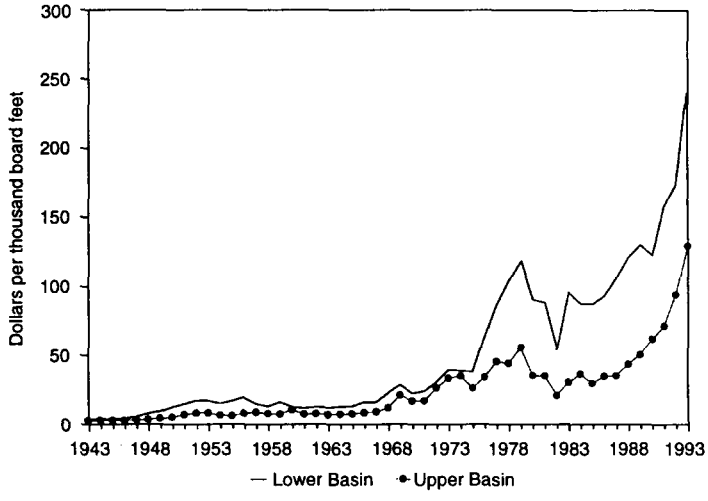


Figure 6.18— Average stumpage prices for National Forest timber, Lower (eastern Oregon and Washington) and Upper (UCRB) portions of the Basin assessment area, 1943-1993.

Table 6.30—Softwood harvest, stumpage prices (in constant 1982 dollars), and lumber and structural panel production in the United States, Eastside and UCRB areas,[1] by land ownership, to 2040.[2]

Item	1952	1962	1970	1976	1986[3]	1991	Projections 2000	2010	2020	2030	2040
Eastside area:	Timber harvest in million cubic feet										
National Forest	100	232	286	292	378	352	152	152	152	152	152
Other Public	48	61	97	89	31	26	18	19	22	24	27
Forest Industry	100	94	117	151	166	100	178	190	218	221	232
Other Private	100	67	48	60	111	116	144	174	236	283	350
Total	348	454	548	592	686	594	491	535	628	681	761
UCRB area:											
National Forest	126	259	319	279	254	231	157	167	176	185	195
Other Public	45	46	40	45	44	56	59	51	53	57	64
Forest Industry	79	114	153	162	228	251	173	77	55	94	151
Other Private	81	72	73	71	44	138	205	218	247	236	230
Total	331	491	585	557	570	676	594	514	531	572	640
United States:											
National Forest	961	1,635	1,918	1,867	2,153	1,789	912	941	968	1,000	1,027
Other Public	403	562	702	822	772	672	750	774	790	804	814
Forest Industry	2,668	2,144	2,758	3,302	4,043	3,936	3,940	4,148	4,984	5,779	6,007
Other Private	3,490	2,981	3,317	3,518	4,295	4,335	5,304	5,646	5,804	6,018	6,891
Total	7,522	7,322	8,695	9,509	11,263	10,732	10,906	11,509	12,546	13,601	14,739
	Softwood sawtimber stumpage price in 1982 dollars per thousand board feet, Scribner log rule										
	Dollars										
Eastside area	66	39	60	105	93	125	203	197	223	219	225
UCRB area	28	23	41	74	31	55	181	164	222	207	214
	Softwood lumber production in billion board feet, lumber tally										
Eastside area	2.3	2.4	2.3	2.7	2.8	2.9	2.3	2.5	2.8	3.0	3.3
UCRB area	1.6	2.8	2.9	3.1	3.4	3.5	3.1	2.5	2.6	2.9	3.4
United States	30.2	26.6	34.6	29.5	34.6	36.4	36.5	38.5	42.2	46.1	48.2
	Structural panel production in billion square feet, 3/8 inch basis										
Eastside area	0.0	0.2	0.8	0.9	0.8	0.9	1.5	2.1	3.1	3.8	4.6
UCRB area						1.3	1.3	1.3	1.3	1.3	1.3
United States	3.0	9.5	14.4	18.6	24.9	24.3	28.4	32.2	37.0	39.8	42.5

Source: Haynes and others (1995).

[1] Eastside = eastern Oregon and eastern Washington; UCRB = Upper Columbia River Basin.

[2] Prices are measured in constant (1982) dollars and are net of inflation or deflation. They measure price changes relative to the general price level and most competing materials.

[3] Tribal lands are included in other private instead of other public for 1986-2040.

Table 6.31—Forest sector employment in the Basin, eastern Oregon, eastern Washington, northern and southern Idaho, and western Montana, 1978-1993 and projections to 2040.[1]

Area	1978	1982	1986	1990	1993	2000[1]	2010	2020	2030	2040
Eastside area[2]										
Eastern Washington	NA[3]	5,564	6,748	7,715	7,290					
Eastern Oregon	16,791	10,926	13,804	15,385	13,900					
Total		16,490	20,552	23,100	21,190	18,943	20,640	24,228	26,273	29,359
UCRB area[4]										
Northern Idaho	10,762	7,314	7,732	8,646	7,634					
Southern Idaho	8,168	4,827	5,283	6,137	6,563					
Western Montana	8,793	6,034	7,162	7,059	6,824					
Total	27,723	18,175	20,177	21,842	21,021	21,423	18,538	19,151	20,630	23,082
Basin Total		34,665	40,729	44,942	42,211	40,366	39,178	43,379	46,903	52,441

Source: State employment agencies.

[1] Projections are available only at the area of the two EISs.

[2] Eastside area refers to those portions of the project covered by the Eastside EIS planning area, that is, Oregon and Washington east of the crest of the Cascade Range.

[3] NA means data is not available.

[4] UCRB refers to those portions of the project covered by the Upper Columbia River Basin EIS planning area, that is, northern Idaho, southern Idaho and western Montana.

In addition to describing the basic primary economic trends, we also need to describe the basic trend in employment in the forest sector [primarily the lumber and wood products industries, or Standard Industrial Classification (SIC) 24]. Past and projected direct employment in SIC 24 is shown in table 6.31. Broadly, the historical data for the lower Basin (eastern Oregon and eastern Washington) suggests that there is no trend in employment (expressed as jobs/million cubic feet) that might be attributed to improvements in technology such as those that occurred west of the Cascade Mountains. In the upper Basin (Idaho and western Montana), there has been a downward trend in jobs per million cubic feet.

During the next two decades we expect modest declines (around 10%) in SIC 24 employment because of continued harvest declines. In the longer term employment is expected to stabilize first and then increase, mirroring increases in harvest levels.

Timber Harvest Projections by BEA Regions

Disaggregating timber harvest into the nine BEA regions poses some difficulties because of the lack of specific county data for harvest by ownership. Recent harvest levels and projections are shown in table 6.32. Four BEA areas (Spokane, Missoula, Redmond-Bend, and Pendleton) account for more than 80 percent of the timber harvest in the Basin.

Timber harvest from lands managed by the FS (88% of total timber harvest from public lands) plays a different role in the forest products industry in different parts of the Basin. In eastern Oregon and Washington, FS timber represented 59 percent of total harvest in 1991; in the UCRB it represented 34 percent (table 6.30). This raises the question of whether the forest products industry is dependent on Federal timber and land management polices. The projections in table 6.30 show that a 50 percent decrease in Federal harvests will reduce lumber production in the Basin by 16 percent.

Table 6.32—Projected timber harvest in the Basin, by Bureau of Economic Analysis (BEA) area and ownership, in million cubic feet, 1993-2040.

BEA Area	1993	2000	2010	2020	2030	2040
	Million cubic feet					
Tri Cities						
National Forest	26.2	19.5	19.7	19.7	20.4	20.9
Other government	10.9	13.2	11.8	12.4	13.4	15.0
Forest Industry	15.4	21.6	16.0	16.0	18.5	22.5
Other public	21.4	42.4	46.4	55.9	60.2	67.4
Total	73.8	96.7	93.9	104.0	112.4	125.7
Spokane						
National Forest	110.3	62.3	68.2	71.1	72.6	73.6
Other government	66.7	66.8	64.6	70.5	75.3	83.1
Forest Industry	129.2	138.4	110.9	115.5	131.7	157.9
Other public	51.0	74.9	88.9	111.3	118.6	130.7
Total	357.2	342.5	332.6	368.3	398.3	445.3
Missoula						
National Forest	41.5	24.3	25.4	25.5	26.1	26.4
Other government	3.6	3.8	3.5	3.7	3.9	4.3
Forest Industry	55.4	61.4	46.9	47.1	53.8	64.5
Other public	45.2	68.6	77.7	93.7	100.0	110.2
Total	145.7	158.0	153.4	169.9	183.7	205.4
Idaho Falls						
National Forest	9.1	6.7	6.8	7.2	7.5	7.9
Other government	1.4	1.8	1.6	1.8	2.0	2.2
Forest Industry	2.4	3.3	2.5	2.6	3.1	3.8
Other public	1.7	3.2	3.6	4.6	4.9	5.6
Total	14.7	15.0	14.6	16.2	17.5	19.6
Twin Falls						
National Forest	0.10	0.3	0.3	0.3	0.3	0.3
Other government	0.02	0.1	0.1	0.1	0.1	0.1
Forest Industry	0.03	0.1	0.1	0.1	0.1	0.2
Other public	0.02	0.1	0.2	0.2	0.2	0.2
Total	0.20	0.6	0.6	0.7	0.7	0.8

Table 6.32 (continued).

BEA Area	1993	2000	2010	2020	2030	2040
	Million cubic feet					
Boise						
National Forest	34.7	21.7	21.6	21.9	22.8	23.8
Other government	3.7	4.1	3.6	3.8	4.2	4.7
Forest Industry	10.3	12.2	8.9	9.0	10.5	13.0
Other public	15.1	24.4	26.4	32.3	35.0	39.7
Total	63.9	62.4	60.6	67.1	72.6	81.1
Pendleton						
National Forest	80.4	58.5	60.9	63.9	66.4	69.0
Other government	1.6	2.0	1.8	2.0	2.2	2.5
Forest Industry	31.2	43.0	32.8	34.4	39.8	49.0
Other public	16.8	31.6	35.7	45.1	48.8	55.2
Total	129.9	135.2	131.2	145.4	157.2	175.7
Redmond-Bend						
National Forest	100.8	69.6	72.9	75.8	78.3	80.8
Other government	16.5	20.2	18.7	20.4	22.0	24.7
Forest Industry	50.8	66.5	51.0	52.9	61.1	74.6
Other public	31.1	55.7	63.3	79.1	85.2	95.6
Total	199.2	212.1	206.0	228.1	246.7	275.8
Butte						
National Forest	5.1	2.9	3.1	3.1	3.1	3.2
Other government	0.4	0.5	0.4	0.4	0.5	0.5
Forest Industry	6.8	7.4	5.7	5.7	6.5	7.8
Other public	5.5	8.3	9.4	11.3	12.0	13.3
Total	17.8	19.0	18.5	20.5	22.1	24.7
Entire Basin						
National Forest	408	266	279	288	298	306
Other government	105	113	106	115	124	137
Forest Industry	301	354	275	283	325	393
Other public	188	309	352	433	465	518
Total	1,002	1,042	1,011	1,120	1,211	1,354

Numbers have been rounded.

Some of the reduced harvest is made up by increases from private timberlands, but private inventories are insufficient to completely offset declines in Federal harvest.

Under this assumption, total employment in the forest sector will decrease by 4,000 direct jobs in the 1990s (10%). This can be compared against overall job growth in the Basin over the same period, which is expected to be more than 265,000 jobs. It is likely there will be opportunities for people who lose jobs in the forestry sector to find employment in other industries.

Salvage Issues[34]

Recently, there has been much discussion about an increase in a salvage logging program (The Taylor Amendment) primarily in the inland West. Such a program has its scientific basis in the Eastside Forest Ecosystem Health Assessment (Everett and others 1994) which envisioned management prescriptions focusing on restoration of high hazard landscapes and aquatic ecosystems. The economic implications of an annual 2-billion-board feet salvage program (starting in 1995) were explored using the timber assessment market model (Adams and Haynes 1980), and are illustrated in table 6.33. Comparing tables 6.30 and 6.33 shows that such a salvage program has nearly instant effects in the Basin. Stumpage prices in the West, for example, drop by 9.8 percent in 1995 and 14.4 percent by the year 2000. Price reductions for softwood lumber are more modest, 2.4 percent per year by the year 2000.

Salvage of dead and dying trees presents several economic opportunities and concerns. These include product recovery, harvesting systems, roads, and desirable and undesirable effects on the residual trees and the rest of the forest ecosystem. Dead and dying timber in the Basin may be economically salvaged for chips, lumber, veneer, and composites. Standard issues in product potential are complicated for dead or dying trees by insect damage, checking, fungal stain, decay, and charring. Losses in both value and volume increase with the amount of time dead trees stay on site; the greatest loss is for uses in which wood appearance is important, such as for millwork or furniture stock. Potential value loss is highest for ponderosa pine because stain can rapidly reduce the value of select-grade lumber from $1,800 per thousand board feet (MBF) to $300 to $500 per MBF. Timber that has remained standing on site for two years also becomes brittle. This increases safety hazards for salvage operators and reduces value because it may result in non-standard log lengths.

Rate of deterioration in dead and dying trees is influenced by species, tree size, location, and timing. Thin bark species are more susceptible to fire and other mortality agents. Cubic volume losses range from 0 to 30 percent the first year depending on species and increase thereafter; the highest volume losses are in true firs, followed by Douglas fir, and then pines. Small trees deteriorate more quickly than large ones. Fungal growth is enhanced in locations in which trees have a moisture content between 15 percent and the fiber saturation point, and the temperatures lie between 41 and 95 degrees Fahrenheit. Checking of the bole is increased by drying winds, sunlight, and high temperatures. Timing of tree death is important relative to weathering agents and timing of insect population flight cycles and preparation of brood colonies.

Scale of salvage operations—If all of the vast amount of timber available for salvage in the Basin were to be harvested, large-scale operations may be required. This could deter use of lower impact harvesting methods (for example, horse logging) and foster a boom-bust dynamic counter to the interests of local community development. Salvage operations can have either positive or negative effects on the residual stand, depending on how they are conducted. Salvage is often promoted for restoration of drought- and disease-prone forests to more typical mixes of fire-tolerant species in the

[34] This section was partly based on a background report provided by S.A. Willits (1995).

Table 6.33—Effect of salvage logging on projections of softwood harvest, stumpage prices, lumber and structural panel production in the Basin, 2000 to 2040.[1]

Item	Projections				
	2000	2010	2020	2030	2040
	Timber Harvest in million cubic feet				
Eastside area: [2]					
National Forest	269	268	268	263	263
Other Public	20	22	25	27	30
Forest Industry	159	174	206	213	222
Other Private[3]	118	144	207	260	331
Total	566	608	706	763	847
UCRB area:[4]					
National Forest	282	294	310	319	338
Other Public	65	63	65	69	77
Forest Industry	131	78	48	87	149
Other Private	174	200	230	220	212
Total	652	636	653	695	776
United States:					
National Forest	1,315	1,341	1,376	1,398	1,426
Other Public	758	789	805	819	831
Forest Industry	3,785	4,045	4,905	5,702	5,897
Other Private	5,151	5,416	5,636	5,883	6,773
Total	11,009	11,591	12,722	13,802	14,927
Softwood sawtimber stumpage price in 1982 dollars/thousand bd ft, Scribner log rule					
UCRB	118	153	206	187	189
Eastside	176	167	193	190	193
Softwood lumber production in billion board feet, lumber tally					
UCRB	3.5	3.4	3.5	3.8	4.4
Eastside	2.9	3.0	3.4	3.5	3.8
United States	37.2	39.1	43.6	47.6	49.6
Structural panel production in billion square feet, 3/8 inch basis					
UCRB	1.3	1.3	1.3	1.3	1.4
Eastside	1.5	2.1	3.2	4.1	5.0
United States	28.4	32.1	36.9	39.9	42.7

[1] Prices are measured in constant (1982) dollars and are net of inflation or deflation. They measure price changes relative to the general price level and most competing materials.

[2] Eastern Oregon and eastern Washington—"Eastside EIS" planning area.

[3] Tribal lands are included in "other private".

[4] UCRB area refers to Upper Columbia River Basin EIS area.

Basin. Properly done, thinning can increase insect resistance of the residual stand by increasing its vigor. On the other hand, thinning also poses a risk of damaging advance regeneration and increases opportunity for insect and disease damage if physical damage to residual trees occurs.

The potential for use of trees salvaged in the Basin for roundstock (fence posts, marine pilings and utility poles) appears limited because the tree species, with the exception of ponderosa pine, are difficult to penetrate with preservatives and markets are distant from the resource. Decay that infects dead trees can continue to degrade the material even after harvest, making them unsuitable for use in log homes. Salvaged timber can be used for lumber, barring complications from breakage, stain, decay, and splits and checks. Decay can lower wood strength, causing problems in using salvaged timber for structural lumber.

Costs—Much of the implementation of ecosystem management will be through existing mechanisms for stand manipulations.[35] One challange will be to find inexpensive objectives. Field trials from eastern Oregon illustrate how a treatment of cattle grazing at the appropriate time and in the appropriate intensity for specific site conditions compared with no cattle grazing is an inexpensive way to reduce fine fuels, and to increase the production of stumpage biomass and stumpage value, while providing income from grazing early in the rotation (Weigand and others 1993). Grazing shifts biomass production away from shrubs and grasses to trees early in the rotation, and facilitates reforestation on dry sites. Emphasis on producing timber quality rather than timber quantity [such as Allowable Sale Quantity (ASQ)] may also produce greater revenue. Weigand and others (1993) found that when timely cattle grazing was combined with silvicultural treatments designed to maximize timber quantity, timber revenues increased 30 percent; when timber quality was emphasized rather than quantity, this combination created 70 percent higher revenues.

Harvesting methods that are consistent with goals for ecosystem management are likely to cost more than traditional methods. A study from the Lolo National Forest (Keegan and others 1993) compares the logging costs of different harvesting methods and increasingly complex stand retention patterns.

Silvicultural Treatment	Harvest method	
	Tractor	Cable
	..... Dollars per MBF	
Clearcut or Seed Tree	$87	$155
Shelterwood	$89	$164
Group Selection	$98	$219

Higher logging costs on national forests relative to private timberlands will lead to lower stumpage prices for national forest timber sales and result in lower payments to counties. On the other hand, such costs may be justified by the increased benefits of improved riparian ecosystem function, reduced fire potential, and increased recreational and scenic values.

The recent and anticipated increases in sawtimber stumpage prices (see figure 6.18) are also changing perceptions about which land management activities might be feasible in the Basin. These recent (real) price trends are consistent with past projections of rising prices for sawtimber and the roughly constant prices for roundwood material, as shown below:

[35] On public lands many of these costs are dispersed and hidden in existing funding mechanisms such as the timber program. For example, in 1992 only 56 percent of the amount funded for timber sales on the Wallowa-Whitman National Forest was for sale-related activities (McKetta and Weiner 1994).

Year	Stumpage price		Logging costs
	Sawtimber	Roundwood	
	..... Dollars per MBF		
1990	100	100	100
2000	189	82	110
2010	184	69	119
2020	208	73	129
2030	206	78	130
2040	212	86	146

The difference in price trends between sawtimber and roundwood reflect the ability of the pulp and paper industry to control the cost of roundwood because most of the supply goes to few buyers who can choose among many different fiber sources (especially the increased use of recycled fiber expected in the 1990s).

These forecasted stumpage prices have significant implications for the economic feasibility of harvesting the small-diameter, dense stands prevalent in some parts of the Basin. Using data provided by the Colville National Forest, we calculated the proportion at which net losses on harvesting chipwood (roundwood) are offset by net profit from harvesting small sawtimber to be 42 to 58 percent. Assuming current price projections and logging costs as shown in the last paragraph, the proportion will change to 59 to 41 percent by the year 2040. The implication is that stands consisting completely of roundwood-size timber (for chips) will not sell. In the future, as now, stands will have to contain some amount of sawtimber to be marketed. While that proportion is currently 58 percent, rising sawtimber prices will reduce it to approximately 41 percent by the year 2040.

Water[36]

Water use and water policies are not controlled by the FS and BLM, yet these agencies are, and will continue to be, affected by how others manage and use water in the Basin. This section examines emerging water allocation issues in the Basin and discusses how they may impact FS and BLM policies.

Western water laws developed in conjunction with hardrock mining laws because of miner's dependence on water to separate gold from gravel. Thus western water laws more closely resemble mineral law than water laws of the eastern United States, which require all landowners bordering a water course to share. Laws enable subsequent interests to withdraw water for legally-sanctioned, beneficial uses, such as mining, agriculture, industry, domestic and municipal supply, raising stock, or hydropower. But those preferring in-stream uses have had little legal recourse. An example of an in-stream use is the desire of American Indians to support fish populations. Historically, western water agencies granted all applications for water rights regardless of whether the water was already fully appropriated. Traditional water users thus have a vested property right to continue using water, making it difficult to reallocate water toward newly evolved and appreciated interests and uses.

Water Allocation and Demand in 1990[37]

Competing water demands in the Basin include withdrawals (for domestic, industrial, commercial, and agricultural uses), hydropower generation (which requires large instream flows to be economically feasible), aquatic habitat to support tribal, recreational, and commercial fishing, and other water-based recreational activities. The Pacific Northwest generates 40 to 50 percent of the Nation's hydroelectric power, mostly on the Columbia and Snake Rivers (Kale and Sifford 1993).

In the 93 counties included in the BEA regions, 34.3 billion gallons per day are withdrawn from both ground and surface water. Irrigated agriculture uses the greatest percentage of water in the

[36] This section was written by Amy L. Horne and Christopher Hanson.

[37] This analysis is based on 1990 data provided by the U.S. Geological Survey on water withdrawals in the 100 Basin counties for all uses.

Table 6.34—Water allocation in the Basin among domestic, industrial, commercial, livestock, and irrigation uses, by Basin Bureau of Economic Analysis (BEA) area, 1990.

BEA Area	Domestic, industrial, and commercial			Livestock use	Irrigation use	Total water use
	From public supply	From self-supply	Total			
	Million gallons per day					
Tri-Cities	408.91	118.14	529.05	12.68	5,295.31	5,835.04
Spokane	210.89	85.83	296.72	6.46	269.31	572.54
Missoula	36.72	47.99	84.71	3.41	920.97	1,009.09
Idaho Falls	58.82	176.38	235.20	7.98	7,801.22	8,044.40
Twin Falls	25.72	15.84	41.56	528.17	5,439.62	6,009.35
Boise	73.95	37.37	111.32	25.51	6,962.85	7,099.68
Pendleton	54.98	88.70	143.68	7.36	1,982.86	2,133.99
Redmond-Bend	42.33	147.00	189.33	5.42	2,822.19	3,016.94
Butte	24.45	4.09	28.54	2.70	585.32	616.56
Total by Use	936.77	721.34	1,658.11	599.69	32,079.70	34,337.50

Source: Personal communication. 1995. Brian Drost. U.S. Geological Survey, Seattle, WA.

Basin (93%), with only minor amounts used for domestic, commercial, and industrial purposes (5%), and livestock (2%)(table 6.34). The Idaho Falls, Twin Falls, and Boise BEA regions account for 62 percent of the water withdrawals, 85 to 95 percent of which is used for irrigation. Irrigation generally uses water withdrawn from surface water, while public supply[38] usually withdraws from groundwater. Groundwater is withdrawn for irrigation in some counties in Idaho: Cassia [which withdrew 1,000 million gallons per day (MGD) in 1990], Minidoka (613 MGD), Bingham (1,200 million MGD), and Jefferson (700 MGD). The withdrawals for irrigation in these counties were substantially higher than the highest groundwater withdrawals for public supply in the Basin. For example, Spokane, Washington withdrew 117 MGD in 1990, followed by Ada, Idaho (37 MGD). Domestic per capita use throughout the Basin is between 120 and 170 gallons per day.

Most water withdrawals for irrigation are from surface water, effectively dewatering some rivers in summer months. The Boise, Idaho Falls, and Tri-Cities BEA regions each diverted over 4.5 billion gallons per day in 1990 while the Twin Falls BEA region diverted over 2.7 billion gallons per day.

Conveyance losses (water lost from irrigation systems and during field application) accounted for 50 to 65 percent of 1993 water use in the Basin.[39] However, some of this water returns to

[38] Public supply in this paper refers to domestic, commercial and industrial uses supplied by a municipal or state agency. In the data this is often referred to as "deliveries from the public supply" so that this water can be distinguished from self-supplied water.

[39] Personal communication. 1995. Brian Drost. Electronic data. U.S. Geological Survey, Seattle, WA.

aquifers or surface water sources and thus is available downstream. Conveyance losses that return to surface water as overland flow may transport nutrients and sediments. In several BEA regions, conveyance losses exceeded all consumptive uses combined (Idaho Falls, 2,700 MGDs; Boise, 3,000 MGD; Twin Falls, 1,700 MGD; and Missoula, 410 MGD).

Future effects of agriculture on water quality need to be recognized in developing strategies for conserving fish. In the United States, 57 percent of sediment discharged from non-Federal, rural lands comes from agricultural cropland. Erosion rates from croplands are five times those of forested landscapes (Brown and Binkley 1994). Sediment from cropland often transports nitrogen and phosphorous that facilitate eutrophication in reservoirs and algal growth in slow moving streams and rivers. It also can transport herbicides and pesticides that are absorbed into the food chain and accumulate in higher concentrations in the tissues of vertebrates such as fish.[40] A number of these agricultural impacts on water quality are described in the Aquatics Species and Habitats chapter.

Water use for agriculture and hydropower have mixed effects on recreational activities. Water withdrawals for irrigated agriculture reduce instream flows that may harm fish populations. The reductions in freshwater fishing that may result may negatively affect business activity driven by fishing. Opportunities for bird watching in the Basin, on the other hand, have improved because wetlands created by the dams have increased migratory waterfowl populations (Muckleston 1993).

[40] Of note is a recent report in *The Oregonian* about high concentrations of mercury found in the tissues of warm-water fish species in reservoirs in central Oregon. The mercury is said to have originated from run-off from long abandoned mines in the region.

Future Water Demand

The quantity of water used for irrigation is likely to become increasingly controversial as the human population continues to grow in the Basin, increasing municipal water demands (table 6.35). Recreational activity is also expected to increase with the population (McCool and Haynes 1996), some of which will increase pressures to maintain certain levels of water quality and in-stream water quantity.

The extent of the conflict over water use between municipalities and irrigators can be seen in projections based on per capita water use for commercial, domestic, and industrial water purposes, including both public and self-supply (table 6.35). Per capita use for each BEA region is largely a function of the amount of water used by commercial and industrial facilities. We assumed everyone will use public supply rather than private wells, so per capita use could be multiplied by the population projections to estimate future demands for public supply. The amount of water available for irrigation was estimated assuming constant rates of application per acre. By subtracting the municipal demand for the year 2040 from the 1990 total withdrawals, the reduction in irrigated acres was calculated for each BEA region. These numbers do not include demand for mining and power generation plants (other than hydropower).

Using these assumptions, eight out of nine BEA regions would have to reduce the amount of land in irrigated agriculture to meet municipal needs. The greatest impact would be in the Spokane BEA region which would have to reduce irrigated agriculture by 155,567 acres (11% of 1992 irrigated acres). Other affected regions would be Idaho Falls (81,531 fewer irrigated acres) and Redmond-Bend (53,443 fewer irrigated acres). The impact on the Pendleton BEA region would be about average for the Basin (35,824 fewer irrigated acres). The Butte BEA region would be one of the least affected (4,620 fewer irrigated acres). Any increases in the efficiencies of water distribution and use would lessen the number of acres affected.

Table 6.35—Projected water allocation in the year 2040 given expected population growth in the Basin, by Basin Bureau of Economic Analysis (BEA) area, 2040.

BEA Area	Municipal consumption per capita[1]	Irrigation use per acre	Total withdrawals[2]	Irrigation withdrawals	Population	Municipal water use[3]	Water available for irrigation[4]	Change in irrigation water[5]	Change in irrigation
	..... Gallons/day		.. Million gallons/day			..... Million gallons/day			.... Acres ....
Tri-Cities	422.10	3,364.02	5,835.04	5,295.31	1,402,569	592.02	5,243.02	-52.29	-15,545
Spokane	401.89	1,698.36	572.54	269.36	1,411,800	567.38	5.15	-264.21	-155,567
Missoula	390.62	3,780.04	1,009.09	920.97	468,197	182.89	826.20	-94.77	-25,070
Idaho Falls	843.90	5,775.22	8,044.40	7,801.22	846,120	714.04	7,330.36	-470.86	-81,531
Twin Falls	166.41	4,465.66	6,009.35	5,439.62	338,724	56.37	5,952.98	513.36	114,958
Boise	272.71	6,142.08	7,099.68	6,962.85	1,005,645	273.91	6,825.77	-137.08	-22,318
Pendleton	810.71	2,960.20	2,133.90	1,982.86	317,112	257.08	1,876.81	-106.04	-35,824
Redmond-Bend	811.59	3,910.15	3,016.94	2,822.19	497,444	403.72	2,613.22	-298.97	-53,443
Butte	278.05	3,907.60	616.56	585.32	177,279	49.29	567.27	-18.05	-4,620

[1] Assumes municipal demands supersede irrigation demand.

[2] Includes public plus self-supply for domestic, industrial, and commercial use.

[3] Assumes constant per capita consumption.

[4] Assumes total withdrawals at 1990 rates and aquifers are not exhausted.

[5] Assumes constant water application per acre.

Only the Twin Falls BEA region would have surplus water and the possibility of increasing the number of irrigated acres, largely the result of the high number of domestic users on wells rather than public supply (25%) and low industrial and commercial use. As commercial facilities expand and municipal services improve, the per capita use in this region is likely to more closely resemble that of other regions (250 to 300 gallons per day).

In parts of the Basin where ground water withdrawal is very high, continuing the current rates of withdrawal may not be physically possible given the geographic extent and recharge rates of the region's aquifers. Non-domestic groundwater use may become controversial as the population grows.

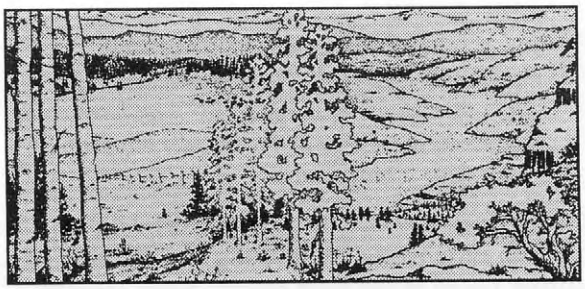
It should be noted that the amount of irrigated acreage decreased ten percent during the agricultural recession of 1982 to 1992 (Jackson 1993). If this trend continues, municipal demands could be met if the current rate of withdrawals can be maintained. Another trend that may ease future conflicts over water allocations is the use of more efficient systems such as drip irrigation. An increase in drip irrigation may also reduce sedimentation associated with agriculture; however, poorly covered croplands will remain sources of sedimentation during heavy rainfall.

Change in water allocation is one of the options available for ensuring the viability of fish populations. Options to consider include conservation measures to guarantee in-stream flows in the long term and, hence, protection of crucial fish habitats. Such measures may result in the retirement of marginal cropland, but offsetting benefits may include higher instream flows for meeting future recreation and municipal demands.

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ECONOMIC POLICY QUESTIONS

This section addresses four economic policy questions of interest to the BLM and the FS. They include the role of commodity production from public lands in providing community stability and the related issue of timber dependency, the role of the two agencies in future development of the regional economies in the Basin, the economic efficiency of public land stewardship, and the economic perspective on sustainability.

Community Stability and Timber Dependency[41]

The discussion of community stability and dependency deals mostly with timber and FS policy. This is because, despite recognition that communities may be dependent on other Federal resources (such as amenities, range, recreation, and water), the FS has implemented specific policy only with respect to timber. For the BLM, which predominantly manages rangeland in the Basin, the question of timber dependency is not as germane as for other agencies. Although there is a general sense that the Federal agencies have responsibility toward local economies in which they manage a lot of land, little is known about range dependence, or its specific dimensions in the Basin (other than what has been said previously in the "Range" section). The lessons from this discussion can be applied to the BLM and range-dependence, and other types of resource dependence by inference.

[41] This section was written by Richard W. Haynes, Amy L. Horne, and Nicholas E. Reyna.

This section first reviews the legal and political evolution of the FS's concept of community stability and the evidence about the extent of the agency's role. It then reviews the question of timber dependency and the process by which the FS defined timber-dependent communities. After evaluating this approach, we develop an improved method which identifies 29 communities in the Basin that may be sensitive to levels of public timber harvest. This approach does not address the dependency of the communities on other FS resources. This section ends with a discussion of the relationship between timber harvest and economic well-being.

Community Stability

The FS has no specific legal mandate to provide economic stability to rural communities; references in law and policy, however, permit and encourage consideration of economic stability when evaluating federal actions (Ashton and Pickens 1995). Dana and Fairfax (1980) summarize their concerns about FS policies on community stability as follows:

> *Mindful of the destructive boom-and-bust cycles which accompanied nineteenth-century forestry, the FS argued that the non-declining even-flow policy was necessary to assure community stability. Their analysis assumes, first, that stability is an accepted goal, as opposed to, for example, growth, diversification, or reorientation of a community's economic base; second, that the FS has a mandate and a capacity to*

contribute to that goal; and, third, that even flows of timber volumes from Federal lands contribute to that goal. None of these assumptions—the validity of the goal, the mandate, or the capacity to achieve it—is broadly accepted as a working assumption.

Initial concerns about the role of Federal timberlands in supporting community stability are usually traced to the early debates about creating forest reserves, first manifested in the Organic Administration Act of 1897 (Society of American Foresters 1989). The FS became an early proponent of promoting stability in forest communities through a sustained yield even-flow timber policy. The BLM received a legislative mandate in the Taylor Grazing Act (1934) to "stabilize the livestock industry dependent on the public range."

The National Forest Management Act (NFMA) of 1976 added to the community stability policy by solidifying a traditional but contentious strategy for timber flow from national forests through the sustained yield and nondeclining even-flow provisions (Section 11, 36 CFR 219.16). Both of these provisions were designed, in part, to address community stability issues (Dana and Fairfax 1980). NFMA also required bidding methods for timber sales to "consider the economic stability of communities whose economies are dependent on such national forest materials." Subsequent regulations required "dependent communities" to be one of several factors considered.

Wilkinson and Anderson (1987) argue that considerations of community stability and nondeclining even-flow are among the most ambiguous aspects of the NFMA's legislative history. This requirement traditionally has been interpreted as evaluating land management alternatives according to their impact on local jobs and income despite absence of any proof of a link between sustained yield of timber and community stability (Schallau and Alston 1987). Maintaining community stability through timber harvest and grazing policies more accurately reflects a political, not economic, choice that may be appropriate when it conforms to societal preferences regarding distribution of wealth. Recent recognition that FS and BLM policies play only a minor role in determining community stability has shifted emphasis toward policies that do not destabilize communities through abrupt increases or decreases in resource use (Forest Ecosystem Management Assessment Team 1993).

The FS took up the cause of stabilizing the economies of rural communities in and around Federal lands primarily through even-flow timber supply policies. Boyd and Hyde (1989) note that "community stability is the FS expression for its objective to maintain the integrity of those small communities scattered throughout the West that are dependent on public timber harvests." They found the agency policy "consistent with aggregate public policies designed to minimize the social costs of a cyclic economy." While resource-based communities have been at the mercy of larger macroeconomic forces, Boyd and Hyde (1989) found that translating this concern into a remedy was more difficult. The literature is ambiguous, at best, regarding the relationship of sustained timber yields and community stability as measured by employment in the timber industry.

There are a variety of social and economic changes over which local communities and the forestry profession have extremely limited influence. These changes include business cycles characteristic of timber and other extraction industries that create instability through changing demand (Berck and others 1992). Interest rates, labor productivity, changing consumer preferences, and international demand are larger economic forces that influence the stability of timber-dependent communities (Force and others 1993, Rasker 1994). For communities, the problem is cumulative. The community has little influence on the business decisions made by the firms operating in their area and the firms have little influence on macroeconomic forces that influence their operations.

Berck and others (1992) sought to examine the influence of timber industry characteristics against that of larger business cycles by separating the effects of being a small, isolated county with an open economy from those of being a county that is dependent on timber. They found that forestry has surprisingly low variation in employment, not significantly greater than that of manufacturing as a whole and much lower than agriculture or fisheries. What is different about forestry is the historic lack of diversity in community economies and their isolation (Berck and others 1992).

Federal regulations [36 CFR 219.12(g)(3)(iii)] pursuant to the NFMA require planning efforts to estimate the effects of alternatives on jobs and income (Schallau and Alston 1987). A growing body of literature argues that regional economic growth can be supported both by traditional extractive industries and by more indirect factors such as amenity values or quality of life (Power 1996). A complete view of economic impacts would examine both direct effects on extractive industries and indirect effects on attracting new business and capital with high quality of life.

Economic impact analyses (which estimate effects of alternatives on jobs and income) indicate how much the economic activity in a region might change as a result of management decisions. They do not indicate whether that change is desireable from society's standpoint. From a broad perspective, any income or employment lost in one region is likely to be gained elsewhere. For example, economic losses in a town affected by reduced FS timber sales may be offset by expansion in other logging communities or in communities producing substitute building materials. While possible economic losses are of great concern to the communities most affected by a policy change, offsetting gains in other communities means that economic impacts to a given community are not equivalent to the total economic costs or benefits. Considering only the jobs or income lost in one region and overlooking offsetting gains elsewhere overstates the net cost of a management action.

Timber Dependency

In response to the NFMA regulations, the FS developed a list of timber dependent communities in 1976 to assist national forests in choosing whether to permit exceptions to sealed bidding when they may endanger the stability of the communities. Timber-dependent communities were defined as those in which primary forest-products manufacturing facilities provided 10 percent or more of the total employment in the community. In 1987, this list was updated using the same definition of timber-dependency. First, the new list assigned communities to national forests and specified mill-dependent volume. Second, it noted that no widely accepted definition of dependency existed. Third, it acknowledged that communities depend on other forest resources in addition to timber.

The number of communities identified in each list as dependent is shown below:

Basin component, each state	1976 list	1987 list
Idaho	26	17
Montana	8	13
Washington	7	13
Oregon	16	23
Basin Total	57	66

Even though the FS articulated shortcomings in the approach to naming timber-dependent communities, making such a list added apparent legitimacy to this notion. Beyond the lack of a widely accepted definition and the recognition that communities may be dependent on other resources besides timber, the 1987 list added further confusion by using the terms "community," "economy," and "industry" interchangeably as in "community-wide share," "community supply," and "community volume under contract." Forest-products firms, not communities, bid on (and directly depend on) Federal timber sales. This

usage means that the distinction between industrial stability and community stability is often overlooked. Industry interests differ somewhat from the communities in which they are located. The dependency between a mill and national-forest-timber supply does not automatically translate to an economic dependency of the local community's economy on those national forest timber supplies (DeVilbiss 1986). The combination of the proportion of the work force and dependency on Federal timber might result in only a small part (as low as 3%) of the total workforce being dependent on national forest timber (Boyd and Hyde 1989).

The criteria used to create the FS lists do not account for important economic factors that affect the relationship between a community and local wood-products firms. Important economic factors include alternative sources of supply, proximity to larger labor markets, inter-mill competition for timber supply, inter-community competition for jobs, and changing technology and mill obsolescence. In today's market, the destination of Federal logs is unpredictable as processors reach far to supply their mills. Local mills will not necessarily be the successful bidder on Federal timber sales nor are local communities guaranteed to receive logging and processing jobs as a result of those sales.

We assessed the 66 communities on the 1987 list to see which ones could still be considered timber-dependent. We added two criteria to eliminate those that are well-connected to larger, diverse economies or are located in counties experiencing robust growth. In the first step, we eliminated those communities that were within 50 miles of other communities whose population was at least 10,000. We then eliminated communities in the 15 recreation counties (Johnson and Beale 1995). The remaining 29 communities represent those which are both isolated and in the slower growing parts of the Basin (see map 6.3). The list can be found in appendix 6-C. These communities are not necessarily less resilient than others (see the Social Assessment chapter). However, Federal land managers may want to focus on them when considering impacts of land management actions.

Change brought the forest industry to rural communities and, in fact, created many rural communities. It is change that is now bringing new industries into the Basin. Rapid social and economic change over the past two decades has complicated the nature of community dependence on Federal land (Society of American Foresters 1989). For example, in 1987, Orofino, Idaho was defined as a timber-dependent community. Its economy changed in the early 1970s when the Federal Government built the Dworshak Dam and a large fish hatchery. Today, Orofino is a destination for recreation tourism and its economy has become dependent on recreation (Force and others 1993). Opponents to the reservoir drawdowns claim that for each foot the reservoir surface is lowered, the community loses one million dollars in tourism revenue.

Economic Well-being

In much of the discussion in this and Social Assessment chapter, we have talked around the relationship between forest dependence and community well-being. The traditional bias among foresters that links sustained yield forestry with community stability has colored this issue. But the broader issue is whether the presence of forestland and the forest products industry are effective at promoting economic growth and development. This issue has been widely studied in forestry. Overdevest and Green (1995) provide a recent overview of the various studies and suggest a hypothesis that can be tested. Using data from rural counties in Georgia, they found that the well-capitalized pulp and paper industry is positively related to county per capita income. They also found that the solid wood products industry has no significant effect and that timberland concentration is negatively related to per capita income and positively related to the poverty rate. This latter finding supports Kromm's (1972) rejection of the axiom that "properly managed and utilized forest resource(s) insures economic well-being in forest regions."

Map 6.3— Timber-dependent communities, as defined in this chapter. These are communities both located more than 50 miles from another incorporated area larger than 10,000 people, and not located in a recreation county, 1995.

We tested the Overdevest and Green hypothesis[42] using county-level data from the Basin and found that neither the presence of forest-products processing facilities nor the acres of timberland (whether Federal, FS only, or private) can explain the variation in per capita income. The implication is that we have to reject the hypothesis that, in the Basin, timberlands or forest industries have a measurable affect on personal income. In the south, where this hypothesis has been accepted, forests are no longer viewed as positive drivers of economic growth. This finding is consistent with similar experience in international forestry situations (Winterbottom 1990).

Rejecting this hypothesis in the Basin suggests that the forest products industry has had a neutral impact on recent economic growth (the data set used was for 1993). Others (Rudzitis 1995, Power 1996) have pointed out the positive role that the scenic quality of forested landscapes have played in the recent economic growth.

Economic Growth[43]

In this section we deal with the development of regional economies in the Basin and the relationship between them and management of BLM and FS lands. It begins with a discussion of the resiliency of regional economies in the Basin, and then presents competing views among economists about the causes of economic growth. We then propose a new approach for viewing economic growth and the role played by BLM and FS management actions. This method looks at the total economy and examines expected trends. The importance of range and timber jobs can then be assessed against the backdrop of the overall economy and its trends. Finally, the type of analysis that would result from this approach is presented using the Tri-Cities BEA region as an example.

Economic Resiliency

In *A Framework for Ecosystem Management* (Haynes and others 1996), one of the assumed goals of ecosystem management was described as attempting to maintain ecological integrity and the resiliency of social and economic systems. Resiliency in this sense was defined as adaptability to change. Social or economic systems with high resiliency would be those capable of absorbing external shocks such as a recession and rebounding in terms of system indicators such as total employment and per capita income.

The adoption of this goal raises the challenge of how to measure economic resiliency. Preliminary research has found a high correlation between diverse economies and economic resiliency.[44] Diversity ratings for the BEA regions and counties in the Basin were calculated using the Shannon-Weaver index,[45] a statistic familiar to ecologists concerned with measuring plant and animal diversities. The employment diversity ratings for 1991 by BEA region are:

[42] We used county data to test whether per capita income was a function of timberland (federal, private) ownership; employment in wood products (SIC 24, 26); percent of the workforce in manufacturing (in one variant of the model we used this as an proxy for employment in wood products); and dummies for metro county status and whether the forest products industry had mills in the county. In the Overdevest and Green (1995) hypothesis, poverty rate was an important variable. Since there is only one federally designated poverty county in the Basin, we dropped this variable.

[43] This section was written by Amy L. Horne and Richard W. Haynes.

[44] Personal cmmunication. 1995. Ervin G. Schuster, U.S. Forest Service Intermountain Research Station, Missoula, MT.

[45] Personal communication. 1995. Greg Alward, U.S. Forest Service Land Management Planning Staff, Fort Collins, CO.

BEA region	Diversity Index
Boise	.81
Butte	.78
Idaho Falls	.81
Missoula	.81
Pendleton	.79
Redmond-Bend	.80
Spokane	.81
Tri-Cities	.79
Twin Falls	.78

These results are largely consistent with both our results and those in the Social Assessment chapter. The diversity indices indicate that the economies within the Basin are diverse (the highest possible score is 1.0) and, by correlation, have high economic resiliency. Little variation in economic diversity is found across the Basin. These findings make sense given our earlier discussion that per capita income is rising rapidly and few pockets of poverty exist (see "Overview" section of this chapter). Furthermore, the economy of the Basin has shown resistance to national recessions except when they greatly affect the agricultural sector.

The highest diversity ratings are for the Boise, Idaho Falls, Missoula and Spokane BEA regions. The BEA regions in which employment associated with recreation is substantial have high diversity ratings, suggesting that they have high resilience to fluctuations in recreation activity (Idaho Falls, Missoula, and Redmond-Bend). The two BEA regions in which timber plays a major role (Redmond-Bend and Pendleton) also have fairly diverse economies suggesting that they are resistant to fluctuations in that industry. The low diversity number for the Butte BEA region may be misleading because diversity was calculated for only that portion of the BEA region lying in the Basin.

Applying the diversity index at the county level provides a different picture requiring some care to interpret. The average diversity index for the 100 counties in the Basin is 0.70, much lower than the statistics calculated for each of the Basin BEA regions. We divided the set of diversity indices that were calculated for every county in the United States into thirds and defined the range displayed by the top third as "high" diversity, the middle third as "medium", and the bottom third as "low". Using these definitions, we found that 17 counties in the Basin have high diversity, 30 have medium diversity, and 53 have low diversity. A policy implication is that, if government wants to make a positive economic impact in counties with low diversity, an effective strategy in the long run would be to avoid distorting evolutions in economic structure, encourage diversification, and possibly mitigate transition costs.

This exercise also points out the hazards of analyzing economic activity at inappropriately fine scales. The BEA regions represent economically linked counties in which people commute between home and work. Thus, they are a reasonable scale at which to evaluate the ability of an economy to absorb external shocks.

Growth

Economists have argued about the causes of economic growth since the beginning of modern economics (Kindleberger 1965). From a theoretical standpoint, economic growth is the expansion path between sets of production functions that are explicit in time. The various theories of growth focus on traditional factors of production (labor and capital) and the role of technology in changing their productivities. Traditional regional economics views growth as a function of expansion in basic manufacturing industries. Contemporary challengers argue that other industries should be considered as part of the economic base (Power 1996, Rasker 1994, and Whitelaw and Niemi 1994). Both approaches recognize that some

locations have unique advantages or endowments that will attract certain types of economic activity. In the traditional view, these are resource endowments for extractive industries. In the contemporary view, these may include amenity or quality of life considerations.

The economic-base concept involves identifying the economic activities which form the foundation of a region's economy with the implication that anything that harms or lessens these activities threatens a region's economy. Careful practitioners divide every industry into the proportion that is exported (basic) versus that which serves local markets (non-basic). Proponents argue that basic activities help support non-basic activities by increasing the flow of money into and within an economic area. The subset of practitioners concerned with forest economics assert that jobs in the manufacturing sector are better than other jobs (Beuter 1995). No evidence exists to support the view that a dollar earned from exporting manufacturing goods is better than a dollar earned from exporting anything else. The economic-base approach is useful as a first approximation for characterizing the current conditions of a region's economy.[46] Where the economic-base approach gets into trouble is when it is used inappropriately as a tool for planning or predicting impacts of greater than one year in duration; a snapshot of current conditions tells little about the form a region's future economy may take.

We adopt the approach that economic growth of the Basin is dependent on those economic activities having excess employment. This is broader than the traditional approach used by the BLM and the FS when placing value on just the jobs in the ranching or manufacturing sectors. It assumes that the various comparative advantages, as expressed by various export sectors of the Basin, will continue to attract capital and labor to support long-term development. This follows the traditional neoclassical approach and takes for granted that factor supply (capital and labor) determines regional output and income while regional demand for goods and services is assumed to respond automatically to growth in production factors (Nijkamp and others 1986).

In the following discussion, we describe a process for discussing regional economic growth. We identify the key factors of regional economies and their relationship to public land management as population; the economy; jobs associated with range, recreation, and timber; and quality of life[47] (fig. 6.19). Trends that will change these key factors, regardless of BLM and FS policy, are population growth and structural changes in the economy.

Projections of structural changes in the economy can be obtained from the U.S. Bureau of Economic Analysis (BEA). The BEA projects structural shifts using the standard "shift-share" approach. They first develop national projections in gross national product (GNP) from projections of population, labor force, employment, and GNP per employee (U.S. Department of Commerce 1990). Employment within each industry is then projected as a damped extension of the industry's historical trend. Damped extensions mean that growth rates in one period are slightly less than in the previous one. The number of jobs in the United States in each sector are then distributed to states, substate areas, and counties according to the share of employment in that sector in the smaller area. Damped projections are used because of the assumption that self-limiting forces preclude the region from declining or growing at high rates for long periods (U.S. Department of Commerce 1992). These projections do not simulate fluctuations caused by business cycles, changes in societal preferences, or changes in technology.

[46] Krikelas (1992) provides a critical review. Nijkamp and others (1986) provide a comprehensive survey of various regional and multi-regional models.

[47] Quality of life can be defined as having three components: social amenities, scenic amenities, and recreation amenities. Social amenities include cultural opportunities and quality of public services and are related to population density. Some argue that quality of life is important to regional economic development because it attracts new business and capital (Power 1996).

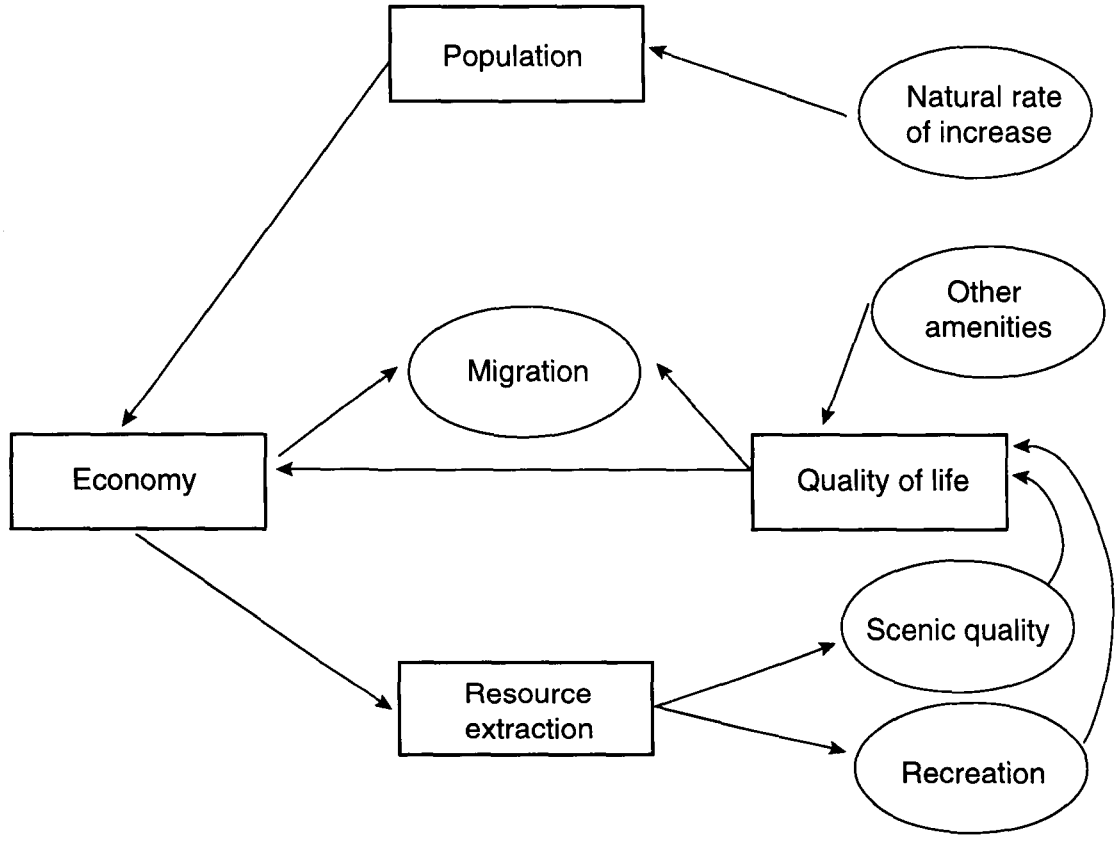


Figure 6.19— Model of regional economic growth.

Population can increase either through natural increase of a region's residents (births minus deaths) or migration. People already living in the Basin are responsible for most of the population growth that will occur in the next half-century because natural increase exceeds in-migration even if highest migration rates are assumed (McCool and Haynes 1996).

Migration can be viewed as responding to employment opportunities and the quality of life. When unemployment is low, in-migration occurs; when high, out-migration occurs. Quality of life attracts people when high and encourages people to move away when low. Capital and labor move when people migrate in or out of the Basin. Data on population growth can be obtained from the U.S. Bureau of the Census (1995) and Day (1993).

The FS and BLM can affect economic activity by the influence their management has on range, recreation, timber, and quality of life. For range and timber, the agencies can directly influence the number of jobs by setting levels of timber harvest and animal unit months. In both cases, jobs in the region can be associated with production from either public or private lands.

The agencies affect the supply of recreation opportunities primarily through their management of the road network: road building, road closures, and road maintenance standards. Building roads to harvest timber in previously unroaded areas presents a clear tradeoff between provision of primitive and roaded natural settings. The agencies also affect recreation by providing access to riparian areas and dispersed recreation sites. The quality of

the recreation experience is affected by the cumulative effects of management actions on scenic integrity. Provision of recreation-specific infrastructure, such as trails, ski-lifts, and campgrounds, is also important.

Currently, there is a great deal of recreation activity in the Basin. Recreation visitor days (RVDs) per resident average 31.5 compared to a national average of 22.3 RVDs per person (Cordell and others 1990). Demand for recreation is a function of population (see "Recreation" section above). At some point, the capacity of the land to support recreation activities becomes constrained due to congestion. At that point, recreation opportunities per person begin to decline.

Scenic integrity of a region results from the cumulative scenic quality of lands in all ownerships in the subregion: FS- and BLM-administered lands, other public lands, private industrial timberland, and other private land. The FS and BLM account for only a portion of the land base in any region. Changes in scenic quality resulting from increased residential and commercial use of private land as the population in the Basin grows may be a more significant factor in some places.

The Tri-Cities BEA Region Example

We explored the potential effect of FS and BLM policy on a regional economy using a model based on the discussion above and on figure 6.19. We ran the model five times, each time with a different set of assumptions about levels of AUMs and timber harvest set by the FS and BLM. The assumptions associated with each run are as follows:

Run	FS and BLM AUM	FS and BLM Timber Harvest
1	CCM	CCM
2	None	CCM
3	Double CCM	CCM
4	CCM	None
5	CCM	Double CCM

Where CCM refers to the quantities expected under continuation of current management. The results show that, given the assumptions described above, jobs in the Tri-Cities region associated with range are not affected by the levels of AUMs set on lands administered by the FS and BLM (fig. 6.20); only a small portion of that industry is dependent on public AUMs in this region. Similarly, jobs associated with recreation are little affected by FS and BLM management (fig. 6.21); decreases after the year 2030 are the result of the population's recreation demand not being met by the supply rather than FS and BLM levels of AUMs and timber harvest. Jobs in the timber industry are changed slightly when public harvest is either doubled or eliminated (fig. 6.22); most of the timber jobs in this region are supported by harvest from private timber land. The effects of FS and BLM levels of AUMs and timber harvest have very little effect on either population growth (fig. 6.23) or total personal income (fig. 6.24). The mode runs show that the economy of the Tri-Cities region is large and diverse. Rapid growth in other economic sectors overwhelms any impact caused by changes in FS and BLM policies either through their impact on range, recreation, and timber jobs or through their impact on recreation supply or scenic integrity.

Economics of Ecosystem Management

This section discusses a number of economic issues related to ecosystem management. Our primary emphasis is to provide an understanding of the market basket of ecosystem goods, functions, and conditions that society will want from the FS- and BLM-administered lands in the Basin over the next 50 years. This discussion may help shape the development of management directions that are economically efficient. We also discuss issues related to financing ecosystem management such as expenditures and revenue sources.

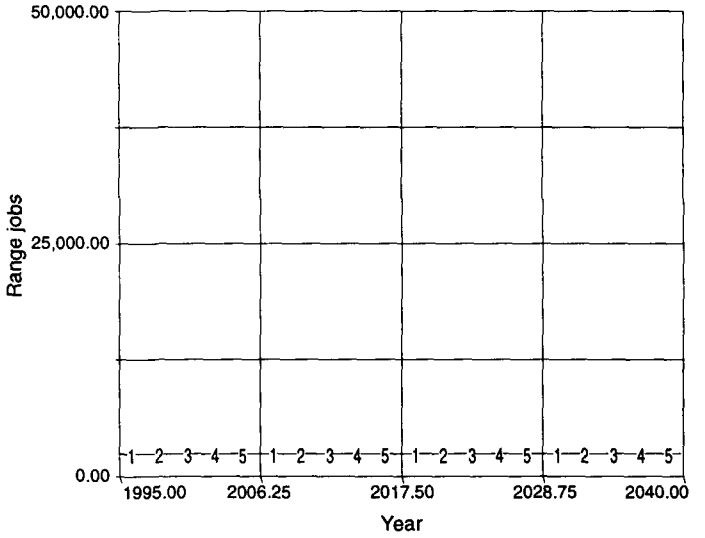


Figure 6.20— Effect of FS and BLM policies on range jobs in the Tri-Cities BEA region.

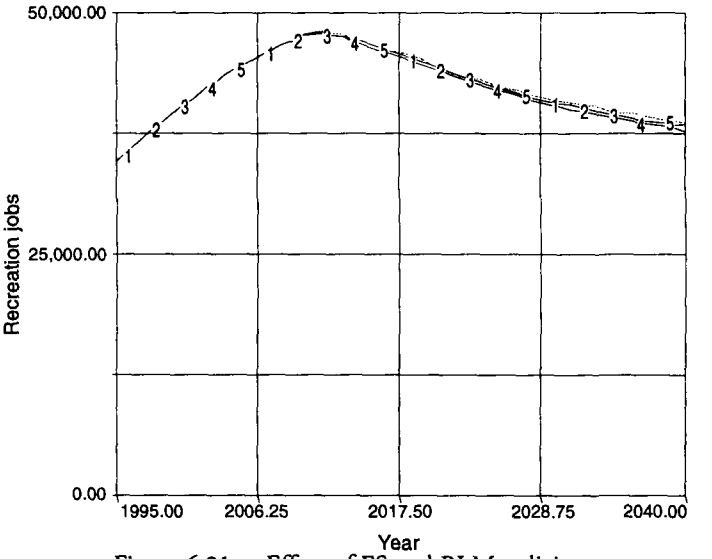


Figure 6.21— Effect of FS and BLM policies on recreation jobs in the Tri-Cities BEA region.

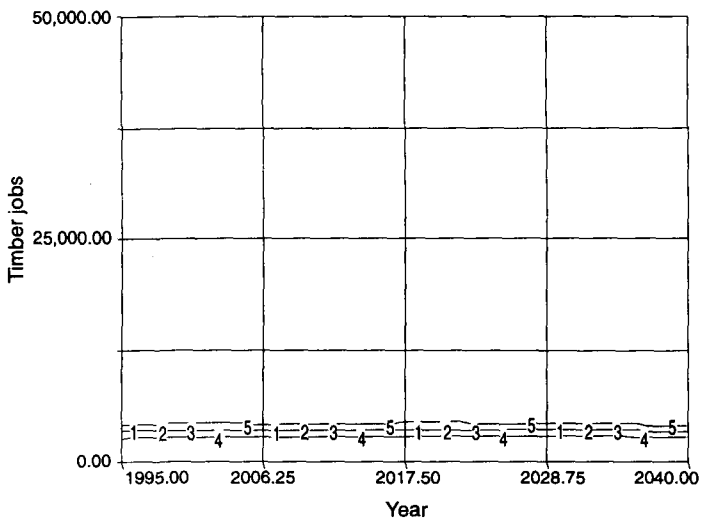


Figure 6.22— Effect of FS and BLM policies on timber jobs in the Tri-Cities BEA region.

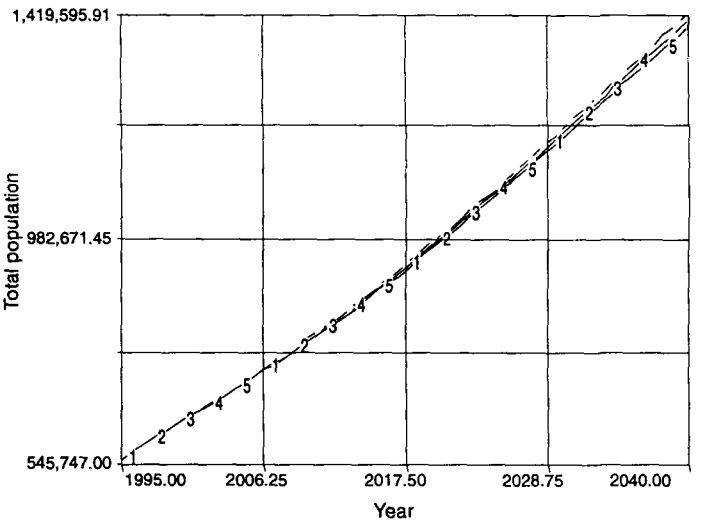


Figure 6.23— Effect of FS and BLM policies on population growth in the Tri-Cities BEA region.

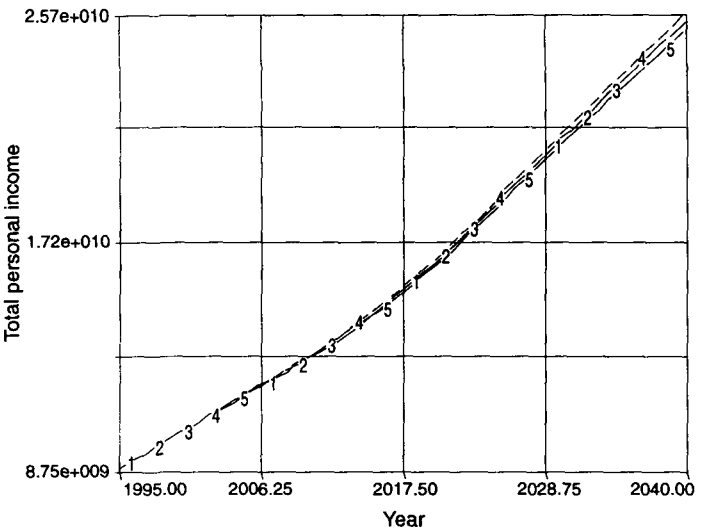


Figure 6.24— Effect of FS and BLM policies on total personal income in the Tri-Cities BEA region.

Key to figures 6.20 to 6.24

1 = AUMs and timber harvest at RPA levels

2 = Public AUMs = 0; timber harvest at RPA levels

3 = Public AUMs double RPA values, timber harvest at RPA levels

4 = AUMs at RPA levels, Public timber harvest = 0

5 = AUMs at RPA levels, Public timber harvest double RPA levels

Resource Valuation

A fundamental notion of stewardship is that land managers work to direct and maintain ecosystems to best fulfill objectives of owners (Smith 1986). The broadest view of societal interests is appropriate for public lands because their constituencies are extensive and diverse. Further, some types of outputs will only be available from public lands (Hyman 1973). An examination of the full array of the costs and benefits of ecosystem management requires a conscious attempt to value intangible benefits, posing problems for the social scientists who need to develop values and for biophysical scientists who need to develop explicit ecosystem output measures.

The FS- and BLM-administered lands in the Basin yield an array of conditions and outputs for the American people. Management directions chosen by FS and BLM managers can lead to changes in these conditions and outputs, thereby creating benefits and imposing costs (Freeman 1993). Resource valuation techniques (benefit-cost analysis) enable policy makers to explore the potential for substantial gains in economic welfare through better resource management (Freeman 1993). Resource valuation provides a framework and a set of procedures to help organize available information (Freeman 1993, Arrow and others 1996). It can help answer questions about what tradeoffs are involved in a given course of action (Freeman 1993). In this way, resource valuation can greatly improve the outcome of policy analysis by revealing preferences and opening up the decision making process for scrutiny.

Given that economics is the study of choices about the allocation of scarce resources between competing demands, providing decision makers with information about the nature of the tradeoffs involved in their decisions is appropriate. The development of sound forest and range management policies requires that consideration be given to the economic benefits associated with competing uses of forest and rangeland resources. The benefits that may be provided under different management regimes include both use values (such as those provided by timber harvesting and recreation) and non-use values, including existence value, option value, and quasi-option value. Many of these benefits are not revealed in market transactions, and thus cannot be inferred from conventional data on prices and costs. Recent developments in measurement techniques, however, have led to the estimation of these benefits for some forest lands (Vincent and others 1995).

Non-economists often express distrust of the values for nonmarket goods and dislike the expression of the preservation of endangered species in dollar terms. Such criticism misses the point that what lies at the heart of resource valuation is an approach to making choices among tradeoffs. These choices are made every day, both by government officials and private individuals, and the choices they make reveal implicit value (Freeman 1993).

Resource valuation is a criterion that can be used in different ways depending the question being asked. In one use it can be used to answer the question "what ought the FS- and BLM-administered lands in the Basin produce?" In another use, once goals and objectives are determined, it can also be used during implementation to identify the most cost-effective way to achieve those goals. Most people are familiar with this latter meaning. Here we use it in the former sense and define economic efficiency within the context of ecosystem management as producing the greatest market basket value of ecosystem goods, functions, and conditions possible from FS- and BLM-administered lands in the Basin.

Information from an efficiency analysis is not a sole criterion for decision making. Decision makers may have other objectives besides economic efficiency. They may be concerned with equity considerations, intergenerational effects, or the sustainability of resource systems or social risk aversion (Freeman 1993).

Outputs and Conditions to Consider

Ecological systems can be viewed as providing society with multiple outputs and conditions, and joint products (Freeman 1993). The basis for deriving measures of the economic value of changes in natural resource outputs is their effects on human welfare. Each individual's welfare depends not only on his or her consumption of private goods and government services but also on the quantities and qualities of nonmarket goods and services he or she receives from an ecosystem. Changes in outputs and conditions have their counterparts in changes in the asset value of the ecological system. The anthropocentric focus on economic valuation does not preclude a concern for the survival and well-being of other species. People can value other species for their uses but also as a source of existence or non-use value. Consequences that were once thought to lie outside the realm of economic analysis (such as the preservation of endangered species and unique ecological systems) are often central issues in the analysis of policy choices today (Freeman 1993). At the same time recent advances in the field of economic valuation make it possible to include in a resource valuation many outputs and conditions that were once considered unquantifiable.

Benefits to society from ecological systems include (1) inputs to the economy (wood and minerals); (2) amenities [opportunities for recreation, viewing wildlife, enjoying scenery, and services that are not related to any direct use of the environment (nonuse or existence values)]; (3) life-support services (clean air and water); and (4) dispersing, transforming, or storing residuals that are by-products of human and economic activity (Freeman 1993). For ecosystem management, we define ecosystem outputs as the ecosystem goods, functions, and conditions society wants the FS- and BLM-administered lands in the Basin to produce. "Ecosystem goods" are specific components of ecosystems such as minerals, timber, forage, mushrooms, huckleberries, salmon, grizzly bears, and grey wolves. "Ecosystem functions" are beneficial processes such as carbon storage and groundwater recharge. "Ecosystem conditions" refer to systemic, or integrated, states that people want to find on the land such as "old-growth" forests, roadless areas, beautiful scenery, and healthy ecosystems.

A "use" typology developed by economists helps to identify which ecosystem outputs to include in a resource valuation. These are outputs that have either consumptive uses, non-consumptive uses, or passive uses. An ecosystem good with consumptive use value is something which is removed from the ecosystem when used and does not remain for others to enjoy, such as timber. Consumptive use values can exist for goods traded in markets and goods for which no market exists. Other ecosystem outputs with consumptive uses include minerals, mushrooms, berries, floral greens, wildlife (to hunt), and fish (to catch).

People are also interested in non-consumptive uses which do not reduce what remains for others to enjoy, such as hiking on trails, viewing scenery, and birdwatching. Still others benefit from non-uses that do not involve direct use. Examples of non-uses are option (knowing a natural resource will be available for personal future use), existence (knowing a natural resource exists even when the likelihood of using it is small), bequest (knowing one's grandchildren will be able to enjoy a natural resource), and stewardship (knowing ecosystems are maintained in a healthy state) (Field 1994). Desires to maintain habitats and protect soils stem from complex motives including ensuring consumptive uses (game to hunt), non-consumptive uses values (birds to watch), and non-uses (maintaining soil productivity seems like good stewardship, and leaves productive ecosystems for future generations).

A list of the ecosystem goods, functions, and conditions that could be included in an ecosystem market basket is shown in table 6.36. Some of these outputs have already been discussed in the resource characterizations; other outputs have been mentioned in the discussions surrounding the ICBEMP: carbon storage, ecosystem health, fire risk, habitats, non-uses, scenic integrity, soil productivity, and water quality.

Table 6.36—Indicator variables for outputs from FS- and BLM-administered lands suitable for an ecosystem market basket.

Indicator Variable
Carbon Storage
Ecosystem Health
Fire Risk to Life and Property
Fish
Game
Minerals
Passive-use Values
Existence of Salmon
Existence of Other Threatened and Endangered Species
Existence of Unroaded Areas
Range
Recreation
Access (Roads)
Access to Riparian Areas
Scenic Integrity
Soil Productivity
Special Forest and Range Products
Timber
Visibility
Water Quality

Economic Characteristics of Outputs

The outputs and conditions from the FS- and BLM-administered lands in the Basin of importance to the American people have a mixture of economic attributes. Some, like timber, are market goods; economists expect markets to allocate timber resources efficiently. Other outputs and conditions have traits of nonmarket goods known as public goods, externalities, or common property resources. For nonmarket goods, market forces cannot be relied on to either allocate these resources efficiency, or to reveal their true values (Freeman 1993). Non-use values are a specific case of a public good, a type of good routinely addressed by resource valuation analysis (Kopp 1993). The non-use value of unroaded areas, for example, is available to all without the possibility of exclusion; one person's enjoyment does not interfere with the enjoyment of others; and, one may enjoy them without any monetary expenditure.

Adding Up Values

The economic value of an ecological system is defined in the literature as the sum of the discounted flows of all the outputs and conditions (Freeman 1993). We differ in that we display flows of the values of outputs and conditions over time rather than the discounted flow. The reason for this is to avoid the controversy over which discount rate is appropriate to use and to let decision makers choose how to distribute benefits and costs between human generations.

There is a substantial and growing body of literature that suggests that healthy forest ecosystems provide substantial non-use value to the American public. If forest management decisions are to be based on sound economic principles, such values must be taken into account. Non-use values associated with forest preservation are potentially very large, and could by themselves dominate the values associated with extractive use (Loomis 1994). For example, estimates of willingness-to-pay for old growth forests west of the Cascades range from $48 to $144 per U.S. household per year (Hagen and others 1992). In another example, Olsen and others (1991) found that households in the Pacific Northwest were willing to pay between $26 and $74 per year to double the size of the salmon and steelhead runs in the Columbia River.

Ignoring non-use values such as existence value and option value may seriously understate the benefits associated with the preservation of wilderness areas, wildlife, old forests, and other goods associated with preservation (Kopp 1992, Vincent and others 1995). In natural resource damage assessments, practitioners recognize that excluding

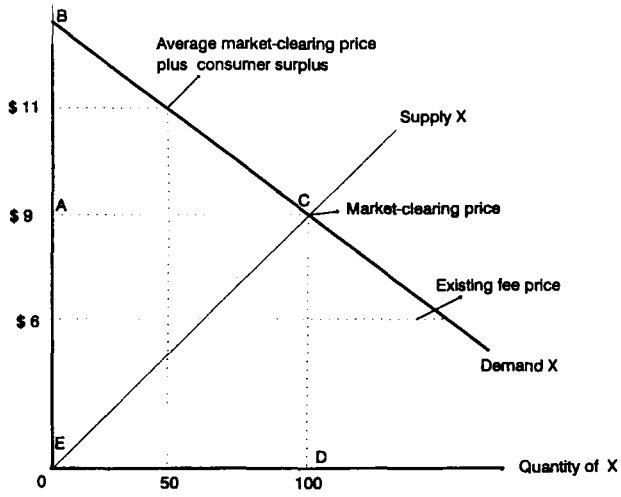


Figure 6.25— Net economic value is the area under the demand curve less the cost of production, here represented by the triangle ABC.

non-use values results in an inefficiently low price signal to those undertaking risky activities, which can lead to more than the optimal number of accidents. The courts have ruled that damages should be set so as to compensate for the full loss in economic value of the resource, where full value explicitly includes non-use value *(Ohio v. United States Department of Interior,* 880 F 2nd 432, D.C. Cir. 1989). A recent study of chinook salmon in the Yakima River calculates their total value as the sum of existence, commercial, recreational, capital, and other values (Anderson and others 1993).

Determination of Values

The question of the values of natural resources in a resource valuation context is often misunderstood and a source of controversy. Some people are distrustful of economists' penchant to extend economic measurements to non-market outputs and to reduce as many variables as possible to monetary measures (Freeman 1993). Dollar values have the advantage of translating the importance of outputs into a common metric by which their relative importance can be assessed. "Willingness-to-pay," the economic value beyond cash flow to producers, is the appropriate measure. Net economic values are the appropriate measure for such an analysis. They are measured as the amount consumers are willing to pay less the cash flow to producers. Since many of these outputs are not bought or sold in markets and do not have market prices, the economic value of them may be quite different from their market value (Freeman 1993). For market goods, net willingness-to-pay equals total willingness-to-pay minus actual payments. In figure 6.25 it is equal to the triangle ABC. For outputs and conditions for which no market data exist, economists have determined that techniques such as travel cost and contingent valuation are appropriate for determining natural resource value (Arrow and others 1996). It is important for the value of all outputs and conditions to be measured using the same accounting stance (U.S. Department of Agriculture, Forest Service 1990). Once this is done it is possible to add the values of market and non-market outputs, and compare the sum of values from different market baskets.

Weighting these outputs by the value society holds for them is an essential part of the process. Knowing how much of each output or condition an ecoregion can produce is the first step but the relative importance of these outputs is not known until all the outputs have been weighted by their values. It is incorrect to define an ecoregion as being efficient for timber production solely because it has higher timber growth than other ecoregions. First, the timber values may be low if the ecoregion is far from timber markets or processing facilities. Second, timber values must be compared with societal values of other outputs from that same ecoregion. An ecoregion with high timber values relative to other ecoregions may also have recreation values that exceed its timber values. Thus, the appropriate course for managers is to plan actions with the total market basket of values for a given ecoregion in mind.

Unroaded areas—A central principle of ecosystem management is to maintain options for future generations. One option to maintain is "unroaded areas," defined as undeveloped public land and water that does not have roads, buildings, mines, clearcuts, or other related development. This definition includes areas having these attributes whether or not they have special status (such as a designation as Wilderness or as a Wild and Scenic River). Unroaded areas have been a central component underlying the debate over management of Federal lands for the past 40 years. The values of unroaded areas have been documented in numerous studies (Barrick and Beazley 1990, McFadden 1994, Pope and Jones 1990, Walsh and others 1984a). Including the value of unroaded areas in a resource valuation for ecosystem management introduces a measure of ecosystem condition.

Unroaded areas are viewed as national assets wherever they remain throughout the United States (Walsh and others 1996), hence the appropriate scale of demand to consider is national. Seventy percent of the unroaded areas greater than 200,000 acres remaining in the lower 48 states lie within the study area ("Recreation" section of this chapter, above). Walsh and others (1996) found that U.S. citizens have an average willingness-to-pay for unroaded areas in the Rocky Mountains of $49 and in the Pacific Coast of $47, with regional differences shown in the tabulation below:

	Region of unroaded area	
Region of resident	Rocky Mountains	Pacific Coast
North	$43	$37
South	$56	$49
West	$55	$65

Pope and Jones (1990) found that residents of Utah were willing to pay $53 per household per year for 2.7 million additional wilderness acres, and $92 per household per year for 16.2 million acres.

The study by Walsh and others (1996) found that people believe that Alaska has the highest quality of unroaded areas by far. The next highest quality unroaded areas are located in the Rocky Mountains, with those in the Pacific Coast ranked a close third. Respondents ranked the unroaded areas in both the Rocky Mountains and Pacific Coast as high for both use and existence values. Both areas received high ratings for a number of existence values including: protecting rare and endangered species, protecting air and water quality, preserving unique plants and animal ecosystems and genetic diversity, knowing that natural areas exist for their own sake, and knowing that future generations will have natural areas.

Walsh and others (1996) also found that use-values of the unroaded areas in the Rocky Mountains and Pacific Coast regions received high ratings for conserving natural areas for educational and scientific study, and for the option of visiting them in the future. About one-half of the respondent households said they had seen natural areas in the Rocky Mountains (53%) and Pacific Coast (46%). Between eight and nine households in ten expressed an interest to see natural areas in both regions in the future. About 93 percent of the households in the west were interested in seeing unroaded areas in the Rocky Mountains and the Pacific Coast. Residents in the east and south had nearly as high an interest in visiting unroaded areas in the Rocky Mountains (84 and 89% respectively) and Pacific Coast (81 and 83% respectively).

Methods

The resource valuation approach involves: (1) defining the spatial areas and time periods to be analyzed, (2) determining how much of each output will be available from each geographic area over the time period, (3) determining the value of each output from each geographic area over the time period, (4) multiplying the amount of each output over the time period by its value, and (5) summing the total values of the outputs for each geographic area in the time period. We call this sum the "market basket." It provides an integrated picture of the benefits possible from FS- and BLM-administered lands in the Basin within the constraints of ecosystem processes and time.

The spatial areas we used for analysis were the Basin and its component ERUs (see map 6.2). These can be thought of as areas having particular abilities to supply outputs desired by society. We made projections for a period of 50 years.

The outputs for which we had quantified projections, and thus could include in this analysis, were range, recreation, timber, and the unroaded areas (including designated wilderness). The projected quantities of AUMs and timber were from other staffs and are uncertain.

The assumptions we had to make to project recreation activity are described in the "Recreation" section of this chapter. In brief, we obtained the current number of acres in each of the three Recreational Opportunity Spectrum (ROS) classes in each ERU from the spatial data collected for the project. We assumed no change in these numbers over the 50-year projection. We assumed that participants in recreation activity on the FS- and BLM-administered lands in the Basin live in the seven states which contain part of the Basin (Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming). We obtained projections of the population in this area and its characteristics from the U.S. Census Bureau (Campbell 1994, Day 1993).

To project the existence value of unroaded areas in the Basin, we assumed they would not change over the next 50 years. We obtained the current number of unroaded areas in the Basin from the project's Spatial Analysis Team. We assumed that the number of households benefiting from the existence of unroaded areas in the Basin was the number of households in the United States. Projections of the number of households in the United States were taken from the U.S. Census Bureau (Campbell 1994, Day 1993).

We used the RPA values (U.S. Department of Agriculture, Forest Service 1990) for range, recreation, and timber because the values of all resource outputs were developed in a consistent manner and are commensurate with one another (tables 6.37 and 6.38). We have used different values for the ERUs whenever available. All RPA values were determined "on forest" or "on range." This means that none of them include the value added with final processing. Thus the benefit for range is related to forage, not beef sold to consumers. Likewise, the costs of components that are associated with an activity but that are not an output from Federal lands are not included. The recreation values do not include the costs of camping equipment or fishing gear; the timber values are stumpage prices plus consumer surplus.

There are no estimates of the willingness-to-pay for the existence value of unroaded areas in the FS- and BLM-administered lands in the Basin, so we inferred a value from Walsh and others (1984a) and Pope and Jones (1990). We first developed an equation for the total value (recreation plus existence value) of unroaded areas from Pope and Jones (1990). We used Pope and Jones (1990) to derive the total demand curve because their study is more recent and their estimates of willingness-to-pay are the lower of the two. We then used Walsh and others (1984a) to calculate the percent of value attributable to existence value for a given amount of unroaded land, and applied this percentage to the total demand curve. The resulting equation for the household willingness-to-pay for the existence of unroaded areas is (fig. 6.26):

cents/year = 4.05E-5 + 3.4718 * (1/1,000 unroaded acres)

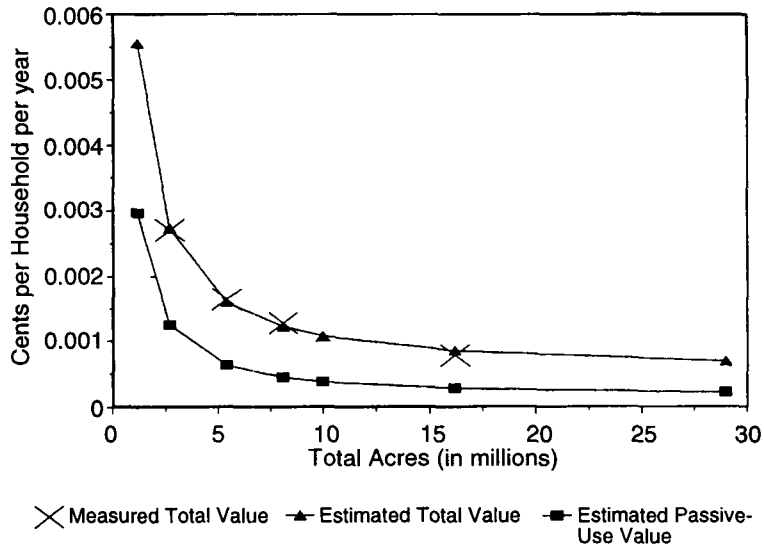


Figure 6.26— Passive-use value per acre of unroaded land.

Table 6.37—Willingness-to-pay values[1] for carbon storage, range, and recreation outputs by Ecological Reporting Unit (ERU) in the Basin, 1994 dollars.

Output	ERU 1-6	ERU 7-9	ERU 10-13
	..... 1994 Dollars		
Carbon Storage (per ton)[2]	65.00	65.00	65.00
Range (per AUM)[3]	8.66	8.66	8.66
Recreation (per person activity day)[4]			
Camping	9.27	6.44	7.25
Day Use	9.27	6.44	7.25
Fishing	54.66	41.40	41.40
Hunting	46.71	48.73	47.72
Motor Boating	2.39	2.39	5.98
Motor Viewing	4.78	4.04	3.33
Non-motor Boating	3.59	9.56	8.37
Off-road Vehicles	4.78	4.04	3.33
Snowmobiling	4.78	4.04	3.33
Trail Use	7.21	6.84	6.74
Viewing Wildlife	31.15	29.80	28.35
Winter Sports	40.26	40.26	40.26
Wilderness[5]	35.65	23.78	23.88

Source: U.S. Department of Agriculture Forest Service (1990). Unless otherwise noted, inflated to 1994 dollars using consumer price index (Council of Economic Advisors 1995).

[1] All willingness-to-pay values are determined "on-forest" and do not include other production costs associated with an activity.

[2] Personal communication. 1995. Steven Winnett, Environmental Protection Agency, Washington, DC.

[3] Personal communication. 1995. Linda Langner, U.S. Department of Agriculture, Forest Service, Economist, Washington, DC. Inflated from 1993 dollars using producer price index.

[4] From U.S. Department of Agriculture Forest Service (1990), inflated from 1989 to 1994 dollars using consumer price index. An "activity day" is the average amount of time spent during 24 hours pursuing that activity. These values include fees but exclude expenditures that represent a cost of production such as travel costs.

[5] Additional value when activity takes place in wilderness area.

The number of unroaded acres in the Basin is within the range of the data collected by Pope and Jones (1990). There are two uncertainties associated with this equation. First, we do not know if the willingness-to-pay for unroaded lands in the Basin is different from the value for lands in Colorado (Walsh and others 1984a) or Utah (Pope and Jones 1990). Second, we do not know the effect of shifting the spatial scale of demand. Both Walsh and others (1984a) and Pope and Jones (1990) estimated demand of state residents for wilderness areas designated within their own state. We have applied this value to all U.S. households. We do not know that people in the east, for example, hold the same existence value for unroaded lands in the Basin as residents of the Northwest; their values could be more or they could be less.

Table 6.38—Willingness-to-pay values for timber and chip outputs by Ecological Reporting Unit (ERU) in the Basin, 1994 dollars.[1]

Ecological Reporting Unit	Timber[2]	Chips
	Dollars per thousand board feet	
Northern Cascades (1)	165.15	144.08
Southern Cascades (2)	124.72	124.72
Upper Klamath (3)	486.67	144.08
Northern Great Basin (4)	294.09	144.08
Columbia Plateau (5)	410.64	144.08
Blue Mountains (6)	255.30	144.08
Northern Glaciated Mountains (7)	222.93	144.08
Lower Clark Fork (8)	179.50	144.08
Upper Clark Fork (9)	136.94	136.94
Owyhee Uplands (10)	11.66	11.66
Upper Snake (11)	56.78	56.78
Snake Headwaters (12)	63.10	63.10
Central Idaho Mountains (13)	428.91	144.08

[1] Source: Regions 1, 4, and 6 of the Forest Service, U.S. Department of Agriculture.

[2] Willingness-to-pay is calculated by adding stumpage price and consumer surplus estimated as 10 percent of stumpage price.

Results

The current market basket value per acre of FS- and BLM-administered lands (fig. 6.27) is highest in the Central Idaho Mountains (ERU 13), Southern Cascades (ERU 2), Northern Cascades (ERU 1), Snake Headwaters (ERU 12), and Lower Clark Fork (ERU 8). Recreation is the dominant value provided in most ERUs. The exceptions are that timber provides the greatest value in the Upper Klamath (ERU 3) and the existence value of unroaded areas provides the greatest value in the Northern Cascades (ERU 1), Northern Glaciated Mountains (ERU 7), Snake Headwaters (ERU 12), and Central Idaho Mountains (ERU 13). Recreation value per acre is highest in the Southern Cascades (ERU 2), Lower Clark Fork (ERU 8), and Central Idaho Mountains (ERU 13). The existence value per acre of unroaded areas is highest in the Central Idaho Mountains (ERU 13), Northern Cascades (ERU 1), and Snake Headwaters (ERU 12). The per acre value of timber is highest in the Southern Cascades (ERU 2), Upper Klamath (ERU 3), Central Idaho Mountains (ERU 13), and Upper Clark Fork (ERU 9). The per acre value of range is highest in the Upper Clark Fork (ERU 9), Lower Clark Fork (ERU 8), and Northern Glaciated Mountains (ERU 7); this value exceeds $1 per acre only in the Upper Clark Fork. The market basket used in this analysis is incomplete and contains only items for which we could develop values. A more complete analysis would include values for ecosystem health, fire risk, and carbon storage, among others.

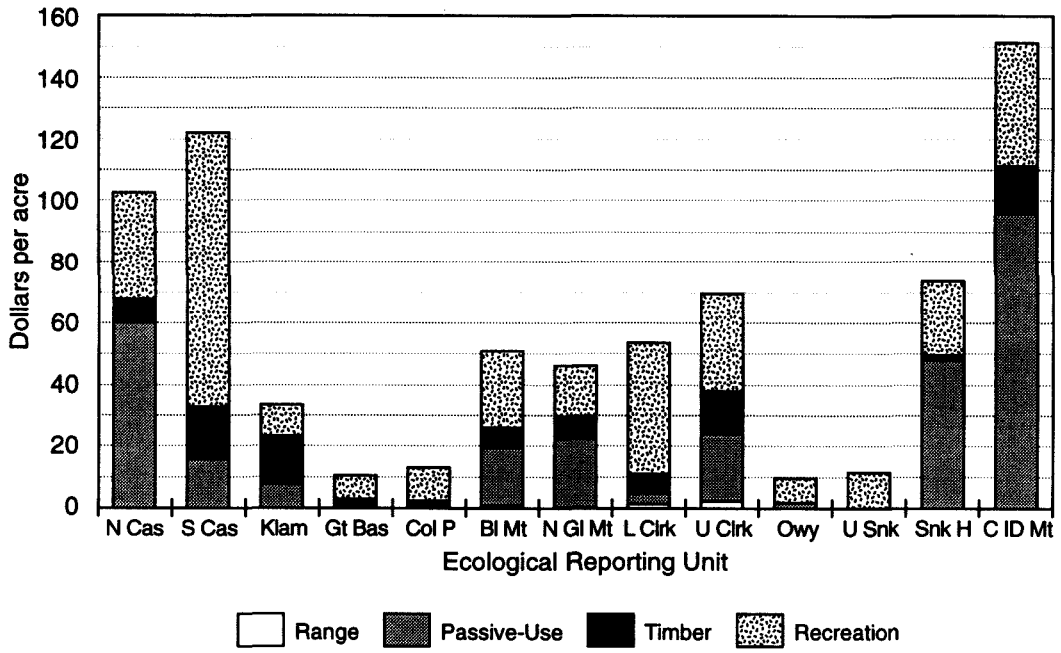


Figure 6.27— Current market basket value of FS- and BLM-administered lands, per acre, within each Ecological Reporting Unit.

Using projections of values and outputs, we can estimate how the relative importance of the various outputs will change over the next 50 years. The tabulation below shows the relative importance of those outputs providing 90 percent of the value provided by FS- and BLM-administered lands in the Basin for the years 1995 and 2045:

Activity	1995 Value	2045 Value
	..... Percent	
Camping	3.45	4.40
Day Use	5.28	8.11
Fishing	9.88	6.64
Hunting	9.48	6.31
Motor Viewing	1.88	9.46
Timber	11.49	5.38
Trail Use	3.28	6.85
Unroad Existence	46.86	41.43
Winter sports	5.05	5.70

As this tabulation shows, the existence of unroaded areas is by far the most valuable output from FS- and BLM-administered lands in the Basin today, and will continue to be so in the year 2045 (fig. 6.28). The relative importance of other outputs will probably shift over time. Today, the three most highly ranked uses from FS- and BLM-administered lands in the Basin are the traditional ones of timber, fishing, and hunting. Our projections indicate that by the year 2045 the three most highly valued uses will be motor viewing, day use, and trail use. This suggests that the FS and BLM will face a fundamental shift in their constituencies. It also suggests that the objectives of land management activities might be different in the year 2045 than they are today. For the Basin as a whole, the relative importance of wildlife viewing, motor and nonmotor boating, range, off-road vehicle (ORV) use, and snowmobiling provided by FS- and BLM-administered lands are less than those activities in the above tabulation.

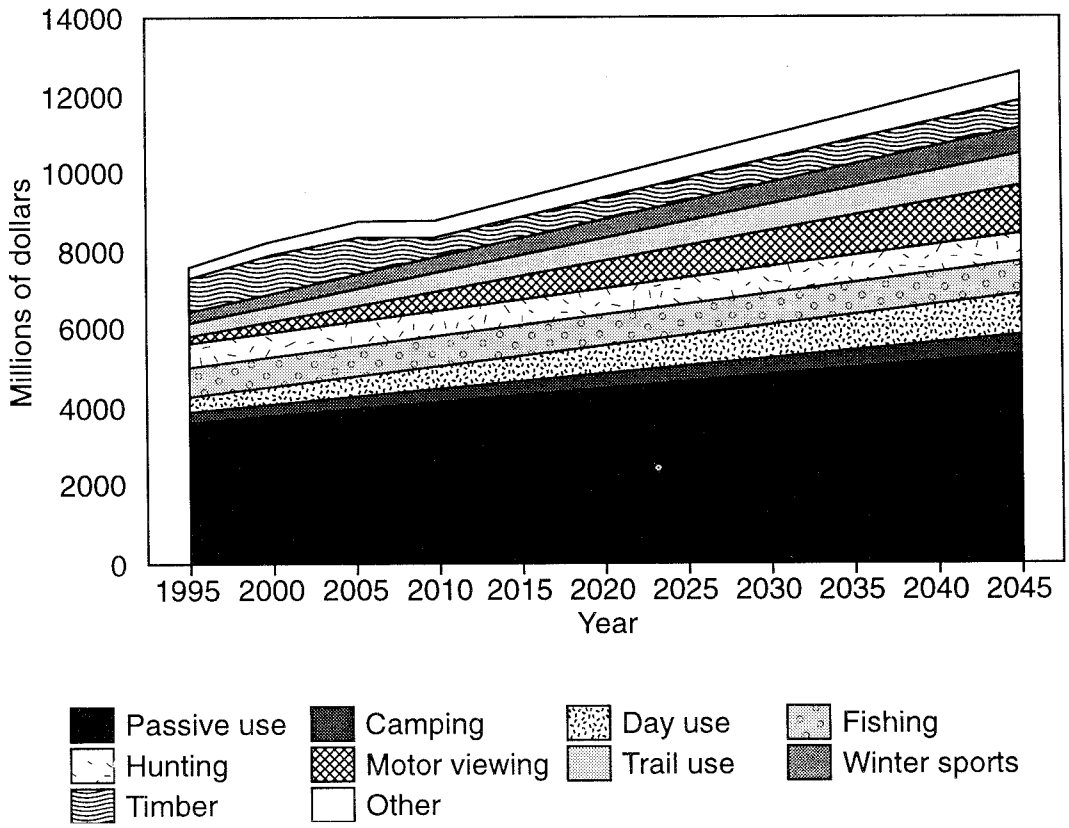


Figure 6.28— Projected increase in value of benefits from FS- and BLM-administered land, by activity, 1995-2045.

Given their differences in natural resource endowments, road infrastructure, unroaded areas, proximity to population centers, and age and income characteristics of residents, each ERU is predicted to provide society with a different bundle of benefits. In most ERUs in the coming decades there will be a re-ordering of priorities, generally toward recreation. Detailed information is shown in table 6.39. Table 6.40 shows the three outputs having the highest relative importance for each ERU in the year 2045. Outputs marked with an asterisk (*) are predicted to increase in relative importance by 10 percent or more over the 50-year period.

In the Southern Cascades ERU and Central Idaho Mountains ERU, the outputs having the highest relative importance in the year 2045 are similar to those for the Basin as a whole: existence of unroaded areas, motor viewing, day use, and trail use. Other outputs are predicted to have high relative importance in other ERUs. Camping will assume a high relative importance in the Upper Klamath ERU and Owyhee Basin ERU. Fishing is predicted to have a high relative importance in the Upper Great Basin ERU, Columbia Plateau ERU, and Upper Snake ERU. Hunting will probably have high relative importance in the Columbia Plateau ERU, Upper Clark Fork ERU, and Upper Snake ERU. Timber will probably be highly important in the Upper Klamath ERU, Upper Great Basin ERU, Columbia Plateau ERU, Northern Glaciated Mountains ERU, and Lower Clark Fork ERU. Viewing wildlife will become highly important in the Northern Cascades ERU. And finally, winter sports will probably be highly important in the Upper Snake ERU and the Snake Headwaters ERU.

Table 6.39—Percent of total value provided by individual activities for each Ecological Reporting Unit (ERU), 1995 and 2045.

ERU	Year	Camping	Day Use	Fishing	Hunting	Motor Boating	Motor Viewing	Non-motor Boating	ORV	Snow mobiling	Trail use	Viewing wildlife	Winter sports	Timber	Range	Unroaded Existence
		Percent														
Northern Cascades	1995	5.87	4.2	1.22	3.22	0.04	1.88	0.05	0.34	0.16	9.29	0.6	5.43	7.76	0.09	59.83
	2045	3.82	3.78	0.59	1.54	0.02	21.24	0.03	0.22	0.09	9.32	18.95	3.85	1.95	0.04	34.55
Southern Cascades	1995	5.18	10.48	19.3	5.7	0.16	4.44	0.99	0.11	0.12	4.42	10.02	12.18	13.86	0.03	13.01
	2045	5.46	13.26	12.1	3.5	0.12	18.49	0.81	0.09	0.07	6	11.02	10.78	2.96	0.02	15.31
Upper Klamath	1995	8.46	4.78	6.21	4.35	0.69	1.09	0.19	0.07	0.12	2.18	1.17	0.93	48.96	0.15	20.66
	2045	12.16	7.28	5.04	3.37	0.65	4.66	0.19	0.06	0.08	3.74	1.56	0.91	21.08	0.12	39.09
Northern Great Basin	1995	8.53	7.93	22.48	14.66	1.09	3.85	0.48	0.55	0.15	3.38	3.35	4.95	27.02	0.07	1.51
	2045	11.64	12.01	16.54	10.68	0.97	16.54	0.45	0.51	0.11	6.09	4.36	5.09	13.77	0.05	1.19
Columbia Plateau	1995	3.76	5.28	51.31	11.46	0.19	1.39	0.58	0.13	0.07	3.76	2.46	1.86	13.41	0.31	4.03
	2045	5.12	8.93	42.01	9.04	0.18	6.96	0.62	0.13	0.06	7.46	3.52	2.15	10.12	0.26	3.43
Blue Mountains	1995	5.01	5.99	11.93	11.08	0.12	1.35	0.08	0.15	0.13	3.66	2.12	6.53	12.65	0.19	39.01
	2045	5.98	9.05	8.28	7.64	0.1	5.79	0.08	0.13	0.09	7.21	2.76	7.41	5.69	0.14	39.65
Northern Glaciated Mountains	1995	3.3	5.1	7.26	9.63	0.27	2.19	0.46	0.16	0.11	2.7	1.01	2.94	14.54	1.05	49.29
	2045	4.23	7.99	4.56	6.32	0.2	9.33	0.37	0.14	0.09	6.38	1.19	3.38	9.36	0.77	45.7
Lower Clark Fork	1995	6.45	12.9	14.18	29.12	0.78	4.22	0.5	0.62	0.3	5.32	1.53	4.2	12.53	1.25	6.12
	2045	6.08	14.15	6.23	13.06	0.41	10.36	0.3	0.37	0.17	9.68	1.38	3.43	16.72	0.63	17.03
Upper Clark Fork	1995	2.63	5.03	7.42	20.53	0.25	1.61	0.35	0.26	0.36	2.92	1.41	3.32	18.74	1.79	33.38
	2045	4.4	9.49	5.25	15.21	0.21	6.68	0.35	0.26	0.33	9.49	2.21	4.43	2.82	1.48	37.39
Owyhee Basin	1995	5.27	3.08	26.75	30.59	4.11	1.77	0.33	0.53	0.09	3.38	1.36	11.79	0.06	1.99	8.93
	2045	8.43	5.55	18.16	21.29	3.53	7.57	0.31	0.49	0.07	8.99	2.15	14.9	0.03	1.53	6.99
Upper Snake	1995	5.84	6.47	26.09	25.57	0.94	2.61	0.32	1.01	0.2	5.26	5.83	19.14	0.18	0.52	0
	2045	8.15	9.79	15.23	15.06	0.68	9.43	0.25	0.79	0.13	11.78	7.81	20.43	0.14	0.34	0
Snake Headwaters	1995	1.93	4.3	5.08	5.52	0.44	1.26	1.05	0.14	0.27	3.59	0.93	7.79	2.52	0.13	65.05
	2045	2.83	6.67	3.3	3.71	0.36	4.88	0.91	0.13	0.21	9.48	1.38	9.44	0.2	0.1	56.41
Central Idaho Mountains	1995	1.84	4.02	5.34	5.89	0.51	1.41	0.34	0.2	0.09	1.66	0.84	3.82	9.99	0.1	63.93
	2045	2.97	7.28	3.93	4.42	0.46	6.23	0.35	0.2	0.08	4.68	1.35	5.08	3.82	0.08	59.07

Table 6.40—Ecosystem outputs currently having greatest relative value from each Ecological Reporting Unit (ERU).

ERU	Outputs with greatest relative value
Northern Cascades	Unroaded existence, motor viewing*, viewing wildlife*
Southern Cascades	Motor viewing*, Unroaded existence, day use
Upper Klamath	Unroaded existence*, timber, camping
Upper Great Basin	Motor viewing*, fishing, timber
Columbia Plateau	Fishing, timber, hunting
Blue Mountains	Unroaded existence, day use, fishing
Northern Glaciated Mtns	Unroaded existence, timber, motor viewing
Lower Clark Fork	Unroaded existence*, timber, day use
Upper Clark Fork	Unroaded existence, hunting, trail use
Owyhee Basin	Motor viewing, trail use, camping
Upper Snake	Winter sports, fishing, hunting
Snake Headwaters	Unroaded existence, trail use, winter sports
Central Idaho Mtns	Unroaded existence, day use, motor viewing

* Increases in relative importance by 10 percent or more by the year 2045.

Scenarios

We used scenarios to address the uncertainty inherent in the projections of timber harvest, grazing levels, recreation activity, and unroaded areas. Scenarios are simplifications that provide a tool for gaining an integrated understanding of biophysical and social systems, and how and to what extent management actions affect them. They are not EIS alternatives; they do not necessarily comply with existing laws and regulations. The uncertainty in the projections results from risks and imperfect knowledge. By varying the assumptions made to address these uncertainties, we can identify those assumptions that make significant differences in the outputs of different management regimes. The procedure starts with development of a series of themes to explore; we chose, as described below, "continuation of current management," "passive management," and "active management."[48]

These scenarios were used in early SIT integration efforts and were developed around five themes: timber harvest, roads, riparian areas, human communities, and biophysical and social processes. Each of the scenarios reflected a different management approach as suggested by its name.

The continuation-of-current-management scenario explores the consequences of maintaining the types and levels of management activity and outputs from Federal lands characteristic of the late 1980s. The road network is assumed to be unchanged and maintained. Timber harvest and silvicultural treatments, including salvage harvesting, are assumed to follow the recent trend. Livestock grazing is assumed to trend slightly downward as Allotment Management Plans are completed.

The passive-management scenario assumes no commodity production from public land. This scenario assumes that no new roads are built and that no road maintenance occurs. Recreation is

[48] There was a fourth, consumptive demand, for which we were unable to project recreation outputs.

affected because roads become impassible over time, particularly in highly erodible areas. It assumes no timber harvesting, no silviculture treatments, and no livestock grazing.

The active management scenario assumes management of natural resources on public lands is aimed toward having healthy, functioning ecosystems. This scenario assumes a small reduction in the road network overall. Some construction of new roads occurs in a manner that reduces adverse effects on watershed and terrestrial systems; this is offset by closing some existing roads to restore or maintain watershed processes. Timber harvesting, salvage, and silvicultural treatments are assumed to focus on achieving forest structures and compositions that reduce risks of fire, insects, and pathogens. Livestock grazing on FS- and BLM-administered lands is assumed to initially decrease by 20 percent while restoration takes place and then gradually return toward current levels.

The specific projections of road density, provided by the Landscape Ecology staff, assumed the following increases in primitive/semi-primitive acres (and decreases in roaded natural acres) under the scenarios as:

Scenario	Increase in Primitive /Semi-Primitive	ERUs
	Percent	
Continuation of Current	0	All
Active Management	5	1,2,3,6,7,8,9,12,13
	0	4,5,10,11
Passive Management	10	1,7,8
	6	2,6,9,12,13
	0	3,4,5,10,11

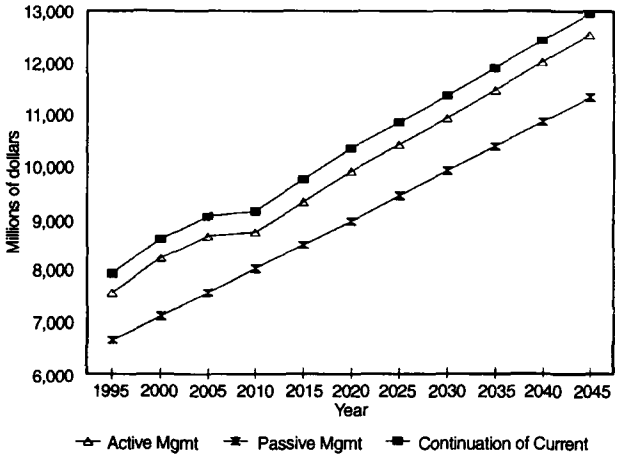


Figure 6.29—Projected annual value of scenario outputs, including range, recreation, timber, and existence of unroaded areas. Scenarios include active-management, passive-management, and continuation-of-current-management, 1995-2045.

Caution should be used in interpreting these results because the market basket used in this analysis is incomplete. It is presented to demonstrate a comparative analysis of use to decision makers. A more complete analysis would include differences between scenarios in ecosystem health, fire risk, carbon storage, among others.

This incomplete market basket analysis indicates that the continuation-of-current-management scenario provides the highest values overall, followed by active management and passive management (fig. 6.29). People who benefit from range and recreation would prefer continuation of current management. It is the least desirable scenario from the perspective of providing existence-of-unroaded-area values which currently comprise 47 percent of the ecosystem market basket. The active management scenario would be first choice for people benefiting from timber harvest, and second choice for all other outputs. In 2045, compared to the continuation-of-current-scenario, active management represents an annual loss of 12.3 million dollars in range, 12.4 million dollars in recreation benefits, an annual gain in benefits of

61.6 million dollars for existence of unroaded areas, and 8.3 million dollars in timber benefits. The passive-management scenario produces the lowest benefits in all categories except the existence of unroaded areas, for which benefits are 86.8 million dollars per year greater in 2045 than under the continuation-of-current scenario. Losses of 49.4 million dollars per year in range, 665.9 million dollars per year in timber, and 527.9 million dollars per year in recreation would result under the passive management scenario.

In all these scenarios the relationship between roads and recreation value changes over time. In the first decade, reductions in road densities increase recreation benefits. In subsequent decades, this relationship shifts until, by the year 2045, reductions in road densities decrease recreation benefits. This flip-flop occurs because of the projections of population growth and age structure in the seven northwest states.

In the year 2045, the value of the current road network for recreation is considerable because it provides access for motorized recreation. By this time, even small reductions in road densities decrease recreation benefits significantly. The recreation activities with highest total value have a common need for roads. Roads are important as resources themselves for activities such as motor viewing and cross-country skiing. They also provide access to trailheads and recreation sites such as campgrounds and day use areas. Closely linked to roads is the issue of access to riparian areas which are important for high value activities such as fishing and viewing wildlife. An economic study of the PACFISH[49] strategy found the greatest losses in benefits resulted not from reduced timber or range values, but from the effects of prohibiting recreation activities in the riparian zone (Bolon and others 1995).

[49] PACFISH is a comprehensive strategy for improved management of habitat for Pacific salmon and steelhead on FS- and BLM-administered lands. The two agencies developed the strategy in 1992 and 1993 (PACFISH 1994, 1995).

Our findings suggest that road closure policies should be examined in light of their simultaneous impacts on multiple factors: fish, wildlife, and recreation. The agencies might be able to identify other methods of achieving the same ecosystem management goals without compromising their ability to meet future recreation demand. For example, rather than closing roads that cause ecosystem damage, agencies could focus on maintaining or redesigning roads to reduce the harm. Although the public may want to protect salmon stocks and prevent the spread of exotic plants, it may feel that being denied access to public lands is too high a price to pay for these benefits.

A clear tradeoff exists between providing road access for some types of recreation and providing primitive and semi-primitive recreation settings for others. Primitive or semi-primitive areas by definition have few or no roads. Fifty-six percent of trail use in the Basin takes place in these low road density settings. Trail use is highly valued in both the Northern Cascades and Central Idaho Mountains ERUs, yet so are activities dependent on roads. Defining the appropriate balance between the amount of roaded natural and primitive/semi-primitive settings is a question that needs further study.

Scenic integrity is another important element of high value recreation activities such as motor viewing and day use. This suggests that placing emphasis on landscape appearance when developing plans or activities could be beneficial, particularly in areas where these activities are a significant percentage of total recreation value. For example, silvicultural prescriptions could be aimed toward assuring a natural appearance and avoiding sharp edges or contrasts.

Complementarity

The efficiency challenge to the land management agencies is shown in figure 6.30 for two outputs: timber harvest and scenic integrity. The curve represents a "production possibility frontier"—the set of all combinations of timber harvest and

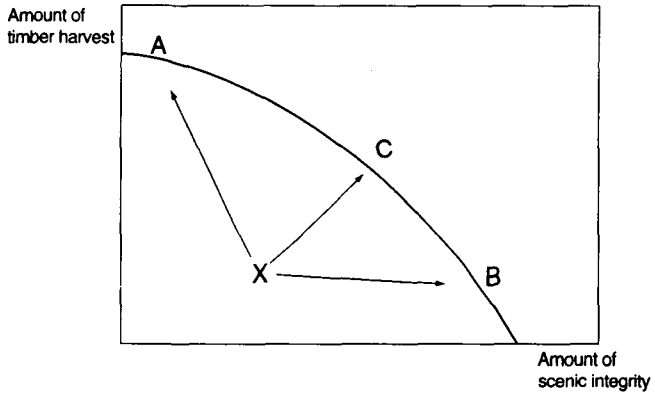


Figure 6.30— Hypothetical joint production function between timber harvests and scenic integrity showing opportunities to increase output of both.

scenic integrity with no waste and no inputs left over from which more of one output could be achieved without giving up some of the other. If our current position is at point X, society could be better off if we moved closer to the production possibility frontier. The problem is that people wanting scenic integrity are afraid that a change will mean a move toward point A at which less scenic integrity will be provided. Similarly, people wanting timber harvest are afraid that change will mean a move toward B at which less timber harvest will occur. Resistance to change means we forego opportunities to move toward C at which more of both scenic integrity and timber harvest are provided and everybody is better off. The challenge is to identify points like C, and the path to reach them, when there are multiple desired outputs. Figure 6.30 presents a challenge to find opportunities for complementary ecosystem management such as point C that allow us to provide greater social benefits with the resources of FS- and BLM-administered lands.

Expenses of Ecosystem Management

The agency costs of ecosystem management are a matter of budget and cost-accounting. Lacking a specific definition of ecosystem management (the activities, area, and time period it involves), it is impossible to estimate its budgetary costs. Some expenditures associated with future risks (such as fire fighting or controlling exotic species) are notoriously unpredictable.

If ecosystem management means increased complexity in agency activities and accounting, it will probably increase disputes over accounting practices. Allocation of direct and indirect costs from relatively straightforward activities such as timber harvest and trail construction is already a matter of dispute among accountants, policy-makers, and stakeholders. For example, witness the two-decades-long debate over below-cost timber sales and range improvements. Already thorny issues are road costs, administrative overhead, pooling of expenses, dedicated funds such as Knutson-Vandenburg (KV), and fire losses.

Another problem is that incentives exist to maximize budgets rather than efficiency (Sumner 1994). Therefore, cost savings from one decision are reallocated elsewhere. In theory, savings could occur. For example, reducing the timber sale program in anadromous drainages as part of a conservation plan for salmon could save 147 dollars in expenditures for every thousand board feet (MBF) of timber not put up for sale (Haynes and others 1992). In some accounting approaches this means that savings would be available for other programs or locations.

One aspect of ecosystem management is ecosystem restoration. Restoration includes three broad categories of activity: returning disturbed or damaged ecosystems to a previous condition, altering the trajectory of existing ecosystems to achieve more desirable future ecosystems (for example, a different stand composition), and restoring missing parts of the landscape (late-seral stages, for example).

The explicit consideration of ecosystem restoration is a significant change in land management. American society traditionally has under-valued sustaining the productivity of land, assuming that enough extra land was available as a low-cost substitute for lost productivity of degraded land.

As a new management practice, ecosystem management focuses attention on analytical processes to determine the appropriate level of restoration. This decision framework requires an integrated understanding of the biological, physical, social, and economic consequences of alternative decisions. Scientific and technical information alone is not sufficient to determine whether a given restoration project should be undertaken. To be efficient, the net benefits of restoration must be found to be greater than the net benefits of mitigation or inaction. In some cases, society's interests may be served best by natural processes with no inputs of human labor and capital.

Revenues for Ecosystem Management

Ecosystem management with its all-inclusive focus on a wide range of goods, functions, and conditions includes many resources that are not formally owned or that are held in common trust. Hardin (1968) described this phenomenon and the associated human behavior as the "tragedy of the commons." In essence, when a resource is publicly available for use, there is an incentive for overuse since there are no incentives to save resources for the future: anything left by one person can be used now by another. As use increases without regulation, depletion of the resource stocks quickly follows as individuals attempt to maintain income or benefits. The collapse of various ocean fisheries is a classic example of this behavior.

Prices are extremely strong signals of human preferences and modifiers of human behavior. Periods of rising prices, for example, point to resource scarcity. Consumers respond by using less, producers respond by making more. Much of current land management's dilemma stems from attempting to discern society's wishes in the absence of price signals. For example, providing free recreational opportunities means that the FS and BLM cannot impartially gauge how people respond to various alternatives other than through planning processes that are vulnerable to influence by special interests.

The ICBEMP is charged with identifying what is required to maintain sustainable or harvestable levels of plant and animal species. Broad indicators suggest that Basin-wide we are already sustaining timber inventory. Other outputs, particularly recreational settings and special products, lack price signals that could moderate use. Given current levels of recreation and harvesting of firewood, publically grown Christmas trees, mushrooms, and berries, these resources may face the "tragedy of the commons." Because these valuable resources are available to the public at little or no cost, there is little incentive for harvesters to conserve these resources. The increases in population predicted for the Northwest suggest that demands on ecosystems and public resources will continue to increase. Charging fees for recreation and special products could protect ecosystem conditions in recreational settings, maintain sustainable or harvestable levels of species, and provide the FS and BLM with sources of revenue more in keeping with the outputs society wants.

Related to the issue of user fees are Federal distributions to county governments [the FS's 25-Percent-Fund and "payments in lieu of taxes" (PILT) used by both the FS and BLM].[50] In the case of the FS's 25-Percent-Fund, these distributions are currently determined from timber sales and grazing permits. Our present focus on ecosystem management demonstrates that the economic value and societal importance of Federal lands has evolved as use increases and unique natural attributes become more scarce. However, this increased value does not now translate into more funds for local governments. Projected recreation value is far in excess of projected timber supply values in the Basin, but recreation contributes little value to local governments to support schools, infrastructure, and public services. This evolution implies that changing the formula for calculating Federal compensation to local governments could better pass along to counties the full

[50] Schuster, E.G. June 26, 1994. Report on 25-Percent-Fund and PILT payments to Montana counties: FY94-FY95. 31 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Missoula, MT.

spectrum of values held for FS- and BLM-administered lands in the Basin.

The difference can be illustrated by comparing payments based on timber and range with non-commodity uses such as recreation value. Using data from CRBSUM (the spatially-explicit model developed by the SIT Landscape Ecology Staff) and from the market basket approach described earlier, we can estimate current and potential payments from the 25-Percent-Fund made by the Federal agencies to the 100 counties in the Basin.

	Total Value	Current Payments	Potential Payments
	..... Millions of dollars		
Range	33.0	8.2	8.2
Recreation	3,326.0	0.0	415.7 - 831.5
Timber	1,379.0	344.8	344.8
Total	4,737.0	353.0	768.7 - 1,184.5

The lower number given for recreation assumes recreational activity is reduced by half by charging fees; the higher number assumes fees have no impact on recreation activity. This emphasizes a policy topic that is of potential importance to local communities, that is, the Federal Government's collection of the true value of Federal-land-produced goods and services and the sharing of this value with local governments. Existing mechanisms that compensate local governments for the non-taxable status of Federal lands apply only to revenue actually generated from Federal lands. Recreation is a high value that increases use of Federal lands. However, it generates little revenue and can impose substantial costs on local governments for roads and emergency services.

It has been suggested that the environmental amenities available on Federal lands adjacent to some communities provide a quality of life that generates economic growth; this in turn contributes to communities through a larger tax base and greater economic activity.[51] Our example suggests that another approach to supporting counties is through modifying the formula that determines Federal payments to counties to reflect the change in uses of Federal lands.

Sustainability

The term "sustainability" has intuitive appeal but is difficult to define. Sustainable forest management has been defined as that which "meets the needs of the present without compromising the ability of the future to meet their own needs" (World Commission on Environment and Development 1987). In the aftermath of the United Nations Conference on Environment and Development held in Rio de Janeiro in June 1992, the participating governments have been developing criteria and indicators for the conservation and sustainable management of temperate and boreal forests. In February 1995, the group working on this task produced the Santiago Declaration, which has been signed by the United States. This declaration identifies seven broad criteria to be used for describing, assessing, and evaluating a country's progress toward forest sustainability. Criterion 6 is the maintenance and enhancement of long-term multiple socioeconomic benefits to meet the needs of societies. The 19 indicator variables address five socioeconomic themes, including

- production, consumption, and recycling of wood and non-wood products,
- recreation and tourism (area, visitor days, facilities),
- investment in the forest sector (research and development, education, technology for forest growth, health, and management, processing, recreation and tourism),
- cultural, social, and spiritual needs and values (including non-consumptive values), and
- employment and community needs (jobs, wage and injury rates, viability and adaptability to changing economic conditions, and amount of forest used for subsistence).

[51]Rudzitis, G.; Watrous, C.; and Johansen, H. 1995. [Manuscript]. Attitudinal survey of Upper Columbia River Basin Residents. Moscow, ID: University of Idaho Department of Geography. [not paged].

Two things should be noted about this list. First, the list of indicators to be tracked is long, reflecting the extreme complexity of sustainability. Second, the diversity of what is to be sustained means that tradeoffs and complementarities are involved. It is unlikely that all indicators can be sustained at current levels. Innovative perspectives are needed if management directions that meet multiple objectives are to be revealed.

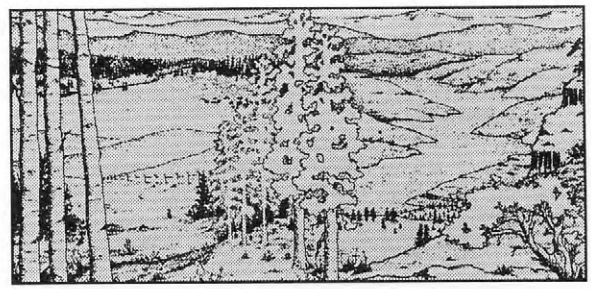
For the Basin as a whole, broad criteria of sustainability indicate that we can and are sustaining forest acreage and inventory volumes. But this comes with the cost of shifting timber harvest from the Basin to other regions in the southern United States and in Canada. For the United States, these changes do not alter the indicators of sustainability; rather, they shift changes from one region of the United States to another. For other criteria indicators, comparisons are more difficult given the problems of measuring any but the simplest indicators of sustainability consistently across regions and nations. This does not address a number of indicator variables, but many of them reflect value judgments and are not measurable with today's science.

For the Basin as a whole and for broad regions within it, the notion of sustainable human communities is difficult to define. With populations expected to double in the Basin, the more pertinent question is how resilient are the communities and their associated economies? Change in the Basin is being driven by population growth, both in the form of in-migration and rates of natural increase that are higher than the U.S. average. Sustainability has the connotation of status quo when associated with the word "communities." A more useful focus would be on the attributes of communities and economies that can accommodate change. Underlying these comments are expectations about economic growth both in total and in the mix of activities. In another sense, much of the thought underlying notions of sustainable communities is the notion that their economic base lies in the nearby resource endowments. In an almost Jeffersonian fashion, proponents speak of sustaining communities and their associated economies on timber, minerals, fish, ranching, and farming activities. The reality in the Basin is quite different. It is true that agriculture plays a major role in the economies of the Basin, especially in the Twin Falls, Tri-Cities, and Pendleton BEA regions. But for the most part, more than half of the Basin's economy is in the financial, trade, and service sectors. The mining and manufacturing sectors account for less of the economy than the national average for those two sectors. Finally, rather than focusing on what seems to be an outdated concept, it may be more profitable to focus on how communities and economies are adapting to change.

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CONCLUSIONS

A fundamental tenet of land stewardship is for managers to direct and maintain ecosystems to fulfill the objectives of the owners. For the FS and BLM, providing a broad array of ecosystem goods, functions, and conditions is appropriate because it is required by laws and regulations and their constituencies are extensive and diverse. The economic challenge of ecosystem management for these agencies is threefold: to produce the bundle of ecosystem goods, functions, and conditions that society wants (economic efficiency), whose distribution of benefits is according to societal wishes (equity), without adversely affecting economic activity. We address each of these issues in turn. At the end, we briefly characterize the economic issues related to fish, minerals, range, recreation, and timber.

Economic Efficiency

Under current management, FS- and BLM-administered lands in the Basin provide society with a wide array of benefits. The current and future importance of the benefits that we could measure and value is shown in table 6.41. This table shows that of the ouputs and conditions we were able to evaluate the existence of unroaded areas is a highly valued condition on FS- and BLM-administered lands in the Basin today. It will continue to be so in the year 2045 although to a lesser degree. The relative importance of other outputs will probably shift over time. Existence values aside, the three most highly ranked uses from FS- and BLM-administered lands in the Basin today are the traditional ones of timber, fishing, and hunting. Our projections indicate that by the year 2045 the three most highly valued uses will be motor viewing, day use, and trail use. This suggests that the FS and BLM will face a fundamental shift in their constituencies. It also suggests that the objectives of land management activities might be different in the year 2045 than they are today. For the Basin as a whole, the relative importance of wildlife viewing, motor and nonmotor boating, range, off-road vehicle (ORV) use, and snowmobiling provided by FS- and BLM-administered lands are less than activities just discussed and are included in the "other" category in table 6.41.

Given their differences in natural resource endowments, road infrastructure, unroaded areas, proximity to population centers, and age and income characteristics of residents, each ERU is predicted to provide society with a different bundle of benefits. In most ERUs in the coming decades there is predicted to be a re-ordering of priorities, generally toward recreation.

The institutional framework and societal desires from public land stewardship continuously evolve. In the course of U.S. history, major land management themes have changed from privatization (1800-1891), to conservation and scientific management (1891-1945), to commodity production (1945-1960), to increasingly complex and contentious demands (1960-present). Today, the agencies are faced with attempting to balance these

Table 6.41— The relative importance of some outputs from FS- and BLM-administered lands in the Basin, for the years 1995 and 2045.

Activity	1995 Value	2045 Value
	Percent	
Camping	3.45	4.40
Day Use	5.28	8.11
Fishing	9.88	6.64
Hunting	9.48	6.31
Motor viewing	1.88	9.46
Timber	11.49	5.38
Trail Use	3.28	6.85
Existence value of unroaded areas	46.86	41.43
Winter Sports	5.05	5.70
Other	3.35	5.72
Total	100.00	100.00

traditional issues with demands for ecosystem health and fire management. Society's objectives for public land stewardship will likely continue to change.

Broad indicators suggest we are sustaining forest acreage and inventory at the Basin-level. Given current levels of recreational activity and harvesting of firewood, publicly grown Christmas trees, mushrooms, and berries, along with some other Federal resources, potentially face the tragedy-of-the-commons. Because these valuable resources are available to the public at little or no cost, there is litte incentive for harvesters to conserve these resources. The increases in human population predicted for the Northwest suggest that demands on ecosystems and public resources will continue to increase. Establishing a fee system for recreation and special products could protect ecosystem conditions in recreational settings, maintain sustainable or harvestable levels of species, and provide new sources of revenue.

Equity

The benefits of the FS- and BLM-administered lands in the Basin are distributed widely. Consumers of beef or timber benefit because these goods are traded in national markets. People who enjoy knowing unroaded areas exist may never visit the Basin yet receive benefits. Millions of people, mostly residents of the Basin and the Northwest, recreate here; there is little difference in participation rates among people with different lifestyles.

About 220,000 jobs are associated with current levels of range, recreation, and timber harvest on FS- and BLM-administered lands. Range accounts for 1 percent of these jobs, recreation 87 percent, and timber 12 percent. In addition, jobs are associated with mining and with harvesting special forest and range products, but the number is unknown.

Federal distributions to county governments from revenue sharing are currently determined from timber sales and grazing permits. Yet some of these counties bear costs associated with recreation such as infrastructure, road maintenance, and emergency services. Including the value of recreation on Federal lands in payments to counties could double or triple their revenues.

Economic Activity

The Basin

Agriculture and agricultural services remain economic strengths of the Basin. The Basin has a large, diverse economy of 1.5 million jobs that is enjoying above average rates of growth. Per capita income is growing faster than the U.S. rate, and the poverty rate is generally lower than the U.S. average. The past two decades have seen rapid population growth, and the evolution of what was a mature, resource-based economy into a diverse economy oriented toward technology, transportation, and service sectors.

We expect the general economic growth in the Basin to continue sustained by in-migration in some areas. Growth is expected in services, finance, insurance, real estate, trade, and agricultural services. Fastest growth is expected in the service sector, which includes health, business, educational, and legal services. The manufacturing, farming, and government sectors are expected to decline as a percent of the economy over the next 50 years.

Traditional regional economics views growth as a function of expansion in basic manufacturing industries. Contemporary challengers argue that other industries should be considered part of the economic base. Both approaches recognize that some locations have unique advantages or endowments that will attract certain types of industries. Traditionalists view these as resource endowments for extractive industries. In the contemporary schema, these include amenity or quality of life considerations that attract business, capital, and skilled labor. Our findings indicate that changes in management strategies by the FS and BLM have little impact on the economy of the Basin or its subregions using either of these two approaches. The effects of the agencies may be more pronounced at specific local levels, however.

The nine regional economies in the Basin are diverse, and they are resilient to changes in FS and BLM commodity outputs. Overall, the forest-products industry has had a neutral impact on recent economic growth. We found no relationship between economic well-being at the county level (expressed as per capita income) and either the forest-products processing facilities or the presence of timberlands, whether Federal, FS only, or private. Basin-wide the cattle industry accounts for 29 percent of agricultural sales, but only 7 percent of it is dependent on BLM and FS forage. Recreation accounts for 14.6 percent of the jobs in the Basin. Mining accounts for 0.5 percent, but we were unable to acquire data to determine what percent of mining jobs is attributable to FS and BLM resources.

The Boise BEA region is strong in agriculture, agricultural services, transportation, finance, insurance, and real estate. The portion of cattle dependent on Federal forage is 12 percent, above the Basin average.

The Butte BEA region is the only regional economy in the Basin without a strong agricultural sector. Mining is very important there along with transportation and services.

The Idaho Falls BEA region is strong in agriculture, agricultural services, construction, and trade. Mining is important, though less so than in the Butte BEA region. Both employment attributable to recreation (30%), and the portion of cattle dependent on Federal forage (11%), are above the Basin average.

The Missoula BEA region is strong in agriculture, agricultural services, construction, and transportation. Employment attributable to recreation is 31 percent, considerably above the Basin average.

The Pendleton BEA region is strong in agriculture, agricultural services, and manufacturing. Both forest products and food processing are important components of its manufacturing sector. Economic diversity is fairly high, suggesting this economy is resilient to fluctuations in the forest-products industry.

The Redmond-Bend BEA region is strong in agriculture and agricultural services. Both employment attributable to recreation (25%), and the portion of cattle dependent on Federal forage (9%), are above Basin averages. Forest products and food processing are both important components of its manufacturing sector. Like the Pendleton BEA region, economic diversity is fairly high, suggesting this economy is resilient to fluctuations in the forest products industry.

The Spokane, Tri-Cities, and Twin Falls BEA regions all are strong in agriculture and agricultural services. In addition, the Spokane BEA region is strong in trade, and the Twin Falls BEA region is strong in construction. None of these regional economies is likely to be affected by changes in FS and BLM commodity outputs.

Counties

Counties grouped according to a typology of income specialization or other characteristics exhibit different patterns of economic behavior. Those dominated by the service sector have consistently shown the highest rates of economic and population growth since 1970; they have also exhibited high resiliency, rebounding faster than other counties after the early 1980s recession. These include counties with trade-center towns and growing recreation and tourism economies. Counties dominated by recreation or retirees have shown consistently high rates of growth in population, total employment, and total personal income over the last 20 years. Between 1979 and 1989, counties in which manufacturing income is dominant showed the highest tendency to evolve to a different kind of economy. Many of these did so because of losses in the wood products or mining sectors.

Community Economies

Maintenance of stability in timber-dependent communities is often thought to be the responsibility of the FS despite their having no specific legal mandate to do so. No facts document a link between sustained timber flow and community stability. What makes timber communities less resilient than others is their tendency to be isolated and lack economic diversity. These traits make their economies sensitive to changes in interest rates, labor productivity, consumer preferences, and national business cycles, all factors over which the FS and BLM have little influence.

In 1987, the FS identified 66 Basin communities as timber-dependent. Today, 29 exhibit characteristics indicating concern may be legitimate for their sensitivity to Federal timber sales. These are isolated communities separate from fast-growing populations and economies in the Basin. Federal policies toward such communities are more accurately viewed as political, not economic, and reflect political preferences about equity or distribution of wealth. Given that human populations in the Basin are expected to double over the next 50 years, the notion that any community may maintain stability is questionable. The more appropriate question is what attributes of communities and their economies best accommodate change.

Characterizations of Specific Resources

Fish

Through a multitude of actions of others such as ocean fishing, government hydropower projects, irrigated agriculture, forestry, and grazing, the FS and BLM are managing some of the last remnants of good quality habitat for declining fish stocks. The net result of these actions, plus habitat degradation, has been the virtual elimination of a valuable commercial fishery. It has also meant incalculable damages to the American Indians for

whom salmon was economically, culturally, and spiritually significant. Spiritual values aside, the greatest value of the much diminished Columbia Basin fishery currently is for recreation, much of which takes place on public lands. The burden on the FS and BLM to maintain habitats that support strong fish populations will probably increase as human population growth and associated land-use changes, commercial fishing pressures, climatic influences on ocean habitat, and fish passage through hydropower facilities continue.

Minerals

There is a smaller percent of mining employment in the Basin than in the Nation (0.45% vs 0.66%), but mining is very important in the six counties that account for 70 percent of the Basin's mineral production value. The Basin produces 30 percent of the Nation's silver, 12 percent of the Nation's phosphate, and 11 percent of the Nation's gold.

Future mineral production will occur in the Basin at rates that will depend on metal prices, laws, and regulations. The extent to which mining activity will affect public lands is difficult to know. The greatest probability for mineral development in the long-term is along three geologic trend-lines which run through six ERUs. One is a northeasterly trend from southeastern Oregon into central Montana (the Owyhee, Central Idaho Mountains, and Upper Clark Fork ERUs), in which the most economically attractive targets include copper, cobalt, and large, low-grade deposits of gold and silver. In the western Northern Glaciated Mountains and North Cascades ERUs, mining for gold and silver will likely continue. This mining will be underground in the short-term, but become open pit mining in the future. Considerable base metal resources lie in a northwesterly trend from southwestern Montana into northeastern Washington (Upper Clark Fork, Lower Clark Fork, and Northern Glaciated Mountains ERUs). Large-scale open-pit mining and processing of phosphate ore is likely to continue in the Snake Headwaters and Upper Snake ERUs over the long term.

Range

The dependency of the livestock industry on BLM and FS forage varies from 1 to 11 percent in the BEA regions, with a Basin-wide average of 7 percent. Sales of cattle dependent on BLM and FS AUMs average 2 percent of total agricultural sales across the Basin. Many of the counties that are most highly dependent on Federal forage have small sales of cattle and calves, suggesting that their rangelands are of low productivity. If current trends continue, forage use will decrease on BLM lands by 18 percent, and on FS lands by 19 percent, over the next two decades.

On average, holders of BLM or FS grazing permits run bigger operations that are more profitable than those of non-permittees. Permit acreage and AUMs are skewed toward the largest permit holders—a small number of individuals, corporations, and partnerships.

Recreation

FS- and BLM-administered lands in the Basin provide over 200 million recreation activity days per year, valued at $1.0 billion per year (in terms of willingness-to-pay). This is over 80 percent of the recreation value provided by all Federal lands in the Basin. At present, recreation on FS- and BLM-administered lands has a higher willingness-to-pay value than the market value of timber or range outputs in every ERU, except in the Klamath Basin in which timber values will be surpassed by recreation by the year 2005. Fishing provides the greatest benefits of all activities ($300 million), followed by day use ($250 million), downhill and cross-country skiing ($230 million), hunting ($146 million), and camping ($75 million). By the year 2045, the most value to the larger and older human population will be provided by (in decreasing order) motor viewing, day use, trail use, fishing, and hunting.

The FS and BLM manage over 90 percent of the federally owned recreation acres in almost every ERU and ROS class in the Basin. Seventy-five percent of all activity days take place in roaded

natural settings (road densities between 1.7 and 4.2 miles per square mile). Roads and access to riparian areas are an aspect of recreation supply common to what will be the most highly valued recreation activities for the next 50 years. If charged, recreation fees could be used to finance road maintenance, and to offset other potential decreases in road funds.

Purchases of food, equipment, lodging, transportation, licenses, and other items associated with recreation on public lands add up to significant expenditures and support some 220,000 jobs in the Basin. The percentage of the job force supported by recreation is above the Basin average in the Idaho Falls, Missoula, and Redmond-Bend BEA regions.

A tradeoff exists between access for some types of recreation and primitive/semi-primitive recreational settings for others. Seventy percent of the unroaded areas of 200,000 acres or greater in the lower 48 states lie in the Basin; 56 percent of trail use in the Basin takes place in the primitive/semi-primitive settings. Trail use is highly valued in both the Northern Cascades and Central Idaho Mountains ERUs, yet so are activities dependent on roads. Finding an appropriate balance between roaded natural and primitive/semi-primitive settings will need further study.

Scenic integrity is another important element of high-value recreation activities such as motor viewing and day use. Managers might consider using silvicultural prescriptions that improve scenic integrity by creating a more natural appearance, and avoiding sharp edges or contrasts, particularly in ERUs such as the Northern Cascades and Central Idaho Mountains that are expected to be highly valued for motor viewing and day use.

Special Forest and Range Products

Little is known about the special forest and range products industry in the Basin because data on jobs and harvest are not regularly gathered. Compared with the industry west of the Cascade Mountains, the industry in the Basin is small but growing and focused around wild edible mushrooms and huckleberries. Rapid expansion in the special forest and range products industry in the Basin is expected to continue. Under the present permitting system and without a fee system, some of these species may be over-harvested.

Timber

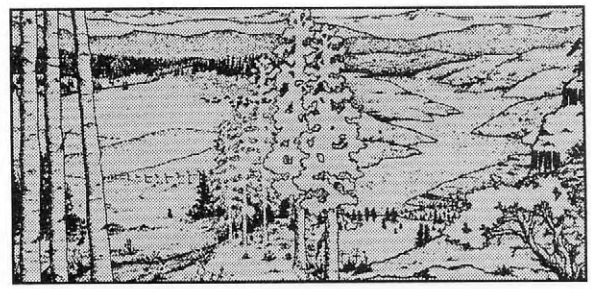
Softwood timber harvest in the United States is projected to increase by 35 percent (0.6% per year), to 14.6 billion cubic feet by the year 2040. In the past five years, Federal harvests have been shifting from western to southern states, such that western states now account for 45 percent of total timber harvest. Timber harvest in the Basin currently accounts for 10 percent of total U.S. harvest; it has declined by 7 percent since 1986 and is expected to decline another 5 percent by the end of the decade. FS and BLM harvest is currently 46 percent of total harvest in the Basin.

In recent years, the number of timber jobs in Idaho and Montana has declined due to technological improvements; no such trend exists for eastern Oregon and Washington. Based on current harvest projections, we expect modest employment declines to continue, related to declines in timber harvest. More than 80 percent of the timber harvest in the Basin occurs in the Spokane, Missoula, Redmond-Bend, and Pendleton economic areas; this includes both private and public timber.

Water

Current water use in the Basin (34.3 billion gallons per day) is almost entirely (93 percent) for irrigated agriculture with only minor amounts used for domestic, commercial, and industrial purposes (5 percent), and livestock (2 percent). Southern Idaho accounts for 62 percent of the water withdrawals. Projections based on per capita water use for commercial, domestic, and industrial water purposes suggests potential conflict over water use between municipalities and irrigators. Eight out of nine economic areas would have to reduce the amount of land in irrigated agriculture to meet municipal needs.

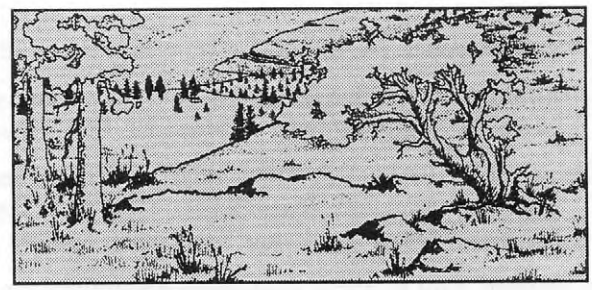
Water use and water policies, while not controlled by the FS and BLM, do affect land management in the Basin. For example, the listing of chinook and sockeye salmon in the Snake River has caused reconsideration of land management practices. In addition, changes in water allocation is one of the options available for ensuring the viability of fish populations. Complicating the water issue is the impact of increasing demands for water based recreational activities many of which take place on federal lands.



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APPENDIX 6-A

Response coefficients for Agriculture, Forestry, and Minerals for each BEA region

AREA SIC Classification	IMPLAN Industry	Industry Name	Employee Compensation Multiplier	Jobs Multiplier	Employee Compensation Response Rate	Jobs Response Rate
BOISE:						
0212	3	Ranch Fed Cattle	1.6629	2.0288	0.9812	41.16
0212	4	Range Fed Cattle	1.8527	1.9993	1.0022	49.34
0214	6	Sheep, Lambs And Goats	1.9320	2.0326	1.0170	51.57
0810, 0830, 0970	24	Forestry Products	6.1064	7.8129	0.5837	36.12
0710, 0720, 0750, 0760, 0279, 0254, 0850, 0920	26	Agricultural, Forestry, Fisheries	2.5006	1.9305	0.8948	63.60
1041	31	Gold Ores	1.9842	3.2496	0.3327	13.27
1044	32	Silver Ores	1.4226	2.4260	0.4216	12.20
1410, 1420	40	Dimension Stone	1.4485	1.6908	0.5796	24.08
1440	41	Sand And Gravel	1.3928	1.6924	0.5988	22.97
1475	44	Phosphate Rock	1.5013	1.9551	0.2704	9.82
2411	133	Logging Camps And Logging Contractors	1.3883	1.7140	0.3434	12.63
2421	134	Sawmills And Planing Mills, General	1.7711	2.7132	0.7010	20.95
2431	137	Millwork	1.9050	2.3333	0.7409	28.11
2434	138	Wood Kitchen Cabinets	1.7231	1.8913	0.7822	35.75
2435, 2436	139	Veneer And Plywood	1.9043	2.7097	0.6478	21.16
2439	140	Structural Wood Members, N.E.	1.6670	2.4113	0.8643	26.08
2620	162	Paper Mills, Except Building	1.5339	2.3442	0.4269	11.96

AREA SIC Classification	IMPLAN Industry	Industry Name	Employee Compensation Multiplier	Jobs Multiplier	Employee Compensation Response Rate	Jobs Response Rate
BUTTE:						
0212	3	Ranch Fed Cattle	1.7507	2.0803	0.9783	46.75
0212	4	Range Fed Cattle	1.8559	2.0236	1.0235	54.26
0214	6	Sheep, Lambs And Goats	1.8618	2.0823	1.0235	52.64
0810, 0830, 0970	24	Forestry Products	8.4218	6.5473	0.4863	33.08
0710, 0720, 0750, 0760, 0279, 0254, 0850, 0920	26	Agricultural, Forestry, Fisheries	2.5243	1.9463	0.8658	65.44
1020	29	Copper Ores	2.7821	4.3208	0.3259	12.34
1041	31	Gold Ores	2.0875	3.4169	0.3178	13.11
1044	32	Silver Ores	1.9026	2.0925	0.4238	22.76
1440	41	Sand And Gravel	1.4380	1.7983	0.4834	19.92
1475	44	Phosphate Rock	1.5949	2.0631	0.2267	9.42
2411	133	Logging Camps And Logging Contractors	1.5888	1.8010	0.2978	15.07
2421	134	Sawmills And Planing Mills, General	2.3177	2.8530	0.6017	28.07
2434	138	Wood Kitchen Cabinets	1.8522	1.9870	0.7627	41.38
2439	140	Structural Wood Members, N.E.	2.1990	2.5846	0.7913	38.05
IDAHO FALLS:						
0212	3	Ranch Fed Cattle	1.5493	2.0357	0.9238	33.77
0212	4	Range Fed Cattle	1.6366	1.9760	0.9473	39.51
0214	6	Sheep, Lambs And Goats	1.6396	2.0045	0.9595	39.10
0810, 0830, 0970	24	Forestry Products	6.1254	8.0199	0.6359	38.13
0710, 0720, 0750, 0760, 0279, 0254, 0850, 0920	26	Agricultural, Forestry, Fisheries	2.2529	1.8800	0.8637	59.78
1041	31	Gold Ores	2.5150	3.0288	0.2985	14.96
1044	32	Silver Ores	1.6235	2.0111	0.4324	19.16
1410, 1420	40	Dimension Stone	1.0750	1.9296	0.3943	1.35
1440	41	Sand And Gravel	1.4016	1.6416	0.5913	25.90
1475	44	Phosphate Rock	1.3943	1.8973	0.2521	8.43
2411	133	Logging Camps And Logging Contractors	1.4135	1.6749	0.3216	13.72
2421	134	Sawmills And Planing Mills, General	1.8255	2.7164	0.6627	22.70
2431	137	Millwork	1.9746	2.3062	0.7068	30.71

2434	138	Wood Kitchen Cabinets	1.5965	1.8869	0.7590	33.51
2439	140	Structural Wood Members, N.E.	1.7268	2.4138	0.8263	28.54
MISSOULA:						
0212	3	Ranch Fed Cattle	1.7892	2.1986	1.0034	47.75
0212	4	Range Fed Cattle	1.9135	2.1311	1.0565	56.19
0214	6	Sheep, Lambs And Goats	1.9469	2.1770	1.0658	56.42
0810, 0830, 0970	24	Forestry Products	4.9548	5.4252	0.4194	26.81
0710, 0720, 0750, 0760, 0279, 0254, 0850, 0920	26	Agricultural, Forestry, Fisheries	2.5906	2.0992	0.9316	67.98
1020	29	Copper Ores	3.3011	4.4890	0.2942	13.53
1041	31	Gold Ores	2.5274	3.7939	0.2640	13.68
1044	32	Silver Ores	1.6612	2.3644	0.4122	17.88
1410, 1420	40	Dimension Stone	1.8662	1.8387	0.5317	33.22
1440	41	Sand And Gravel	1.4757	1.9053	0.4969	20.83
2411	133	Logging Camps And Logging Contractors	1.6188	1.8699	0.3061	15.40
2421	134	Sawmills And Planing Mills, General	2.1097	2.9391	0.6276	27.13
2431	137	Millwork	2.1783	2.6211	0.7257	34.74
2434	138	Wood Kitchen Cabinets	2.2933	2.2311	0.8669	50.84
2435, 2436	139	Veneer And Plywood	2.0824	3.0665	0.6251	25.27
2439	140	Structural Wood Members, N.E.	3.2515	2.7030	0.7812	46.24
PENDLETON:						
0212	3	Ranch Fed Cattle	1.5548	1.7539	0.8952	41.82
0212	4	Range Fed Cattle	1.7635	1.8095	0.8633	46.69
0214	6	Sheep, Lambs And Goats	1.8617	1.8340	0.8808	50.38
0810, 0830, 0970	24	Forestry Products	5.5080	5.9391	0.4368	28.59
0710, 0720, 0750, 0760, 0279, 0254, 0850, 0920	26	Agricultural, Forestry, Fisheries	1.8439	1.6317	0.7167	50.97
1020	29	Copper Ores	2.0222	2.9299	0.2757	8.05
1041	31	Gold Ores	2.5669	2.2296	0.2131	12.83
1410, 1420	40	Dimension Stone	1.3169	1.5050	0.3941	16.31
1440	41	Sand And Gravel	1.5960	1.4668	0.4949	34.64
2411	133	Logging Camps And Logging Contractors	1.3062	1.5087	0.2798	11.30
2421	134	Sawmills And Planing Mills, General	1.8545	2.2658	0.5509	20.95

AREA SIC Classification	IMPLAN Industry	Industry Name	Employee Compensation Multiplier	Jobs Multiplier	Employee Compensation Response Rate	Jobs Response Rate
PENDLETON continued						
2431	137	Millwork	1.9223	1.9351	0.5734	28.07
2435, 2436	139	Veneer And Plywood	2.0343	2.3360	0.5166	21.00
2620	162	Paper Mills, Except Building	1.3696	1.9560	0.3588	9.59
REDMOND-BEND:						
0212	3	Ranch Fed Cattle	1.6532	1.8798	0.9482	44.39
0212	4	Range Fed Cattle	1.8681	1.9343	0.9299	49.42
0214	6	Sheep, Lambs And Goats	1.9123	1.9379	0.9609	52.48
0810, 0830, 0970	24	Forestry Products	6.2402	6.3969	0.5005	30.76
0710, 0720, 0750, 0760, 0279, 0254, 0850, 0920	26	Agricultural, Forestry, Fisheries	1.9234	1.7603	0.8095	52.14
1020	29	Copper Ores	3.6698	3.5675	0.2288	10.81
1041	31	Gold Ores	2.1367	2.9607	0.2460	11.33
1410, 1420	40	Dimension Stone	1.4484	1.6012	0.4305	19.87
1440	41	Sand And Gravel	1.5034	1.5911	0.5019	25.86
2411	133	Logging Camps And Logging Contractors	1.3940	1.6259	0.2964	12.14
2421	134	Sawmills And Planing Mills, General	1.9592	2.4803	0.5934	22.67
2431	137	Millwork	1.8986	2.2214	0.6682	27.93
2434	138	Wood Kitchen Cabinets	1.7068	1.8797	0.7511	33.80
2435, 2436	139	Veneer And Plywood	2.1984	2.5763	0.5636	23.00
2439	140	Structural Wood Members, N.E.	2.2026	2.2766	0.7353	34.11
SPOKANE:						
0212	3	Ranch Fed Cattle	1.6663	2.2159	0.9936	36.72
0212	4	Range Fed Cattle	1.7582	2.1574	1.0296	42.29
0214	6	Sheep, Lambs And Goats	1.7830	2.2206	1.0268	41.37
0810, 0830, 0970	24	Forestry Products	4.0850	6.7987	0.5794	30.23
0710, 0720, 0750, 0760, 0279, 0254, 0850, 0920	26	Agricultural, Forestry, Fisheries	2.4342	2.1256	1.0131	63.16
1020	29	Copper Ores	2.1999	3.2665	0.2624	9.44
1041	31	Gold Ores	1.9501	3.3208	0.3348	12.43

1044	32	Silver Ores	1.5575	2.3395	0.4461	15.44
1410, 1420	40	Dimension Stone	1.5474	1.8595	0.4795	20.02
1440	41	Sand And Gravel	1.4534	1.8414	0.5693	21.55
1475	44	Phosphate Rock	1.5615	2.0390	0.2798	10.20
2411	133	Logging Camps And Logging Contractors	1.4610	1.9212	0.2798	13.58
2421	134	Sawmills And Planing Mills, General	2.0670	2.8621	0.3772	24.79
2431	137	Millwork	2.3964	2.5785	0.7034	35.06
2434	138	Wood Kitchen Cabinets	2.2104	2.1585	0.7730	46.46
2435, 2436	139	Veneer And Plywood	2.0149	2.9666	0.9034	23.12
2439	140	Structural Wood Members, N.E.	2.2857	2.6347	0.6959	37.11
2620	162	Paper Mills, Except Building	1.7198	2.5432	0.8748	13.38
TRI-CITIES:						
0212	3	Ranch Fed Cattle	1.5169	1.7953	0.8933	35.05
0212	4	Range Fed Cattle	1.5958	1.7377	0.9236	41.81
0214	6	Sheep, Lambs And Goats	1.5582	1.7634	0.9134	38.64
0810, 0830, 0970	24	Forestry Products	3.4998	6.9682	0.5315	29.64
0710, 0720, 0750, 0760, 0279, 0254, 0850, 0920	26	Agricultural, Forestry, Fisheries	2.1705	1.6622	0.7495	55.94
1041	31	Gold Ores	1.7958	2.4164	0.2645	10.24
1410, 1420	40	Dimension Stone	1.5011	1.4926	0.4393	24.15
1440	41	Sand And Gravel	1.3648	1.5005	0.4687	20.60
2411	133	Logging Camps And Logging Contractors	1.3608	1.5649	0.2859	11.59
2421	134	Sawmills And Planing Mills, General	1.9811	2.3273	0.5530	21.65
2431	137	Millwork	1.8789	2.0186	0.6030	27.14
2434	138	Wood Kitchen Cabinets	1.6735	1.7125	0.6727	34.20
2435, 2436	139	Veneer And Plywood	3.7567	2.2855	0.4119	24.83
2439	140	Structural Wood Members, N.E.	1.8673	2.1210	0.7099	29.60

AREA SIC Classification	IMPLAN Industry	Industry Name	Employee Compensation Multiplier	Jobs Multiplier	Employee Compensation Response Rate	Jobs Response Rate
TWIN FALLS:						
0212	3	Ranch Fed Cattle	1.4494	1.8296	0.8636	31.12
0212	4	Range Fed Cattle	1.5114	1.7814	0.8862	36.55
0214	6	Sheep, Lambs And Goats	1.5265	1.8221	0.8929	35.86
0810, 0830, 0970	24	Forestry Products	4.4717	6.2759	0.5067	30.09
0710, 0720, 0750, 0760, 0279, 0254, 0850, 0920	26	Agricultural, Forestry, Fisheries	1.8459	1.6604	0.7501	51.02
1041	31	Gold Ores	1.8810	2.5985	0.2640	12.24
1044	32	Silver Ores	1.4041	1.8271	0.3830	15.26
1410, 1420	40	Dimension Stone	1.4396	1.4749	0.6031	35.13
1440	41	Sand And Gravel	1.2542	1.5083	0.5354	19.77
1475	44	Phosphate Rock	1.6482	1.6045	0.2155	13.29
2411	133	Logging Camps And Logging Contractors	1.3907	1.5759	0.2499	12.00
2421	134	Sawmills And Planing Mills, General	1.5111	1.9197	0.4808	18.11
2431	137	Millwork	1.3810	1.8534	0.5884	19.73
2434	138	Wood Kitchen Cabinets	1.3288	1.6983	0.6814	23.67
2439	140	Structural Wood Members, N.E.	1.3076	1.8290	0.6755	19.43

APPENDIX 6-B

Recreation Response Coefficients for Each BEA Region, by Activity.

AREA	Residency	Activity	Jobs		Millions of 1991 dollars of employee compensation		Average expenditures per person per day
			Total effects	Direct effects	Total effects		
	R= Resident NR= Nonresident		Per thousand person days of recreation activity		Per thousand person days of recreation activity		In dollars
BOISE	R	Camping	0.50	0.97	0.0061	0.0126	25.82
	R	Day Use	0.67	1.26	0.0085	0.0167	33.52
	R	Fishing	0.90	1.67	0.0095	0.0201	38.28
	R	Hunting	3.07	5.55	0.0386	0.0737	130.15
	R	Motorized Boating	0.57	1.08	0.0071	0.0141	28.37
	R	Motorized Viewing	1.00	2.03	0.0118	0.0260	54.76
	R	NonMotorized Boating	8.48	16.79	0.0998	0.2166	381.65
	R	Off Road Vehicle Use	0.17	0.32	0.0024	0.0045	10.25
	R	Snowmobiling	2.48	4.49	0.0288	0.0573	107.60
	R	Trail Use	0.75	1.38	0.0084	0.0173	30.57
	R	Viewing Wildlife	0.29	0.56	0.0035	0.0072	14.13
	R	Winter Sports	1.50	2.58	0.0143	0.0297	46.87
	NR	Camping	0.41	0.72	0.0041	0.0084	14.47
	NR	Day Use	0.30	0.54	0.0034	0.0067	11.65
	NR	Fishing	0.44	0.78	0.0049	0.0096	17.14
	NR	Hunting	0.27	0.46	0.0032	0.0059	11.35
	NR	Motorized Boating	1.46	2.64	0.0170	0.0334	60.85
	NR	Motorized Viewing	2.34	4.39	0.0285	0.0577	104.60
	NR	NonMotorized Boating	0.99	1.80	0.0102	0.0215	36.99
	NR	Off Road Vehicle Use	0.02	0.03	0.0003	0.0004	1.14
	NR	Snowmobiling	0.49	0.85	0.0048	0.0098	15.89
	NR	Trail Use	1.20	2.19	0.0116	0.0256	40.07
	NR	Viewing Wildlife	2.42	4.47	0.0267	0.0559	98.16
	NR	Winter Sports	1.06	1.84	0.0100	0.0209	32.36

AREA	Residency	Activity	Jobs		Millions of 1991 dollars of employee compensation		Average expenditures per person per day
			Total effects	Direct effects	Total effects		
	R= Resident NR= Nonresident		Per thousand person days of recreation activity		Per thousand person days of recreation activity		In dollars.
BUTTE	R	Camping	0.49	0.98	0.0059	0.0123	25.82
	R	Day Use	0.64	1.26	0.0082	0.0164	33.52
	R	Fishing	0.80	1.54	0.0085	0.0183	38.28
	R	Hunting	3.14	5.89	0.0373	0.0735	130.15
	R	Motorized Boating	0.55	1.08	0.0069	0.0138	28.37
	R	Motorized Viewing	0.95	1.99	0.0115	0.0251	54.76
	R	NonMotorized Boating	8.71	17.94	0.0939	0.2139	381.65
	R	Off Road Vehicle Use	0.16	0.32	0.0024	0.0045	10.25
	R	Snowmobiling	2.56	4.84	0.0308	0.0610	107.60
	R	Trail Use	0.76	1.45	0.0081	0.0171	30.57
	R	Viewing Wildlife	0.31	0.60	0.0035	0.0074	14.13
	R	Winter Sports	1.44	2.59	0.0141	0.0292	46.87
	NR	Camping	0.40	0.73	0.0039	0.0082	14.47
	NR	Day Use	0.30	0.55	0.0032	0.0065	11.65
	NR	Fishing	0.44	0.79	0.0047	0.0094	17.14
	NR	Hunting	0.26	0.47	0.0031	0.0059	11.35
	NR	Motorized Boating	1.37	2.56	0.0165	0.0322	60.85
	NR	Motorized Viewing	2.26	4.45	0.0270	0.0560	104.60
	NR	NonMotorized Boating	1.00	1.86	0.0101	0.0214	36.99
	NR	Off Road Vehicle Use	0.02	0.03	0.0003	0.0005	1.14
	NR	Snowmobiling	0.48	0.85	0.0046	0.0095	15.89
	NR	Trail Use	1.19	2.24	0.0108	0.0246	40.07
	NR	Viewing Wildlife	2.59	5.00	0.0247	0.0565	98.16
	NR	Winter Sports	1.04	1.86	0.0095	0.0202	32.36
IDAHO FALLS	R	Camping	0.55	1.03	0.0062	0.0126	25.82
	R	Day Use	0.74	1.36	0.0088	0.0170	33.52
	R	Fishing	0.93	1.68	0.0100	0.0200	38.28
	R	Hunting	3.27	5.77	0.0397	0.0734	130.15
	R	Motorized Boating	0.62	1.13	0.0072	0.0140	28.37
	R	Motorized Viewing	1.07	2.08	0.0119	0.0253	54.76

AREA	Residency	Activity	Jobs		Millions of 1991 dollars of employee compensation		Average expenditures per person per day
			Total effects	Direct effects	Total effects		
	R= Resident NR= Nonresident		Per thousand person days of recreation activity		Per thousand person days of recreation activity		In dollars
	R	NonMotorized Boating	9.15	17.48	0.0944	0.2081	381.65
	R	Off Road Vehicle Use	0.19	0.34	0.0023	0.0045	10.25
	R	Snowmobiling	2.65	4.71	0.0270	0.0547	107.60
	R	Trail Use	0.81	1.46	0.0087	0.0173	30.57
	R	Viewing Wildlife	0.32	0.59	0.0034	0.0070	14.13
	R	Winter Sports	1.63	2.75	0.0156	0.0306	46.87
	NR	Camping	0.44	0.75	0.0043	0.0085	14.47
	NR	Day Use	0.33	0.57	0.0035	0.0068	11.65
	NR	Fishing	0.50	0.85	0.0054	0.0101	17.14
	NR	Hunting	0.30	0.52	0.0034	0.0064	11.35
	NR	Motorized Boating	1.61	2.80	0.0181	0.0340	60.85
	NR	Motorized Viewing	2.57	4.68	0.0294	0.0581	104.60
	NR	NonMotorized Boating	1.05	1.85	0.0102	0.0209	36.99
	NR	Off Road Vehicle Use	0.02	0.03	0.0003	0.0005	1.14
	NR	Snowmobiling	0.52	0.88	0.0051	0.0099	15.89
	NR	Trail Use	1.26	2.23	0.0113	0.0245	40.07
	NR	Viewing Wildlife	2.74	4.95	0.0266	0.0564	98.16
	NR	Winter Sports	1.16	1.95	0.0111	0.0217	32.36
MISSOULA	R	Camping	0.53	1.12	0.0060	0.0133	25.82
	R	Day Use	0.70	1.44	0.0084	0.0176	33.52
	R	Fishing	0.85	1.74	0.0089	0.0200	38.28
	R	Hunting	3.29	6.52	0.0362	0.0768	130.15
	R	Motorized Boating	0.57	1.20	0.0069	0.0147	28.37
	R	Motorized Viewing	1.00	2.25	0.0117	0.0270	54.76
	R	NonMotorized Boating	9.09	19.83	0.0972	0.2295	381.65
	R	Off Road Vehicle Use	0.17	0.37	0.0024	0.0048	10.25
	R	Snowmobiling	2.57	5.15	0.0298	0.0622	107.60
	R	Trail Use	0.79	1.59	0.0081	0.0180	30.57
	R	Viewing Wildlife	0.31	0.64	0.0035	0.0076	14.13
	R	Winter Sports	1.57	2.98	0.0146	0.0324	46.87

AREA	Residency	Activity	Jobs		Millions of 1991 dollars of employee compensation		Average expenditures per person per day
			Total effects	Direct effects	Total effects		
	R= Resident NR= Nonresident		Per thousand person days of recreation activity		Per thousand person days of recreation activity		In dollars
	NR	Camping	0.42	0.81	0.0041	0.0090	14.47
	NR	Day Use	0.32	0.62	0.0033	0.0070	11.65
	NR	Fishing	0.49	0.93	0.0049	0.0105	17.14
	NR	Hunting	0.29	0.55	0.0032	0.0064	11.35
	NR	Motorized Boating	1.52	3.00	0.0170	0.0355	60.85
	NR	Motorized Viewing	2.45	5.07	0.0277	0.0607	104.60
	NR	NonMotorized Boating	1.03	2.05	0.0103	0.0229	36.99
	NR	Off Road Vehicle Use	0.02	0.03	0.0003	0.0004	1.14
	NR	Snowmobiling	0.51	0.97	0.0048	0.0106	15.89
	NR	Trail Use	1.23	2.47	0.0115	0.0270	40.07
	NR	Viewing Wildlife	2.59	5.28	0.0255	0.0593	98.16
	NR	Winter Sports	1.14	2.15	0.0100	0.0227	32.36
PENDLETON	R	Camping	0.47	0.80	0.0054	0.0096	25.82
	R	Day Use	0.64	1.05	0.0073	0.0127	33.52
	R	Fishing	0.84	1.36	0.0082	0.0150	38.28
	R	Hunting	2.97	4.74	0.0335	0.0571	130.15
	R	Motorized Boating	0.54	0.90	0.0062	0.0108	28.37
	R	Motorized Viewing	0.95	1.62	0.0108	0.0195	54.76
	R	NonMotorized Boating	8.07	13.70	0.0899	0.1639	381.65
	R	Off Road Vehicle Use	0.17	0.29	0.0021	0.0037	10.25
	R	Snowmobiling	2.41	3.79	0.0291	0.0478	107.60
	R	Trail Use	0.69	1.11	0.0073	0.0128	30.57
	R	Viewing Wildlife	0.29	0.47	0.0032	0.0056	14.13
	R	Winter Sports	1.32	2.03	0.0122	0.0217	46.87
	NR	Camping	0.37	0.58	0.0035	0.0063	14.47
	NR	Day Use	0.27	0.42	0.0029	0.0049	11.65
	NR	Fishing	0.40	0.63	0.0039	0.0069	17.14
	NR	Hunting	0.24	0.38	0.0025	0.0043	11.35
	NR	Motorized Boating	1.32	2.10	0.0139	0.0242	60.85
	NR	Motorized Viewing	2.10	3.40	0.0244	0.0421	104.60

AREA	Residency	Activity	Jobs		Millions of 1991 dollars of employee compensation		Average expenditures per person per day
			Total effects	Direct effects	Total effects		
	R= Resident NR= Nonresident		Per thousand person days of recreation activity		Per thousand person days of recreation activity		In dollars
	NR	NonMotorized Boating	0.92	1.46	0.0092	0.0163	36.99
	NR	Off Road Vehicle Use	0.02	0.03	0.0002	0.0004	1.14
	NR	Snowmobiling	0.44	0.67	0.0039	0.0070	15.89
	NR	Trail Use	1.09	1.71	0.0102	0.0185	40.07
	NR	Viewing Wildlife	2.32	3.69	0.0244	0.0429	98.16
	NR	Winter Sports	0.91	1.38	0.0078	0.0142	32.36
REDMOND-BEND	R	Camping	0.48	0.87	0.0063	0.0118	25.82
	R	Day Use	0.63	1.13	0.0086	0.0155	33.52
	R	Fishing	0.80	1.39	0.0095	0.0178	38.28
	R	Hunting	3.03	5.19	0.0406	0.0715	130.15
	R	Motorized Boating	0.53	0.96	0.0071	0.0131	28.37
	R	Motorized Viewing	0.91	1.72	0.0122	0.0235	54.76
	R	NonMotorized Boating	8.36	15.50	0.1004	0.2010	381.65
	R	Off Road Vehicle Use	0.16	0.29	0.0023	0.0042	10.25
	R	Snowmobiling	2.33	3.96	0.0326	0.0561	107.60
	R	Trail Use	0.73	1.25	0.0089	0.0163	30.57
	R	Viewing Wildlife	0.29	0.52	0.0036	0.0069	14.13
	R	Winter Sports	1.39	2.26	0.0151	0.0276	46.87
	NR	Camping	0.37	0.61	0.0039	0.0073	14.47
	NR	Day Use	0.28	0.45	0.0033	0.0058	11.65
	NR	Fishing	0.43	0.72	0.0051	0.0092	17.14
	NR	Hunting	0.25	0.42	0.0033	0.0056	11.35
	NR	Motorized Boating	1.34	2.28	0.0174	0.0307	60.85
	NR	Motorized Viewing	2.22	3.86	0.0288	0.0527	104.60
	NR	NonMotorized Boating	0.95	1.62	0.0108	0.0204	36.99
	NR	Off Road Vehicle Use	0.02	0.03	0.0003	0.0004	1.14
	NR	Snowmobiling	0.46	0.75	0.0050	0.0091	15.89
	NR	Trail Use	1.05	1.78	0.0108	0.0212	40.07
	NR	Viewing Wildlife	2.02	3.42	0.0214	0.0416	98.16
	NR	Winter Sports	1.01	1.65	0.0106	0.0199	32.36

AREA	Residency	Activity	Jobs		Millions of 1991 dollars of employee compensation		Average expenditures per person per day
			Total effects	Direct effects	Total effects		
	R= Resident NR= Nonresident		Per thousand person days of recreation activity		Per thousand person days of recreation activity		In dollars
SPOKANE	R	Camping	0.44	0.92	0.0060	0.0131	25.82
	R	Day Use	0.58	1.20	0.0083	0.0174	33.52
	R	Fishing	0.75	1.52	0.0092	0.0205	38.28
	R	Hunting	2.71	5.37	0.0374	0.0768	130.15
	R	Motorized Boating	0.48	1.01	0.0069	0.0147	28.37
	R	Motorized Viewing	0.86	1.90	0.0119	0.0271	54.76
	R	NonMotorized Boating	7.73	16.46	0.0934	0.2233	381.65
	R	Off Road Vehicle Use	0.14	0.29	0.0023	0.0046	10.25
	R	Snowmobiling	2.19	4.37	0.0293	0.0617	107.60
	R	Trail Use	0.67	1.33	0.0081	0.0179	30.57
	R	Viewing Wildlife	0.26	0.54	0.0034	0.0075	14.13
	R	Winter Sports	1.33	2.51	0.0148	0.0324	46.87
	NR	Camping	0.37	0.70	0.0039	0.0088	14.47
	NR	Day Use	0.27	0.52	0.0032	0.0069	11.65
	NR	Fishing	0.39	0.74	0.0047	0.0098	17.14
	NR	Hunting	0.23	0.45	0.0030	0.0061	11.35
	NR	Motorized Boating	1.25	2.46	0.0162	0.0341	60.85
	NR	Motorized Viewing	2.06	4.17	0.0282	0.0599	104.60
	NR	NonMotorized Boating	0.88	1.73	0.0098	0.0224	36.99
	NR	Off Road Vehicle Use	0.02	0.03	0.0003	0.0004	1.14
	NR	Snowmobiling	0.43	0.80	0.0045	0.0099	15.89
	NR	Trail Use	1.08	2.12	0.0106	0.0261	40.07
	NR	Viewing Wildlife	2.38	4.78	0.0249	0.0608	98.16
	NR	Winter Sports	0.95	1.76	0.0094	0.0216	32.36
TRI-CITIES	R	Camping	0.44	0.77	0.0057	0.0106	25.82
	R	Day Use	0.58	1.00	0.0077	0.0139	33.52
	R	Fishing	0.81	1.34	0.0090	0.0170	38.28
	R	Hunting	2.77	4.53	0.0344	0.0608	130.15
	R	Motorized Boating	0.50	0.86	0.0065	0.0118	28.37

AREA	Residency	Activity	Jobs		Millions of 1991 dollars of employee compensation		Average expenditures per person per day
			Total effects	Direct effects	Total effects		
	R= Resident NR= Nonresident		Per thousand person days of recreation activity		Per thousand person days of recreation activity		In dollars
	R	Motorized Viewing	0.86	1.54	0.0114	0.0215	54.76
	R	NonMotorized Boating	7.71	13.36	0.0917	0.1758	381.65
	R	Off Road Vehicle Use	0.15	0.27	0.0022	0.0039	10.25
	R	Snowmobiling	2.24	3.62	0.0281	0.0491	107.60
	R	Trail Use	0.68	1.10	0.0076	0.0140	30.57
	R	Viewing Wildlife	0.26	0.44	0.0033	0.0060	14.13
	R	Winter Sports	1.32	2.05	0.0137	0.0248	46.87
	NR	Camping	0.37	0.59	0.0038	0.0071	14.47
	NR	Day Use	0.26	0.42	0.0030	0.0054	11.65
	NR	Fishing	0.38	0.61	0.0043	0.0077	17.14
	NR	Hunting	0.23	0.36	0.0027	0.0048	11.35
	NR	Motorized Boating	1.21	1.98	0.0150	0.0266	60.85
	NR	Motorized Viewing	2.01	3.32	0.0271	0.0474	104.60
	NR	NonMotorized Boating	0.89	1.43	0.0094	0.0175	36.99
	NR	Off Road Vehicle Use	0.02	0.03	0.0003	0.0004	1.14
	NR	Snowmobiling	0.43	0.66	0.0043	0.0078	15.89
	NR	Trail Use	1.06	1.70	0.0105	0.0203	40.07
	NR	Viewing Wildlife	2.29	3.72	0.0248	0.0466	98.16
	NR	Winter Sports	0.93	1.42	0.0087	0.0162	32.36
TWIN FALLS	R	Camping	0.54	0.91	0.0064	0.0110	25.82
	R	Day Use	0.74	1.20	0.0090	0.0148	33.52
	R	Fishing	0.94	1.51	0.0104	0.0174	38.28
	R	Hunting	3.26	5.16	0.0410	0.0650	130.15
	R	Motorized Boating	0.61	1.00	0.0074	0.0123	28.37
	R	Motorized Viewing	1.08	1.87	0.0123	0.0220	54.76
	R	NonMotorized Boating	8.93	15.07	0.0973	0.1751	381.65
	R	Off Road Vehicle Use	0.19	0.31	0.0024	0.0039	10.25
	R	Snowmobiling	2.56	4.03	0.0304	0.0489	107.60
	R	Trail Use	0.80	1.27	0.0091	0.0150	30.57

AREA	Residency	Activity	Jobs		Millions of 1991 dollars of employee compensation		Average expenditures per person per day
			Total effects	Direct effects	Total effects		
	R= Resident NR= Nonresident		Per thousand person days of recreation activity		Per thousand person days of recreation activity		In dollars
	R	Viewing Wildlife	0.31	0.50	0.0035	0.0059	14.13
	R	Winter Sports	1.61	2.45	0.0159	0.0265	46.87
	NR	Camping	0.44	0.68	0.0043	0.0074	14.47
	NR	Day Use	0.32	0.50	0.0036	0.0058	11.65
	NR	Fishing	0.48	0.74	0.0056	0.0089	17.14
	NR	Hunting	0.30	0.45	0.0035	0.0055	11.35
	NR	Motorized Boating	1.59	2.50	0.0187	0.0300	60.85
	NR	Motorized Viewing	2.51	4.04	0.0302	0.0496	104.60
	NR	NonMotorized Boating	1.03	1.62	0.0107	0.0181	36.99
	NR	Off Road Vehicle Use	0.02	0.03	0.0003	0.0004	1.14
	NR	Snowmobiling	0.52	0.79	0.0052	0.0086	15.89
	NR	Trail Use	1.26	1.99	0.0117	0.0211	40.07
	NR	Viewing Wildlife	2.59	4.14	0.0278	0.0474	98.16
	NR	Winter Sports	1.12	1.70	0.0114	0.0188	32.36

APPENDIX 6-C

Communities Defined as Timber-Dependent in the Economic Assessment of the Basin.

These communities are located more than 50 miles from another incorporated area with more than 10,000 people, and are not located in either recreation or metropolitan counties.

Idaho
Bonners Ferry
Council
Elk City
Grangeville
Kamiah
Kooskia
Moyie Springs
New Meadows
Weippe

Montana
Darby
Eureka
Fortine
Rexford
Seeley Lake
Superior
Thompson Falls
Trout Creek

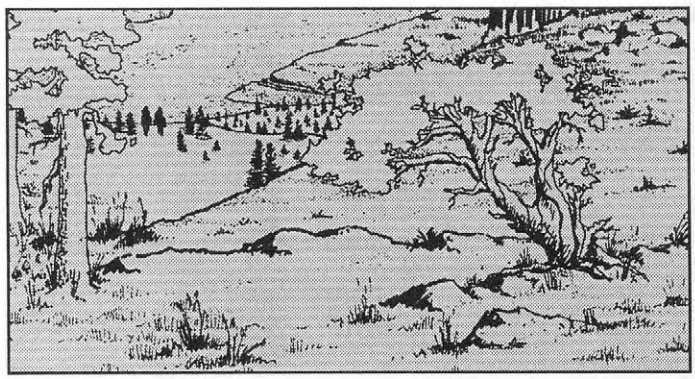
Oregon
Burns
Heppner (Kinzua)
John Day
Lakeview
Long Creek
Mt. Vernon
Paisley
Prairie City

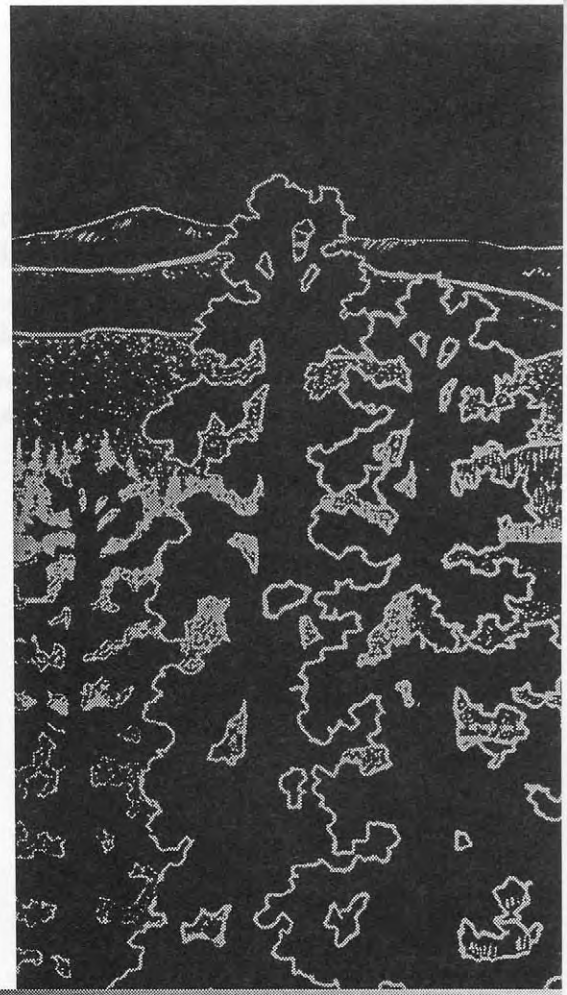
Washington
Colville
Ione
Kettle Falls
Republic

Continue

Previous

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CHAPTER 7

Social Assessment

Stephen F. McCool, James A. Burchfield,
Stewart D. Allen

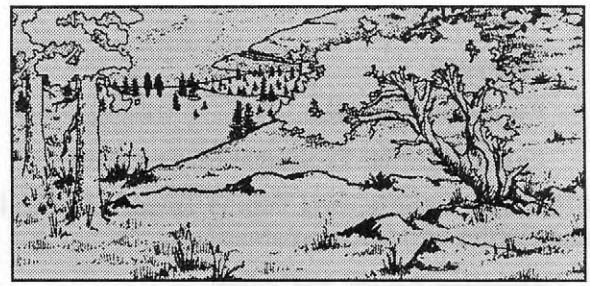


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TABLE OF CONTENTS



Introduction 1877

Purpose and Objectives 1877

Rationale for the Social Assessment 1878

Environmental Concern 1878

Human Effects on the Environment 1878

Effects of Agency Actions on People 1879

Trust Responsibilities for American Indians 1879

Symbolic Values and Meanings 1879

Social Assessments Versus Social Impact Assessment 1879

Organization of Social Assessment Chapter 1880

History of Human Settlement and Resource Use 1883

Native American Settlement 1883

Arrival of Euro-Americans 1884

Overland Emigration 1884

Mining 1886

Transportation and Access 1886

Grazing 1887

Timber Harvest 1888

Fishing and Dam Construction 1889

Recent Legal and Political Climate 1890

Implications for Ecosystem Management 1892

Population and Demographic Characteristics 1893

Population Dynamics and Characteristics 1893

Population Trends 1894

Projected Population Growth 1897
Migration 1897
Population Lifestyles 1898
Implications for Ecosystem Management 1899
Attitudes, Beliefs, and Values Toward Natural Resources and Public Land Management 1901
Attitudes, Beliefs, and Values 1901
Attitudes 1902
Beliefs 1902
Values 1902
Guidelines for Using Attitude Surveys 1903
Environmental Concern 1904
Values Regarding Natural Resources 1904
Sense of Place 1907
Attitudes and Beliefs Relevant to Ecosystem Management 1909
Active and Passive Management Approaches 1909
Ecosystem Disturbances 1910
Attitudes Toward Endangered Species 1913
Attitudes Toward Tradeoffs in Public Land Management 1914
Attitudes Toward the Federal Government 1915
Level of Trust in Various Institutions 1916
Attitudes Within the Forest Service 1919
Implications for Ecosystem Management 1919
American Indian Peoples: Their Place in Ecosystems and Their Role in Ecosystem Strategies 1921
Cultural History 1921
History of Legal Standing 1923
Treaty-Making Period 1924
Development of Federal Indian Policy 1925
Indian Case Law and Federal Administrative Policy 1926
Place in Basin Ecosystems 1927
Implications for Ecosystem Management 1931

Communities: From Dependency to Resiliency 1933
Community Definition and Relation to Ecosystem 1933
Economic and Social Changes Affecting Communities 1934
Legal, Policy, and Social Context 1936
Community Resiliency 1938
Components of Community Resiliency 1939
Measurement of Community Resiliency 1945
Quality of Life 1949
FS and BLM Roles in Promoting Community Resiliency 1949
Employment and Income 1949
Federal Revenue Sharing 1952
Federal Employees 1953
Implications for Ecosystem Management 1955
Social Benefits of Amenities on Public Land 1957
Recreation Opportunities 1957
Supply of Recreation Opportunities 1958
Demand for Recreation Opportunities 1958
Scenery 1960
Supply of Scenery 1961
Demand for Scenery 1964
Amenities and In-migration 1964
Implications for Ecosystem Management 1966
Role of the Public in Ecosystem Management 1971
Current Public Participation Efforts 1972
Recent Agency Initiatives 1974
Implications for Ecosystem Management 1975
Working Together: Institutional Components of Ecosystems 1979
Structure of Government 1979
Executive 1980
Legislative 1980
Judicial 1981

Cross-Jurisdictional Strategies 1982
Policy Formulation 1982
Previous Cross-Jurisdictional Efforts 1982
Land and Property Rights 1987
Implications for Ecosystem Management 1987
Acknowledgments 1991
References 1993

LIST OF TABLES

Table 7.1 Rural-based lifestyles in the Basin. 1900
Table 7.2 Self-assessment of communities' preparation for future. 1943
Table 7.3 Counties receiving extra benefits from timber harvest, 1992. 1954
Table 7.4 Existing landscape themes in the Basin. 1962
Table 7.5 Wilderness acreage for counties in the Basin. 1967

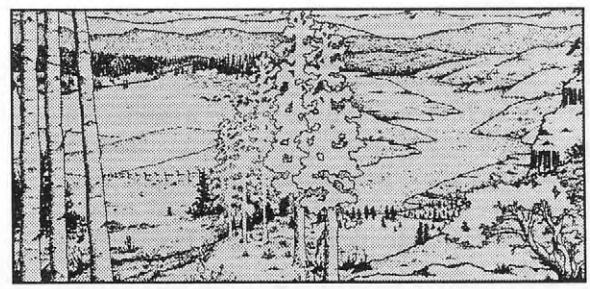
LIST OF FIGURES

Figure 7.1 Population of the Basin by decade. 1895
Figure 7.2 Estimated Basin population by decade using two different projection assumptions. 1897
Figure 7.3 Transfer payments. 1935
Figure 7.4a Community employment profiles by size of community. 1940
Figure 7.4b Community employment profiles by size of community. 1941
Figure 7.4c Community employment profiles by size of community. 1942
Figure 7.5a Community employment profiles by resiliency of community. 1946
Figure 7.5b Community employment profiles by resiliency of community. 1947
Figure 7.5c Community employment profiles by resiliency of community. 1948

LIST OF MAPS

Map 7.1 Change in percent of population by county, 1990–1994. 1896
Map 7.2 Indian reservations in the Basin. 1922
Map 7.3 Primary landscape themes. 1963
Map 7.4 Scenic integrity classes. 1965

INTRODUCTION



Human use of natural resources in the Basin is a major determinant of ecosystem conditions. Over time, human uses have changed dramatically, resulting in equally dramatic effects on the land, water, air, and other species. Human values regarding ecosystems have changed as well, as have the economic needs of an increasingly complex society.

To understand how people relate to and interact with the environments in which they live or have an interest, it is essential to recognize that people are part of the ecosystem, both in the sense of being another species dependent on ecosystem components and because humans determine how ecosystems are socially defined, studied, and managed. The public and federal agencies agree that ecosystem management should consider this "human dimension" of ecosystems. Past management has not adequately accounted for the linkages between people and their environment, the ways people affect the environment, the cultural and spiritual values people place on environments, and the meanings that people attach to specific areas and localities.

The Human Dimensions Task Group (1993) describes six types of information important to understanding the human component of ecosystems: historical context, perceptions of resource character, existing social conditions, existing managerial situation, societal needs and demands, and the effects of humans on ecosystems. Corresponding regional efforts have also been developed that list principles and related strategies for incorporating the human dimension into ecosystem management (Human Dimension Study Group 1994). Our understanding of nature and human relationships with the environment are cultural expressions used to define who we were, who we are, and who we hope to be at this place and in this space (Greiger and Garkovich 1992).

Purpose and Objectives

This social assessment incorporates the human dimension into ecosystem management by characterizing the values, processes, and conditions that are the human components of ecosystems. This assessment also explains the tradeoffs among these components that may be acceptable to society. The overall goal of the social assessment is to inform decision-makers about the social, political, and cultural context of their decisions and to provide information helpful in defining and addressing important policy questions and public issues. Two specific objectives of the assessment are:

- To describe in a variety of ways the people who either live, or have an interest, in the Basin. Emphasis is given to the issues confronting people living in the Basin relative to past and proposed natural resource management.
- To discuss interactions between people and their environments, particularly the recreation, scenic quality, and cultural and emotional dimensions, as well as the influence and response of political and institutional structures to these interactions. This discussion includes some social implications of changing economic conditions in the Basin as described in chapter 6, the Economic Assessment.

The social assessment is integrated with other sciences. The Economic Assessment is a close companion to the Social Assessment; the two should be read in combination for a more complete understanding of socioeconomic issues. In some ways, the other assessments (chapter 3, Landscape Dynamics; chapter 4, Broad-scale Assessment of Aquatic Species and Habitats; and chapter 5, Terrestrial Ecology) are social assessments as well, by virtue of their focus on conditions produced in part by humans and because they reflect human values by the emphases assigned to various topics.

The social assessment may be helpful not only to decision-makers, but to people who live in the Basin and others who care about the physical, biological, social, and economic conditions of Basin ecosystems. Because this social assessment is the first attempt at describing the types of social values and forces that help shape ecosystems Basinwide, however, it should be viewed as a starting point for societal discussion, rather than an end point.

Rationale for the Social Assessment

General reasons for including people in ecosystem assessments are listed and discussed below:

- People are concerned about the environment.
- Human actions affect the environment.
- Agency management of public lands affects people.
- The Federal Government holds certain trust responsibilities with respect to American Indians.
- The natural environment holds significant symbolic values for people.

Environmental Concern

People are concerned about their futures, the influence of environmental quality on those futures, and the condition of the environment. Surveys and public opinion polls demonstrate that environmental concern has been strong since Earth Day in 1970. Jones and Dunlap (1992) show how support for the environment has been stable or increasing, with the vast majority of Americans favoring increased environmental protection. The same trends are present among Basin residents. However, these attitudes vary by topic and among different populations of respondents. Therefore, to develop appropriate policy there must be a better understanding of environmental concerns, the acceptability of various management practices, and people's preferences for implementing management.

Human Effects on the Environment

In a biological sense, humans are transfer agents of energy and matter. Studying the dimensions of these human transfers, just as scientists do for any other species, helps to understand how ecosystems function. Such transfers are not limited to ordinary biophysically determined boundaries, such as a watershed, but extend far beyond due to the many ways people affect the environment.

To assess people's role in the environment also requires a better understanding of how people perceive the environment and how institutions and traditions are formed to regulate environmental impacts. Research on logging impacts, for example, informs decision-makers about the effects of various logging practices on different ecosystem components, including physical, biological, social, and economic elements. However, this type of information does not describe the acceptability of different or new forms of logging and the institutional mechanisms for such practices, nor transfer the knowledge and technology needed to adopt new logging practices.

Effects of Agency Actions on People

Management actions designed to produce goods and services from the environment, restore forest health, or protect environments and species affect not only natural resources, but people and social systems as well. Agency activities affect the land,

water, air, plants, animals, and other ecosystem components on which people depend and care. Agency activities also influence access to economic opportunity for current and future generations of individuals whose livelihoods are closely linked to public lands and Federal programs. Because the actions of Federal agencies are viewed as major factors that influence their quality of life, Basin residents believe that quality of life should be an important consideration in public land management (Brunson and others 1994).

Agency management activities also affect people who do not live in the Basin. For example, ecosystem conditions influence people who visit the Basin for recreation; people who may visit, work, or live in the Basin in the future; and people who may never visit the Basin but benefit from knowing its resources and opportunities exist and will continue to be there for future generations. These national benefits are substantial, even compared to more direct benefits of Basin resources (see chapter 6, Economic Assessment).

Trust Responsibilities for American Indians

The Basin contains a significant American Indian population, 20 Indian reservations, and one colony (Hanes 1995). Under the provisions of treaties with various tribes, the Federal Government has assumed trust responsibilities for managing natural resources. These responsibilities include ensuring access to, and sufficient quantities of, traditionally used plants and animals. Many of the usual and accustomed locations for traditional uses are on lands administered by the Forest Service (FS) and Bureau of Land Management (BLM).

Because of these various factors, the relationship of public land management activities to treaty and trust responsibilities is a critical component of ecosystem management. This relationship occurs at a government-to-government scale due to the legal status of American Indian tribes. However, the Federal Government and tribal governments often have different definitions of what constitutes trust responsibilities.

Symbolic Values and Meanings

Humans attach meanings to environments. Understanding the biological and physical attributes of resources does not adequately describe the symbolic significance of federally managed resources nor characterize people's attachments to places. "To understand human interactions with their environments, it is crucial to understand human emotional responses to environments and the evolutionary history of those responses" (Parsons and others 1993).

Spiritual and cultural connections to the environment are deeply embedded in American Indian society. The importance of places in the environment in terms of their symbolic value to various cultures also is being recognized (Williams 1995). For example, Old Faithful Geyser in Yellowstone National Park is a powerful symbol in American society; any management and policy that affect the geyser or its viewing access are closely scrutinized. Other places in the Basin may not have such wide national recognition, but have great meaning and importance for local and regional residents. Because these social and cultural meanings are not necessarily related to distinctive spatial attributes (Firey 1945), their inventory and assessment are difficult. However, because ecosystem management ultimately involves management of places, attempting to understand the meanings that people attach to certain places enables managers to make better informed decisions.

Social Assessments Versus Social Impact Assessments

There is sometimes confusion between social assessments and social impact assessments. Social impact assessments are attempts to predict the effects of a specific program (such as a Forest or District plan) or a specific project (such as a dam, campground, or timber harvest) on people and social systems. These assessments are typically conducted by first identifying characteristic baseline social and economic conditions of the area of influence, which is usually a town, county,

group of counties, or group of states, but may include relevant national and global conditions. Next, these assessments describe trends in these conditions. The impact assessment then estimates changes in these conditions or trends that would likely result from either the proposed action or the set of alternatives being assessed.

Although social assessments collect information similar to the baseline data needed to conduct impact assessments, they typically address a broader geographic area and are more in-depth. This chapter assessment, for example, has the mission of describing existing social conditions and interactions with economic, physical, and biological processes.[1]

Social impact assessment has resulted in extensive scientific literature addressing conceptual issues and methodological procedures. Particularly relevant literature includes a recent publication on standards and guidelines (Interorganizational Committee on Standards and Guidelines for Social Impact Assessment 1994), and conceptual discussions such as Burdge (1994), Gramling and Freudenberg (1992), Dietz (1981), Finsterbusch (1985), Finsterbusch and Wolf (1981), and Leistriz and Murdock (1981).

Much of the social impact assessment literature for developing social assessment information databases relates to identifying issues typically of concern to people and procedures. Richardson (1993) provides an example of the link between social assessments and impact assessments. Her report, written in response to concerns about the adequacy of socioeconomic analyses in six draft resource management plan/environmental impact statements released in 1992, was designed to provide more comprehensive and detailed analysis of socioeconomic conditions likely to be affected by BLM management activities in western Oregon.

[1] A separate document, *An Evaluation of EIS Alternatives by the Science Integration Team*, addresses potential social effects of management alternatives described in the draft EISs.

Organization of Social Assessment Chapter

This social assessment is organized into eight topics describing interactions between people and the environment, and the role played by management of FS- and BLM-administered lands. Each topic includes specific conclusions entitled "Implications for Ecosystem Management." The eight topics are:

- A brief overview of settlement patterns in the Basin, with an emphasis on human uses of natural resources and their changes over time. This is provided as historical context to help explain some of the social origins of existing ecosystem conditions.
- The Basin's human population today, trends in population patterns, and projected population growth rates. This information, when considered along with the economic conditions and trends reported in Chapter 6, The Economic Assessment, provides a socioeconomic overview of the existing role of people in Basin ecosystems.
- The relevant attitudes, beliefs, and values of people who care about the Basin's physical, biological, economic, and social components. Ecosystem management, like other land management philosophies and activities, reflects human values. These diverse values and the related attitudes and beliefs regarding natural resources and human uses can be reflected by ecosystem management only to the extent they are articulated and understood.
- American Indians, the longest term residents of the Basin, and their unique status based on numerous treaties, laws, and court decisions. The Federal Government relates to tribes on a government-to-government basis and has trust responsibilities that have not been well defined in the past. Ecosystem management asks for clearer definition and greater incorporation of the needs and concerns of American Indians. Although some of those needs and concerns overlap with broad public issues, many others are unique.

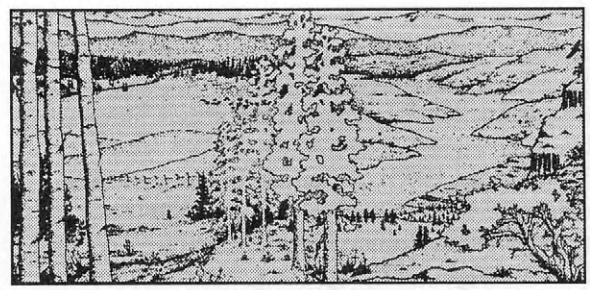
- Existing conditions in small, rural communities in the Basin. Community as a scale or unit of analysis is critical because it has meaning for people. The quality of life in Basin communities and its relationships to management of FS- and BLM-administered lands is one of the major social issues and debates facing ecosystem management.
- Amenities that are based on natural resources, such as scenery and recreation opportunities, and their value to Basin residents and nonresidents. Chapter 6, the Economic Assessment, contains a more detailed description of recreation as a land use and generator of income. Discussion in this social assessment is focused more on the social meaning and benefits of resource-based amenities.
- The role of the public in FS- and BLM-management of public lands. In many ways, people are becoming more involved in decisions that determine which activities take place on public lands. Included are discussions about the various forums for public involvement, the likelihood of reaching stated objectives, and opportunities for public participation.
- An overview of the development and current status of institutions that manage natural resources and are affected by their management. Ecosystem management as a new concept for public land management raises many issues that cross beyond FS- and BLM-administered lands. Many social scientists and members of the public have suggested studying current institutions to assess any needs and likelihoods of their changing to meet challenges posed by ecosystem management.

For the eight topics discussed in this chapter, the scale or unit of analysis varies depending on the issue and data availability. Descriptions of characteristics and processes at the Basin level mask socially important processes and characteristics at the community level. Descriptions of conditions at the community level tend to obscure higher order processes important in understanding social conditions in a broader sense. Data found at one scale may not be available at others, making aggregation or disaggregation inconsistent. Because there was no consistent way to address scale, the discussions occur at the scale considered most appropriate for the topic.

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HISTORY OF HUMAN SETTLEMENT AND RESOURCE USE

The following text reviews the history of human occupation in the Basin and some Federal policies that have helped to shape human uses of resources.[2] The main purpose of this discussion is to develop a better understanding of the relationships between settlement patterns and the progression of natural resource use in the Basin. A brief description of land-use practices of American Indians is included, but more details of the relationships between American Indians and Basin resources are presented later in this chapter.

Native American Settlement

The Columbia Basin has been occupied by people for at least 12,000 years, from the time it is believed migration occurred across the Bering Straits land bridge from northern Asia. After continued warming conditions caused glacial retreat, early hunting societies diversified and began fishing and gathering, creating localized cultural groups that followed the seasonal patterns of flora and fauna.

Although the lifeways of native cultures evolved with important regional differences (including distinctive languages), the tribal groups within the Columbia Basin exhibit enough common elements to be considered together. The term "Columbia Plateau culture" is frequently used to differentiate the original inhabitants of the Basin from their neighbors (Beckham 1995).

[2] Much of this discussion is based on Stephen Beckham's report (1995) produced under contract to the ICBEMP.

American Indians were linked to their environment by careful observation, economic calculation, ritual monitoring, and religious explanation. People in the Columbia Plateau culture possessed lifeways and a knowledge of the land gained over centuries of occupation. Specific places for fishing, hunting, and gathering within a yearly rhythm of seasonal rounds became important to tribal groups. Hundreds of native plant and animal species developed cultural importance through subsistence, spiritual, and commercial uses. Favored areas for berry picking, root gathering, hunting, and collecting of other necessary materials offered a familiarity and continuity of use that affirmed people's spiritual beliefs that their lives had been ordered by their "right" behaviors in association with the land.

Access to major rivers was critical. The rivers provided salmon, steelhead, sturgeon, lampreys, suckers, and trout. Methods such as dip-net fishing were especially successful adjacent to major waterfalls of the Columbia River, including Kettle Falls, Priest Rapids, Celilo Falls, Five Mile Rapids, and the Cascades, as well as other rapids on the upper Snake River. Because rivers were arteries for both commerce and food, people resided in permanent villages on terraces adjacent to major streams for most of the year. Family unit structure was based on seasonal harvesting chores. Villages provided a structural coherence among family groups, bringing tribal members together during the winter and early spring to hear the stories of elders and to share in ritual feasts, dances, and renewal (Beckham 1995).

Contrary to the beliefs of non-Indian emigrants arriving in the region in the 19th century, the Basin and adjoining areas were not pristine wildernesses, but ecological systems in which humans had been an active component (MacCleery 1994, Woolfenden 1993). American Indians liberally employed fire as a tool to manage vegetation (Fowler 1986, Robbins 1994). Their fires differed from fires ignited by lightning in terms of seasonality, frequency, and intensity (Lewis 1985).

The low intensity, high frequency fires set by American Indians served many purposes. They were used to enrich grazing; encourage vegetation for browse for large mammals and berries for human and animal consumption; signal other tribes or send warnings; and conduct ceremonies. The widespread use of fires by American Indians over long periods shaped the mosaic of vegetation and the associated animal communities in the West, resulting in an anthropocentric landscape that could only be "natural" to the extent that people are considered a natural part of the ecosystem.

The long-standing patterns of interaction between humans and the land on the Columbia Plateau were disrupted, however, early in the 19th century. In addition to changes in land uses and resulting effects on a broader scale, the introduction of infectious diseases caused population declines in Indian villages of 20 to 50 percent by episode and loosened the cultural fabric of tribal social bands (Boyd and Hyde 1989).

Arrival of Euro-Americans

By 1780, the coastal areas of the Pacific Northwest had been charted by navigators from Russia, England, France, and Spain, yet the Basin remained unexplored by visitors of European origin. Lewis and Clark's expedition from 1804 to 1806 offered Euro-Americans the first glimpse of the potential of the American West: a seemingly endless expanse of land, game, and rivers that attracted adventurers, fur trappers, and homesteaders.

The fur trade soon lured many newcomers. By 1820, 450 vessels had sailed into coastal waters to engage in the fur trade. Fur trappers and traders established outposts throughout the Pacific Northwest in the first decades of the 18th century. The Hudson's Bay Company held a near-monopoly on the fur trade in the Basin. It tried to maintain this dominant position by trapping the fur-bearing animals of the Snake River plains to extinction, discouraging potential competitors.

Missionaries began traveling west in search of converts, bringing not only religion but family-based agriculture, venturing into eastern and western Oregon in the mid-1830s. The success of agricultural operations on the American frontier was a major draw for families (West 1994).

Overland Emigration

The 1840s brought profound change to the American West, as restlessness seized a generation of Americans. Many factors fueled people's desire to seek a new life in the Pacific Northwest. The Panic of 1837 created a prolonged economic recession that hit hard on farmers and land speculators in the Mississippi and Missouri River valleys. Repeated floods in the late 1830s in these same river valleys ruined agricultural production and created infestations of mosquitos that carried malarial fevers. People from Illinois and Missouri were lured by reports of the Willamette valley where neither floods nor pestilence would harm them (Beckham 1995). Another factor was technological expansion; the advent of railroads, steamboats, and communications by telegraph made distant travel and far-flung commerce seem possible. By 1845, Asa Whitney and other investors were already proposing a transcontinental railroad, which was viewed favorably by the Federal Government. A westward movement appeared as practical as it was romantically appealing.

Based on the success of early missions, families began making the nearly 2,000-mile trek on the Oregon Trail from Independence, Missouri, to the Willamette Valley in Oregon. In 1843, 900 people arrived in Oregon in what was called the "Great Migration," followed in 1844 by another 1,200 new settlers.

During the 1840 to 1860 period, most overland migrants passed through the Basin en route to the Willamette Valley's greener pastures and the proximity to navigable waters. Other destinations, particularly California after the gold strike in 1848, lured emigrants away from the Pacific Northwest. To those who had grown accustomed to the lush landscapes of eastern hardwood forests, the Snake River plains seemed too dry, rocky, and forbidding. The Cascade Range has a strong rain-shadow effect in eastern Oregon and Washington with substantial portions of the Basin receiving less than 12 inches of precipitation annually. Even a Federal land donation program between 1850 and 1855 did not entice many settlers to claim land east of the Columbia Gorge.

In this era, a series of Federal laws reflected current policy: to transfer public lands as easily as possible to settlers who could use them. The Congress offered settlers free land through passage of the Homestead Act of 1862. Claimants could receive 160 acres of land for a modest filing fee and proof of five years of residence and improvements. In later congressional acts, including the Desert Land Act of 1877, the Forest Homestead Act of 1906, the Enlarged Homestead Act of 1909, and the Stockraising Homestead Act of 1916, larger size tracts more appropriate for the arid environment were authorized for disposition to settlers.

Passage of the Newlands Reclamation Act in 1902 established the Reclamation Service in the Department of Interior. The Act deposited profits from the sale of western lands into a reclamation fund to support irrigation projects, allowing the Federal Government to underwrite the building of dams, canals, and ditches beyond the capabilities of communities or the private sector. This made it possible for far more people to settle in the Basin.

Not surprisingly, early migrants chose to settle in the environments most likely to sustain them, which were fertile valleys and areas along waterways. In 1860, the Census described just two centers of Euro-American population in the Oregon Country east of the Cascades: The Dalles, Oregon and Walla Walla, Washington, each with about 1,300 inhabitants. At that time, the estimated Euro-American population was just 50,000 in Oregon and 12,000 in Washington, which were great increases from the total of about 13,000 in 1850. From 1860 to 1900, the Euro-American population in Oregon increased to more than 400,000, and in Washington to more than 500,000.

The national survey system established land-use patterns throughout the West. The Ordinance of 1785 ordered the Northwest Territory surveyed into sections measuring one square mile. (At the time, the "Northwest Territory" was the region north and west of the Ohio River, not the Pacific Northwest as the term is used in this document.) Next, the Ordinance of 1787, or the Northwest Ordinance, established a plan of government for the territory that the legislators assumed (incorrectly) would soon be sold and settled. Although modified slightly over the decades, both laws were eventually extended to include lands beyond the Mississippi. These ordinances determined the political form of the growing nation. In 1786, government surveyors laid out a baseline westward from the precise point where the Ohio River left Pennsylvania. They laid the first townships and sections, then built more onto those, range after range, westward to the Pacific. That first square inch of the first surveyor's stake was a polestar of national development (West 1994).

This creation of a national grid system affected the way people thought about land. Presented as squares or rectangles, land can be easily subdivided and turned into a commodity. The shape of land's presentation to an owner dictated styles of farming, allowing each field to be "plowed into straight lines among straight fences besides straight roads" (West 1994).

As in much of the West, settlement and development of the Basin hinged on the use of natural resources and associated economic opportunities. A closer look at the history of mining, transportation and access, grazing, and timber harvest shows the developing interactions between the growing population and the Basin's natural resources.

Mining

Coal deposits had been reported as early as 1833 by an employee of the Hudson's Bay Company, and significant base metal and silver lodes were discovered in eastern Washington during the late 1800s and early 1900s. It was the discovery of gold, however, that attracted many people to the Basin. In 1862, several placer deposits were announced, including deposits on the John Day River near Canyon City, Oregon; at Florence, Idaho, on the Snake River; and at Pierce City and Orofino, Idaho, on the Clearwater River. Strikes in the Boise basin and other locations soon followed. Thousands of miners came to the region, leading to development of towns and their infrastructures, which in turn attracted stock raisers and farmers.

The General Mining Law of 1872, following the precedent of the Mining Law of 1866, opened minerals on public lands to all. Mining practices of the 19th century also established the logic behind western water law: first in time, first in right. Water became a user's property from the moment of its first use until its use was abandoned.

Transportation and Access

The evolution of transportation played a major role in commercial development of the Basin. Public lands were distributed not just to families, but to transportation companies and speculators via auctions in eastern states. Federally supported railroad developments changed the shape of the West. From 1862 to 1871, 61 different land grant subsidies to railroads were offered in the region, the largest to the Northern Pacific Railroad, which eventually secured 39 million acres. The famous "checkerboard" ownership patterns of lands in central Washington state and elsewhere are a legacy of these land grants.

By the 1880s, it was possible to arrive in the Pacific Northwest in five days instead of five months. Commerce and exchange with other regions expanded, establishing patterns of external trade relations that continue to dominate the Northwest's economy. The railroads either "made or broke" a town because a road network of any consequence did not develop until after World War I. Until then, railroads moved cattle, lumber, wool, and other products to major markets.

Railroads allowed more efficient development of base metal and silver districts, compared to initial mining of only the highest grade ores that could be shipped at a profit to distant smelters. Development of communities throughout the Basin followed both the expansion of mining and the extension of the railroad network. Mining towns assumed an urban cast, with hotels, restaurants, general stores, blacksmith shops, sawmills, laundries, and other service businesses that supported workers.

In the early 1900s, road construction began to open entry into the forests of eastern Washington and Oregon. Constructed mainly through river valleys, riparian areas, floodplains, and adjacent hillsides, the roads efficiently provided access but decreased the land's effectiveness as wildlife habitat and provided a new avenue for erosion and discharge of sediment into streams.

In 1916, the region's first paved rural road, the Columbia River Highway, opened to link the western and eastern slopes of the Cascades. The Joint Board on Interstate Highways within the U.S. Department of Agriculture designated a "comprehensive system of through interstate routes," changing previously local initiatives to a coordinated, Federal highway system that remains today. During the interwar years, the miles of hard-surfaced all-weather roads increased in Idaho and Washington by nearly 300 percent and in Oregon by nearly 250 percent. In 1940, the Pacific Northwest had a total of 12,000 miles of roads.

Automobile access provided people with the means to travel throughout the Basin for recreation. In 1916, the National Park Service was created to administer the growing set of national parks and monuments. Although the early parks had been promoted for local economic development, increased visitation and public sentiment to protect natural features led to the Park Service's Organic Act of 1916, mandating a mission of limited development to: "...conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

Grazing

Historically, a wide variety of ungulates, including deer, elk, mountain sheep, antelope, and bison, populated eastern Washington and Oregon. Natural predators kept the numbers of ungulates in balance. Because these animals had wide-ranging mobility, their grazing and browsing did not have extensive effects on vegetation. The widespread presence of bunchgrass initially attracted migrant herders who could walk their stock to markets. By the 1870s, ranches and farms were established throughout the Great Basin, Snake River Plains, and Columbia Plateau. The goal of most ranchers was to secure a base of operations with dependable water supplies and the ability to cut and store sufficient hay to feed livestock during the winter; this type of base has sustained many cattle operations to the present day.

Cattle have dominated livestock production throughout the Basin since the first agricultural data collection in the Census of 1870, which reported a total of approximately 76,000 head. Twenty years later, that figure had multiplied over tenfold to approximately 793,000 head. The number of cattle grew steadily throughout the 20th century from 1.4 million in 1910, to 2.6 million in 1950, and to 4.1 million in 1969, a level that has remained relatively constant.

As Euro-American settlement began, not only were many predators displaced, but sheep, and then cattle, were introduced in rapidly increasing numbers. Toward the end of the century, sheep were so numerous on eastern Oregon rangelands that anecdotal reports and photographs suggested summer ranges so laden with sheep that they appeared to be snow drifts. Fescues and other bunchgrasses were irreversibly modified by extensive grazing in the late 1800s and early 1900s. Overgrazing damaged stream and riparian vegetation in many basins in eastern Oregon and Washington. Overgrazing also facilitated the spread of annual cheatgrass and reduced vegetation that had provided fuels for fires. When combined with later fire suppression efforts, the result was reduction of an important ecosystem disturbance.

In the 1920s, ranchers and others recognized that overgrazing of public lands, in combination with drought conditions, was severely impairing the land's ability to support their operations. Impetus for initial regulations also came from Frederic V. Coville's influential *Forest Growth and Sheep Grazing in the Cascade Mountains of Oregon,* published in 1898. His recommendations led to an allocation and permit system in which stockraisers secured grazing rights within bounds of regulations established by the Forest Service.

The Taylor Grazing Act of 1934 brought range regulation to 142 million acres in 11 western states, removing the land from potential sale and placing it under the jurisdiction of the Grazing Service, which evolved into the Bureau of Land Management in 1946. Range improvement projects were undertaken and local advisory boards established to allocate and manage the rangelands. The condition of rangelands in the Basin has generally improved since then, with the exception of riparian areas, which have continued to decline in much of the Basin.

Timber Harvest

Vast stands of timber on the eastern slopes of the Cascades and in the Bitterroots and Rockies were another resource subject to increasing demand. Following on the heels of mining and agriculture, a third leg of the Basin's economy, the timber industry, took off near the close of the 19th century. The industry paralleled development of mines and railroads; railroads needed wood for ties and trestles, mines needed timbers for shoring, and lumber mills needed access to the woods to extract logs.

Serving only local markets in the early years after settlement, the industry began to change with completion of the Northern Pacific Railroad in 1883 and the advance of the Oregon Railway and Navigation Company's line eastward to the Blue Mountains and southeast via the Oregon Short Line to connect with the Central Pacific. Their construction created an important market for ties, trestle materials, and finished lumber for warehouses, depots, and dwellings for workers.

The influx of settlers engaged in farming created local markets for forest products. Spokane, Washington became one of the important regional manufacturing centers that met these needs. In 1888, the Spokane Mill Company produced 15 million board feet of lumber, 6,000 doors, and 10,000 windows. The following year, Spokane had nine mills that cut an estimated 30 million board feet of lumber valued at $2.2 million. Loggers supplied these plants with timber transported down the St. Joe, St. Maries, and Coeur d'Alene rivers and then rafted across Lake Coeur d'Alene.

By the end of the 1880s, mills in the Blue Mountains of Oregon were harvesting up to 30 million board feet annually, and the Clearwater River in Idaho was reported as a "floating woodyard." By 1900, exhaustion of the supply of trees in the upper Midwest invited timber investors to look westward, and the northern Basin became the focus of a new scramble for wood supplies. The rapid increase in harvest levels was reflected in Idaho, where 65 million board feet of lumber was cut in 1899. By 1910, Idaho was producing 745 million board feet, and its market had shifted from local to national. The railroads enabled mill owners to supply and compete favorably in the Dakotas, Nebraska, Wisconsin, Iowa, Colorado, and other states. Employment data in the logging and lumbering industry for Idaho shows the growth of those enterprises in the early 20th century. In Idaho, for example, employment of loggers, rafters, and sawmill workers increased from just over 300 in 1880, to more than 8,000 in 1920, and to 14,900 in 1995.

Because smaller stems could not be processed efficiently, early harvesting concentrated on the largest trees of the more important commercial species, such as ponderosa pine and western larch. Eastern markets in particular demonstrated a preference for ponderosa and Idaho white pine, leading to select cutting where other species in mixed forests were left standing.

The Forest Service was established in 1905 to conserve water, as well as to manage a growing inventory of Federal forest reservations that dated to 1891. Theodore Roosevelt entered office in 1901 with 41 million acres in reserves; when he left office in 1909, there were 151 million acres of national forests whose management was to ensure a sustained yield of timber to contribute to national growth and the stability of local economies. In the view of Gifford Pinchot, the first Forest Service Chief, the forests could protect water supplies for irrigation and western cities, provide cheap grazing, and repay the Federal treasury with timber sales. After nearly a century of policies to dispose of public lands, the Federal Government started to view the remaining public domain as a storehouse to sustain productive values. The Progressive Movement influenced leaders in government to emphasize "scientific" management of physical resources for more "efficient" development.

Exclusion of fire from ecosystems began systematically in the early 1900s; fire was viewed as a threat to forests, as well as to the lives and property of increasing numbers of settlers. The newly created Forest Service, unaware of the increased problems

with wildfire control and forest health, believed that fires killed regeneration under larger trees. This societal attitude prevailed until fairly recently as fire's natural role as a disturbance came to be more widely understood. While fire was being used west of the Cascades to reduce slash after logging, fire was being excluded from the east side of the Cascades where it historically had occurred more frequently. Although well intended, this management philosophy over time resulted in changing forest stands from seral fire-adapted species, to species that are more susceptible to fire and that tend to form unhealthy stands more prone to larger-scale fires, as well as increased outbreaks of insects and disease.

Growth of the timber industry continued in subsequent decades, driven by demand for wood products in growing urban centers, especially in the Midwest and California. Development of the skidder, caterpillar tractor, log truck, and chain saw lowered costs, increasing production dramatically. The easier terrain of eastern Oregon and Washington facilitated the change to more mechanized equipment. Timber cutting practices were adapted to fit the technology available, leading to clearcutting.

From 1945 to 1970, timber harvest on Federal lands in the Basin increased about 5 percent per year, or 50 percent faster than the growth of the national economy. This increase was important to the expansion of softwood and plywood production in the western states, which supported many communities. Nationwide, harvest volume increased from 4 billion board feet in 1950, to 11.4 billion board feet in 1970, 90 percent of which came from western national forests, and 41 percent from Washington and Oregon.

Fishing and Dam Construction

When Euro-American settlers arrived during the early 1800s, salmon were abundant and diverse. Spawning runs of chinook salmon made their way up the mainstream Columbia to the Snake River, and on up to the headwaters of the Owyhee and Bruneau rivers and Salmon Falls Creek as far as Nevada.

Estimated historical run size for all species of salmon and steelhead in the Columbia River ranged from 10 to 16 million adult fish. Not only was their course unimpeded by dams, but there was ample suitable habitat to support these populations. Fur trappers and traders reported extensive stands of willows and alders growing side-by-side across many of the valleys and along moist gulches and draws; they also reported wide, wet meadows along stream systems throughout the Basin. The Ochoco Mountains take their name from an American Indian word meaning "streams lined with willows."

Commercial harvest began in earnest when the first cannery started operating on the Columbia in 1866 and soon exceeded sustainable levels. Commercial catches of chinook salmon in the Columbia peaked in 1883 when about 43 million pounds of fish were landed. Coho, sockeye, chum, and steelhead also were abundant in the Basin. Catch of coho peaked at 6.8 million pounds in 1895, and catch of sockeye and steelhead totaled 4.5 million pounds.

By the late 1800s, overfishing was blamed for broad declines in chinook salmon runs. By 1900, certain fishing gear was banned to protect spawning runs but impacts from mining, timber harvest, livestock grazing, and agriculture had begun.

New Deal[3] programs were critical in sustaining and building infrastructure in the Basin. Perhaps the most publicized Federal programs were the dam projects along the Columbia and Snake rivers. The Army Corps of Engineers had been involved in surveys, navigation, and flood control along the Columbia River since the 19th century, but these activities were of low intensity compared to the major dams constructed during the Depression[4] and after World War II on the Columbia River. In 1938, Bonneville Dam became the first dam on the Columbia, and the Grand Coulee Dam was built in 1942.

[3] Policies and programs for economic recovery and reform, relief, and social security introduced during 1930s by President Franklin D. Roosevelt and his administration.

[4] Period of severe economic hardship in early 1930s.

Although the Federal initiatives from the New Deal did not extend to regional planning, such as in the Tennessee Valley, the effect of Federal actions in the Depression years pulled the region out of the frontier and onto the main stage of late 20th century development. As Abbott (1994) wrote:

> *Whether residents liked to admit it or not, the federal initiatives saved the West from collapse. There were fewer farmers and miners in 1940 than in 1920, and there were more abandoned towns on the high plains and plateaus. By and large, however, the West in 1940 had new resources in place for an economic take-off: new electric power, new expertise in large-scale construction, workers with new skills for an industrial economy, and a renewed commitment to the progressive agenda of efficient resource development.*

A broad public consensus on construction of the dams helped the Nation out of economic crisis, even though biologists recognized at the time that dams would likely be barriers to native salmon runs. Later, however, the debate over dams symbolized new types of emerging social values. After World War II, as more citizens became affected by environmental changes, grassroots action and citizen demands began to bring to the forefront other values that were deemed environmental. This citizen movement set the course for conflict between forces associated with large-scale management and technology and those emphasizing protection of environmental quality. This change was symbolized by debate over dams in Hells Canyon, which shifted from who should build them and how many to the possibility, voiced by Supreme Court Justice William O. Douglas, that maybe the river had greater value in its free-flowing condition.

Another landmark decision regarding social priorities for fish resources came in 1974, which marked the beginning of a key set of court decisions with a *United States v. Washington District Court* decision reaffirming the priority of off-reservation fishing rights. Tribes were allowed up to a 50 percent share of harvestable fish returning to accustomed traditional fishing sites. More detail on laws specific to American Indians is provided later in this chapter.

Recent Legal and Political Climate[5]

Social discussion regarding land uses described above has been reflected in a series of laws, policies, and court decisions. A brief history of some of these social actions helps to provide context for understanding current debates about ecosystem management.

Since passage of the Multiple-Use Sustained-Yield Act of 1960, the Forest Service and Bureau of Land Management have had increasingly complex and conflicting demands on Federal land stewardship, with policy dictating that multiple demands be met from a limited resource base. In the late 1950s, the Forest Service experienced difficulties with ambiguities of its Organic Act mandates and subsequently evolving responsibilities. Wilderness enthusiasts and others sought to put recreation on an equal footing with other uses. The traditional users, which were timber operators, ranchers, and miners, argued for greater allocation to their particular needs, causing the Forest Service to seek legislative clarity from the Congress (Coggins and Wilkinson 1981).

The result was the Multiple-Use Sustained-Yield Act of 1960 (MUSYA) which defined multiple use as "management of all the various renewable surface resources of the National Forests so that they are utilized in the combination that will best meet the needs of the American people...without impairment of the productivity of the land, with consideration being given to the relative values of the various resources, and not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output."

The Multiple-Use Sustained-Yield Act has meant all things to all people. The literature on the meaning and application of multiple-use sustained-yield management has burgeoned with-

[5] The initial draft of this section was written by Christopher E. DeForest and Amy L. Horne. Horne is an economist at the USDA Forest Service, Pacific Northwest Research Station; DeForest is an independent contractor.

out appreciably clarifying the concept as a legal standard (Coggins and Wilkinson 1981). The Act could have marked a clear continuation of emphasis on commodity production. It could also have stated what weight to give to society's different demands on the land. Instead, it institutionalized uncertainty and ambiguity, and marked the beginning of the modern period of conflict over what constitutes proper stewardship of the public lands.

The 1970s have been called the decade of "Regulating Public Lands" (Caldwell and others 1994). In 1975, a Federal court enjoined timber sales on the Monongahela National Forest in West Virginia, finding the Forest Service in violation of the 1897 Organic Act. The Forest Service complied with the court order to develop a new multiple-use plan and to limit the size and range of clearcuts, extending these policies to all National Forests.

The Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 was intended to institute long-term strategic planning in the Federal Government (Cubbage and others 1993). In the name of multiple use, the Forest Service assembled plans to manage all resources in an attempt to diffuse arguments that the agency concentrated on timber at the expense of other outputs. However, congressional failure to allocate the necessary funding resulted in maintaining the status quo of primarily focusing on timber (Cubbage and others 1993).

Senator Frank Church of Idaho chaired congressional hearings in 1972 that culminated in a report recommending major restrictions on the size and suitability of clearcuts; the Church Report was instrumental in the development of the National Forest Management Act of 1976 (NFMA), an amendment to the RPA. The Federal Land Policy and Management Act of 1976 (FLPMA) gave the Bureau of Land Management a multiple-use mandate similar to the Forest Service's in MUSYA and requirements for comprehensive long-range planning similar to those in NFMA (Cubbage and others 1993).

The 1980s were characterized as a decade of "Clashing Imperatives" (Caldwell and others 1994). There was bitter debate about Northwest old growth among the Congress, several administrations, and the courts, in which the spotted owl was used as legal leverage to redefine desirable management of the national forests. The polarities were seen as protecting ecosystems by protecting endangered species, versus maintaining local timber-dependent economies. The decade included Judge Dwyer's rejection of the 1986 Forest Service spotted owl management guidelines,[6] which enjoined timber sales pending revisions to the guidelines. Then, there was a 1989 congressional rider to undo the injunctions for two years; subsequent scientific reports on old growth, spotted owls, timber, and tradeoffs; and the Supplementary Environmental Impact Statement (EIS) and Forest Ecosystem Management Assessment Team report (FEMAT 1993). A new approach to reserving old-growth ecosystems (Option 9 of the Northwest Forest Plan) was adopted but has been under almost continuous challenge.

The 1990s are being characterized by continued controversy and public concern about ecosystem health and its physical, biological, economic, and social meanings. The costs and benefits of programs for activities, such as salvage logging and its appropriate role, have become national issues. The aggressive fire suppression policy of Federal land-managing agencies has been increasingly criticized as agency and academic foresters learned more about natural fire cycles (Langston 1994, Everett and others 1994). The health of forest, rangeland, and aquatic systems is under close public scrutiny, as are the tradeoffs associated with achieving various levels of health at various places in the Basin. Recent debate over reform of Federal rangeland management demonstrates the social and political intensity of rangeland, as well as forest, issues. It remains to be seen whether ecosystem management will be viewed as the solution to these complex issues.

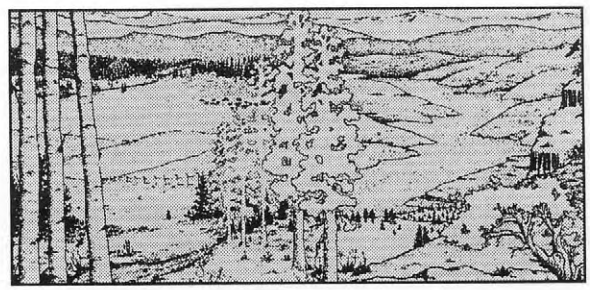
[6] *Seattle Audubon Society* v. *Evans*, 771 F. Supp. 1081 (W.D. Wash) 1991.

Implications for Ecosystem Management

A brief look at the history of interactions between people and other ecosystem components of the Basin provides some explanation for past actions. Besides explaining how present ecosystem conditions evolved, this discussion also provides rationale for human uses of natural resources and the basis for people's judgements about the acceptance of those uses and their effects. Several lessons emerge from study of the history of people's interactions with physical and biological resources in the Basin:

- People's perceptions of Basin resources have changed dramatically in a relatively short time. Initially viewed by Euro-American settlers as unpriced, seemingly limitless supplies to be disposed of efficiently, many natural resources are now increasingly scarce and subject to highly competitive uses. Federal laws and policies regarding resource use reflect the changes in both the supply of resources and public perceptions of their values.
- Although the industries that led to settlement and infrastructure development of the Basin (mining, timber, ranching, and transportation) still play critical roles in the social and economic functioning of Basin ecosystems, their roles have changed with time and the tremendous growth of new industries.
- Landscape ecology analyses suggest that even if society wanted a return to pre-European settlement conditions, it would not be possible to achieve. The question now is: "What does society want to accomplish through ownership and management of BLM- and FS-administered lands?"

POPULATION AND DEMOGRAPHIC CHARACTERISTICS



Management of Federal lands in the Basin occurs within a context of the human population, its size and growth, and other demographic characteristics. The following text describes current human populations, reviews recent and projected patterns of population growth, and discusses lifestyles of the rural population in the Basin. When considered in conjunction with economic trends described in the Economic Assessment, including poverty, unemployment, and other economic measures that have obvious social implications, this information gives land managers and other decision-makers an idea of demands likely to be placed on natural resources. Detailed demographic characteristics are provided in a supplemental report (McGinnis and Christensen 1996).

Population Dynamics and Characteristics

The Basin is sparsely populated, with a density of about 11 people per square mile compared to the national average of 70. Although the counties in the Basin account for about 8 percent of the land area in the United States, they have only 1.2 percent of the Nation's population.

The total 1990 population in the Basin was just less than three million people (USDC 1991a and b). Washington residents comprise 38 percent of the Basin's population, compared to 27 percent for southern Idaho, 12 percent for Oregon, 11 percent for Montana, 7 percent for northern Idaho, and 5 percent for the other states (Wyoming, Utah, and Nevada). The most populated county is Spokane in Washington, which has approximately 361,000 people. Nearly half of the population is located in 12 of the Basin's 100 counties, although just 6 of these (Ada and Canyon in Idaho; and Benton, Yakima, Franklin, and Spokane in Washington) are large enough to be called metropolitan counties.

The age distribution of Basin residents is similar to that of the Nation, but the Basin has a greater proportion of people younger than age 18 and a smaller proportion in the prime wage-earning years of 25 to 49 (McGinnis and Christensen 1996). Between 1980 and 1990, the age structure of Basin residents changed significantly. The 65-and-older age group increased by a greater proportion (28%) than other age groups, and the 18-to-24 age group declined by 20 percent. This proportion reflects in-migration rates and the aging of the baby boomers.

The Basin has a larger proportion of Whites (92%) and American Indians (2.5%) than the Nation as a whole (80% and 0.8%, respectively), and a smaller proportion of Blacks (0.6% compared with 12% nationally). The Basin also has a smaller proportion of Hispanics (6.7% compared with 9% nationally), although Hispanics are the largest non-Anglo group in the Basin. From 1980 to 1990, the Hispanic population increased by 69 percent.

Ethnic minorities who have come to the Basin use public lands for income and recreation. Many minorities were drawn to the Basin by jobs in irrigated agriculture. Few of the significant numbers of minorities who arrived in the Basin in the 1940s settled permanently. Many spoke only Spanish, lived lifestyles confined to camps, worked long hours during harvest season, and returned to their homeland when the crop season ended. Few had opportunity to realize or discover the Basin's recreational possibilities (Valle 1994). Some migrant workers who journeyed with their families began to settle in the Basin in the 1950s and 1960s (Gamboa 1990). Increasing numbers of single workers began to come from Mexico in the 1970s, first from northern and central Mexico and lately from southern Mexico. Some of these also settled in the Basin.

As children of the first migrant settlers have attended school, learned English, and entered jobs outside of agriculture, their available time has increased. Recreation has become more important. Although family outings to nearby parks constitute some of this recreation, increasing numbers of this population segment hunt, fish, and camp on public lands. Although the numbers using public lands are proportionately low for their population, increasingly more are expected as more of the first and second generation work outside agriculture (Pfister 1993).

Public lands are used by large numbers of minorities who earn income in forestry-related activities, including reforesting, pruning, and thinning trees (Hansis 1995). Migrant workers and southeast Asians harvest special forest products, such as huckleberries, beargrass, and mushrooms. Other products, such as medicinal plants, may become the next commodity of interest for Southeast Asians. Besides providing income, some harvesting may be a basis for family and social cohesion. In some cases, entire families go to public lands, camp, pick beargrass and mushrooms, and socialize in extended kin networks.

The Basin contains or overlaps 20 American Indian Reservations and one Colony, which includes some trust lands; these areas total about 14,000 square miles or 5 percent of the Basin. In six counties, reservation and trust lands account for more than 40 percent of the land base. In 1990, about 115,000 people lived within the borders of these lands. Hanes (1995) contains a list of Indian tribal governments having interests in the region.

Nearly two-thirds of the Basin's population live in towns, villages, and cities. The Bureau of Census recognizes 400 incorporated places and 76 "Census Designated Places," which are locations that are unincorporated but have an identity to the local population. Although 65 percent of the Basin's population (as recorded in the 1990 Census) live in a town, village or city, most of these communities are relatively small. Only about 30 of these communities have more than 10,000 population; most have less than 2,500 people. Additional detail about the Basin's small, rural communities is included later in the section on community resiliency.

Population Trends

Concerns about the effects of rapid growth in the rural West have been widespread in the media. Although people in rural communities desire economic opportunities that are associated with population growth, they are concerned about social and environmental consequences and the ability of communities to cope with a new "Rocky Mountain resurgence." What is clear from recent growth statistics and media discussions is that such rapid growth brings various impacts. This is an issue not only for local governments, but also for managers of adjacent Federal lands.

To understand how the Basin's population has changed in the past and may change in the future requires understanding the two major components of population change, which are natural increase and net migration. Natural increase is the number of deaths subtracted from the number of births in

a year; this indicates if an area's population is increasing or decreasing as a result of shifts in fertility or mortality. For many rural areas, natural increase has been negative, paralleling national trends for the past few decades.

Net migration is the difference between out-migration and in-migration. The sum of these two components shows changes in the population base; a negative figure indicates that more people are moving out of an area than are moving into it. There have been two major trends in migration patterns in the United States since 1900: (1) migration to the western and southern states, and (2) migration from rural to urban areas. The West as a whole has gained population through migration.

The Basin's demographic patterns have followed national trends over the past 45 years. Figure 7.1 shows the population of 100 counties in the Basin by decade. During the first two decades of this period, 1950 to 1970, there was a significant national level out-migration from rural to urban settings. This pattern was also reflected in the Basin, where over one-third of the counties showed population losses in this period.

During the 1970s, the second trend changed significantly (Fuguitt and others 1989). During this time, most counties in the Basin reported population increases, reflecting the "rural renaissance" occurring for the Nation as a whole in that decade. Brown and Beale (1981) regard the population turnaround of the 1970s as "one of the most significant demographic events of recent decades." The 1980s demonstrated a return to traditional migration and population patterns (Johnson 1993), as 41 percent of the counties in the Basin showed population declines.

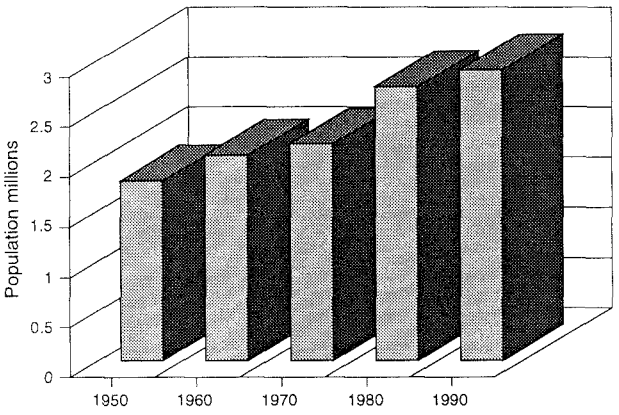


Figure 7.1 - Population of the Basin by decade.

However, in the early 1990s, another urban-to-rural migration began. Johnson and Beale (1994) report that nationally about 43 percent of the population growth in nonmetropolitan counties between 1990 and 1992 was due to migration. Census data for the Basin shows that an even higher proportion (64%) of the net population increase from 1990 to 1994 could be attributed to migration. Nationally, counties that attract retirees or are "centers of recreation" were more likely to gain population, and 82 percent had net migration in the 1990 to 1992 period. In the Basin, 96 percent of the counties increased in population for the period 1990 to 1994, reversing the trend of the 1980s (Johnson and Beale 1994). Map 7.1 shows population growth by county for the 1990 to 1994 period. The absolute increase in population in this four-year period is equal to one-third the increase occurring in the previous three decades.

The impact of in-migration differs among counties. One type of county that showed large increases was "recreation counties," which are counties in which recreation and tourism play a major role in the economy (Johnson and Beale 1994). In recreation counties, about 77 percent of the population growth could be attributed to net migration. The figures for metropolitan and other rural counties were 60 and 57 percent respectively. Recreation counties are particularly important centers of growth in the Basin; although recreation counties accounted for 17 percent of the population in 1990, they accounted for 24 percent of the total population increase in the Basin and 29 percent of the total net migration.

Map 7.1 - Change in percent of population by county, 1990-1994.

Although most communities and counties are growing, some traditionally agricultural counties are experiencing population declines, principally because of rising production efficiency in agriculture. Counties distant from metropolitan areas also have generally experienced slower growth or population decline.

Projected Population Growth

There are several reasons for considering future human population growth. First, population is a significant component in understanding the context within which ecosystem management decisions will occur. Second, demands of human populations for both commodities and amenities associated with natural resources on Federal lands are partly functions of population levels. Third, the additional development resulting from population increases escalates the potential for habitat fragmentation, particularly in popular "recreation" counties located in ecologically diverse settings. Finally, although development occurs on private lands, people also affect nearby Federal lands, so population change suggests a need for appropriate Federal and local cooperation.

This assessment compares two projections of potential population growth in the region, each based on its own set of assumptions, especially specific to net migration (fig. 7.2). The first, and lower, population projection was developed by the Bureau of Economic Analysis (BEA) in 1994; it is strongly influenced by projected economic conditions and patterns of population growth that occurred in recent periods. However, BEA projections are below the current population for many counties in the Basin, suggesting the need for an alternative projection based on new assumptions.

The second, and higher, population projection was made by ICBEMP staff (McCool and Haynes 1995). They based their assumptions about a natural increase on persistent differences between the Basin and the Nation, with the Basin averaging about 22 percent higher. Their projection also assumed a rate of net migration from the years

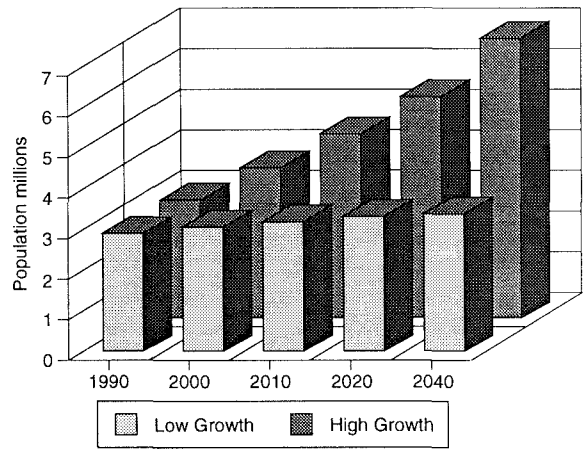


Figure 7.2 - Estimated Basin population by decade using two different projection assumptions.

1995-2000 equal to the 1990-1994 rate, and then a reduced rate to zero by the year 2030. Another assumption of this projection was that recreation and metropolitan counties in the region would record higher growth rates than other counties.

Both projections were developed for counties, and then aggregated to the 100-county Basin level. Beginning in 2010, the projections depart dramatically. Although uncertain and subject to alteration by many factors, both projections call attention to likely demands on resources, potential conflicts, and growth management issues. Although the high projection results in what could only be termed spectacular population growth, the overall population density within the Basin would remain well below the national average. This population would be concentrated on private lands, which compose 48 percent of the Basin's total area.

Migration

Migration is an issue for several reasons. The low population growth estimate cited above assumes, for all practical purposes, no net migration into the Basin; in the higher estimate, migration forms the bulk of the population increase. People's reasons for migrating can be affected by public land

management policies and actions. Knowing the reasons for migration can help managers to better understand the potential of individual areas for in-migration and to become active in mitigating effects on Federal lands.

The Basin's overall growth in opportunities for employment, as discussed in the Economic Assessment chapter, continues to be a central factor in people's decisions to relocate. In addition, recent literature shows that migration decisions often contained not just economic dimensions such as employment opportunities, but noneconomic dimensions such as amenities or family ties (Wardwell 1992). The migration literature traditionally was principally concerned with economic motives, such as moving for a new job or a job transfer. Census enumerators did not ask people about quality of life or lifestyle factors as motivations for relocation. Wardwell (1992) argued that research demonstrated the economic explanations were insufficient to explain the return to rural areas during the 1970s, although increases in communication and transportation technology made rural areas more feasible as bases of operation.

Only since the "rural renaissance" of the 1970s have scientists explored non-economic reasons for migration (Zuiches 1980, 1981). Long (1988) reported that about 50 percent of the households moving between states in the 1979 to 1981 period relocated mainly for other than work-related reasons:

> *A case can be made that a great many moves are not accounted for by classic economic approaches linking long-distance migration to employment opportunities... Many of the 10.1 percent of moves that could not be classified in one of the 34 preset categories may have represented persons seeking lifestyles and values that do not appear to be governed strictly by economic considerations.*

Between 1979 and 1981, motivations for migration were strongly related to age (Long 1988). Job-related motives were most frequently cited by younger movers, while older movers listed climate and family among other reasons. As the regional and U.S. population ages, these latter motives will have a greater influence on the population. Areas high in amenities attractive to seniors will experience higher than average population growth. Lifestyles of these individuals may be more oriented toward outdoor recreation and protection of natural resources. The 20 counties classified as "recreation" counties in the assessment area already have a different lifestyle composition than other counties in the region, as discussed in following text.

The economic impact of retirement can be substantial; population, employment, and personal income increased significantly faster over the period 1969 to 1989 in rural counties classified as retirement counties than in other rural counties (Deller 1995). Besides being higher as a source of personal income than for the Nation as a whole, transfer payments within the Basin have increased much faster than the national average (see discussion on communities in this chapter and also in the Economic Assessment, Chapter 6).

Population Lifestyles

A description of Basin population characteristics relevant to ecosystem management would be incomplete without an overview of Basin lifestyles. The character of rural life in the Basin varies as much as the people do, and the Basin population is diverse in many ways. Although describing Basin lifestyles at this broad scale oversimplifies the many ways that people live and earn a living in the Basin, there are some advantages, such as being able to compare Basin lifestyles with those elsewhere. Not surprisingly, many Basin lifestyles are tied closely to the natural environment and to public land management.

To better understand lifestyles within the Basin, the ICBEMP used a lifestyle segmentation system called PRIZM developed by Claritas (1994). PRIZM describes people's lifestyles through multivariate analysis of household characteristics combined with consumer purchasing behaviors. The two primary criteria defining lifestyles are affluence and residence (urban to rural). The database

describes 62 lifestyles located in 12 major groups, each representing about 1.5 percent of the Nation's households. Not all 62 lifestyles are represented in the Basin, because several exist only in large cities or have strong regional affinities.

Twelve lifestyles tend to be found in rural areas or small communities in the Basin (table 7.1). These lifestyles are most subject to change as the population grows and as the underlying economic structure of communities shifts. Certain rural-based lifestyles are found more frequently in the Basin, and their distribution is much different from the west side of the Cascades. Rural-based lifestyles account for more than 50 percent of the Basin's population, compared to about 20 percent of the population nationally or west of the Cascades.

The Basin is dominated in rural areas by agriculturally based lifestyles. However, in rural counties where rapid population growth is occurring, Basin lifestyles differ significantly from other areas. In general, compared to households nationally or those west of the Cascades, lifestyles in the Basin's rural areas experiencing rapid growth appear more oriented toward the natural environment, with occupations related to natural resources, and recreation activities dependent on resources from Federal lands. The importance of environmentally based amenities to Basin lifestyles is discussed in more detail later in the chapter addressing social benefits of amenities.

Implications for Ecosystem Management

Besides being helpful to ecosystem managers for decision-making, information on population and lifestyle changes results in significant and often controversial discussions about the future of communities and Federal lands within the Basin. Even assuming modest in-migration, the level and characteristics of the population will affect any such debates and lead to additional demands on public lands and resources within the Basin.

Rapid population growth in the Basin presents major challenges to the BLM and FS, especially in locations having high levels of environmental amenities. In these areas, growth and associated development threaten the qualities that make such places attractive for recreation, retirement, and new businesses. At the urban-wildland interface, where such growth is most dramatic and developments are most visible, habitat fragmentation and fire protection are critical issues. Habitat loss on private lands translates into increased pressure on remaining habitat on Federal lands, further exacerbating constraints on natural resource commodity production. Increased numbers of residential dwellings adjacent to forest and rangelands present new challenges in fire prevention and suppression for Federal and local agencies.

Johnson and Beale (1995) showed that counties with either rapidly increasing or declining populations tend to have more difficulties raising revenues for needed services. Although the amenities on Federal lands are sources of economic growth, they indirectly present problems in planning and managing growth by stretching the response capacity of local governments to develop and implement solutions. Changes in Federal revenue resulting from policy changes may exacerbate such local capacity.

The important conclusion from lifestyle data is that lifestyles vary significantly within the Basin, and also differ from those experienced elsewhere. Management actions affecting Federal lands differentially affect people across the Basin based on the distribution of lifestyles at specific locations. In addition, the ability of agencies to meet demands for outdoor recreation may vary according to population growth and lifestyle composition. Population growth and changes in lifestyles distribution also suggest a rethinking about vegetation management alternatives and their potential to affect people with varying lifestyles. For example, rapidly growing rural areas generally attract people whose lifestyles suggest sensitivity to environmental modification.

Table 7.1—Rural-based lifestyles in the Basin.

Lifestyle Segment Label	Definition
Small Town, Blue-Collar Families	Moderately-affluent people living in mid-scale, low-density towns located at outskirts of larger cities. Tend to be skilled workers in industrial and blue-collar occupations, primarily mining, milling, manufacturing, and construction. Very outdoor oriented.
Mid-scale Families and Farmland	Have average college education and income levels well above U.S. median. Well-paid, skilled craftsmen, machinists, and builders, living in scenic locales. Family-centered; devoted to hobbies, hunting, and boating.
Rural White- and Blue-Collar Farm Families	Only rural segment with above average college educations. Has even mix of white- and blue-collar jobs and high index for personal computers, reflecting several new, hi-tech industries in pristine, ecological sanctuaries.
Middle-Class Rural Families	Blue-collar occupations. Live in wide variety of agricultural settings.
Rural Blue-Collar Workers and Families	Least affluent of rural clusters. Consist of large proportion of blue-collar workers, mostly married with children. Bowl, hunt, sew, and attend auto races.
Retirement Town Seniors	Found over wide range in country. Includes myriad of rustic towns and villages in scenic areas where seniors choose to retire. Younger and less urban and affluent than other retirees. A few play golf, but most prefer to adopt local customs.
Older Families, Mine and Mill Towns	Tends to have very low incomes; ranked 56th out of 62 segments. Older, largely single, with fewer children. Towns are located in scenic areas.
Rural Farm-Town and Ranch Families	Includes farming, forestry, fishing, ranching, mining, and other rural occupations. Close to median income level, large families, and like fishing.
Farm Owners and Tenants	Centered in Great Plains, but has large representation in the Basin as well. Primarily owners and tenants of farms; not very wealthy. Hgher than average proportion of Latino migrant workers.
Moderate Blue-Collar/Farm Families	Tends to be in more isolated areas. Low income, with large families. Prefer hunting, fishing, and camping.
Low-Income, Older, Rural Couples	Third most elderly segment in nation. Have relatively-low incomes, but preference for country clubs, power boats, and sailboats. Oriented around rural environments.
Poor Isolated Areas With Older Families	One of lowest income segments in the Basin. Rural lifestyle; primarily blue-collar occupations.

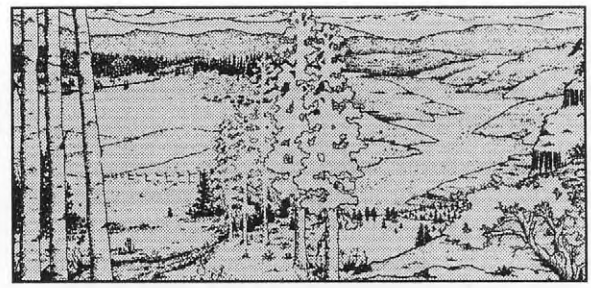
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ATTITUDES, BELIEFS, AND VALUES TOWARD NATURAL RESOURCES AND PUBLIC LAND MANAGEMENT



A Framework for Ecosystem Management in the Interior Columbia Basin and Portions of the Klamath and Great Basins (Haynes and others 1996) states that a main feature of an ecosystem approach to managing natural resources is to include people, their values, and activities. The *Framework* acknowledges that people may make demands on ecosystems that exceed physical and biological capabilities in the long term. Developing and implementing an ecosystem management plan requires knowledge of the type and quantity of human demands for ecosystem products and the human values associated with these expectations.

The Forest Service's National Human Dimensions of Ecosystem Management Task Force concluded: "The human dimension of ecosystem management must include information about people's traditional and changing perceptions, beliefs, attitudes, behaviors, needs, and values and the past, present, and possible future influences of humans on ecosystems." The ICBEMP Charter reflects this thought by referring to consideration of sustained long-term economic, social, and ecological values of the region and issues identified in scoping. In addition, one of the ICBEMP's key policy questions (November 8, 1994) addressed the impact of ecosystem management on major social issues by requiring an understanding of local, regional, and national attitudes, beliefs, and values associated with natural resources and public land management.

Because ecosystem management is a human construct, like multiple-use management or other public land management systems or philosophies, the decisions on whether and how to implement it are made in a political arena. The desirability of different alternatives is a decision normally determined with public input to reflect the values of the groups involved in the debate over a preferred alternative. Knowledge of prevailing social attitudes relevant to ecosystem management provides a basis for evaluating social acceptability and developing appropriate mitigation. Existing laws, regulations, and policies reflect prevailing social views, but may not adequately describe public sentiments regarding current issues. Finally, surveys that sample populations of interest, such as the Nation's population-at-large or Basin residents, provide a context for interpreting frequently expressed demands of special interest groups.

Attitudes, Beliefs, and Values

The historical overview presented early in this chapter described social mind-sets regarding the role of humans in ecosystems and changing perceptions over time. The following text provides more detail on the current wide range of attitudes people hold toward natural resources and public land management. The objective is to create a more complete understanding of these attitudes, as well as people's expectations for implementing ecosystem management. Several research efforts

have helped identify people's various values, beliefs, and attitudes toward natural resources, the environment, and the agencies that manage land for the public.[7]

Because the terms "attitudes, beliefs, and values" have been used differently by social scientists, definitions are provided before presenting the research. The purpose is not to suggest what definitions are best nor to redefine the terms, but to provide descriptions and examples that lead to common expectations in the presented text.

Attitudes

Attitudes reflect people's evaluations of something as favorable or unfavorable. Although definitions and methods of measuring attitudes vary widely, a definition with many common elements was proposed by Fishbein and Ajzen (1975): "A learned predisposition to respond in a consistently favorable or unfavorable manner with respect to a given object." The evaluative or affective component (like/dislike or favorable/unfavorable) distinguishes attitudes from other concepts. Attitudes can be strong and well-formed or weak and broad, and are generally developed through various learning processes. Social scientists have developed and refined diverse methods for accurately measuring attitudes over the past 60 years. Many survey research efforts to explore interactions between people and the environment have focused on attitudes. For example, asking people how much they like or dislike the Bureau of Land Management is one way of measuring attitudes toward the agency.

Because attitudes are learned, they are subject to change. Substantial literature is devoted to understanding the nature of attitude change, whether by experience, new information, persuasion, cognitive dissonance, propaganda, behavior change, advertising, or other methods. An undeniable conclusion of this research is that attitudes, although defined as consistent evaluations of an object, are subject to manipulation.

[7] Trent (1995) summarized the results of numerous surveys that described people's attitudes, beliefs, and values relevant to understanding perceptions of natural resources and public land management in the Basin. Much of the material presented here is derived from that report.

Beliefs

Beliefs reflect what people think is true about something. Fishbein and Ajzen (1975) defined beliefs as statements indicating a person's subjective probability that an object has one or more attributes. Beliefs can be one reason for having a certain attitude. An example of a belief might be that the Forest Service accomplishes planned harvest levels, or protects habitat for endangered species.

Beliefs also are subject to change based on new information, life experiences, or other learning processes. Fishbein and Ajzen (1975) believed that attitudes and beliefs are part of a system that also includes behavioral intent, defined as "a person's intentions to perform various behaviors." Both beliefs and behavioral intentions have a strength component, which is based on people's perceptions regarding the likelihood that an object really does have some characteristic, or the subjective probability that a person will actually perform the behavior in question. Another component of beliefs is behavior, which is defined as observable actions.

Values

Values reflect things that people consider being precious. They are generally regarded as important life goals or standards of behavior toward which the person has a strong, positive attitude. "Values are the most important and central elements in a person's system of attitudes and beliefs" (Oskamp 1977). People's value systems could be viewed as building blocks of many attitudes and beliefs. Although dynamic like attitudes, values are more deep-rooted and resistant to change (Burch and Deluca 1984).

For some people, a core set of values can be so strong as to essentially dictate an individual's behavior in a wide range of settings and situations. Many of the toughest social issues facing our Nation today seem difficult or impossible to resolve because they are based on fundamentally conflicting and strongly held values. Value conflicts also form the basis of many disputes about natural resources, suggesting that such disputes are difficult to resolve in a manner acceptable to a wide range of stakeholders in public land management. Part of a land manager's job is to understand these various values and their influence on people's perceptions of land management actions.

Values, like attitudes and beliefs, change over time, creating new expectations and demands for public land management. Gale (1991), for example, argued that one reason for conflict over public lands in the West has been the increase in the variety of expectations about what goods and services such resources should produce. Ecosystem management is the BLM and FS's response to these changing social and cultural values and new scientific understanding of landscape ecology.

Guidelines for Using Attitude Surveys

Although basing public land management on prevailing public attitudes at any given point in time is dubious, the attitudes and the underlying beliefs and values of stakeholders should be considered. Measuring attitudes, however, is also a trying exercise because people's responses can be influenced by many factors, such as wording of questions; order, context, amount, and type of information provided to respondents; and social desirability. A major event can affect societal attitudes almost overnight. Sampling methods, survey administration, and analysis techniques all have specific effects on the validity and reliability of survey results and their general application to the population being surveyed.

A main information source for public attitudes toward natural resource issues was the Survey of Natural Resource Issues on Public Lands in the West (referred to as the CRB survey throughout this chapter), conducted in July and August of 1994 by scientists at Utah State University, Oregon State University, and Washington State University (Brunson and others 1994). The survey's intent was to provide the ICBEMP staff with specific information about attitudes of the local, regional, and national population toward important issues confronting the agencies managing Federal lands in the Basin. It was hoped that the survey would provide additional clarity in identifying the public's feelings about ecosystem management.

Four populations were sampled: eastside public (people living in Basin counties east of the Cascades); westside public (people in Basin counties west of the Cascades); national public (people from the 48 contiguous states); and project participants (people on the Eastside Ecosystem Management Project mailing list or who had participated in the scoping process). Response rates for the four sample groups were uniformly low, ranging from 18 percent of the national sample to 38 percent of the project participants. Because of the low response, the results were treated as responses of respondents only, not as representative of broader populations. However, the data were valuable in describing the range and types of attitudes, beliefs, and values that people hold.

Surveys were just one source of information on attitudes, beliefs, and values used in this assessment. Other sources, though not scientifically collected, provided insight into people's attitudes relative to issues important to the ICBEMP. Among the other information sources were issues identified during project scoping conducted by the EIS team, position statements submitted to the project by various groups and organizations, newspaper editorials and accounts of current events, journal articles, legal proceedings, and political cartoons.

Environmental Concern

A 1989 Gallup survey that explored public attitudes toward environmental protection and the environmental movement found that 76 percent of a national sample considered themselves to be either "strong" environmentalists or environmentalists. Nearly half reported validating this self-perception with behavior: 49 percent said they had contributed money to an environmental, conservation, or wildlife preservation group. In a more recent survey (Roper Starch 1994), 23 percent of a national sample described themselves as "active environmentalists," 56 percent said they were "sympathetic but not active," 16 percent claimed neutrality, and 2 percent were unsympathetic.

Dunlap and Scarce (1991) examined trends in attitudes toward environmental issues over the past 20 years, including issues such as threats posed by environmental problems, support for government actions, willingness to pay for environmental protection, perceived seriousness of environmental problems, and tradeoffs between environmental protection and economic development. When asked to name the two most important problems facing the United States, about 20 percent volunteered "the environment," a rate that has remained fairly constant. They concluded that, as of 1991:

> *Public concern for environmental quality has reached an all-time high. While questions about the strength of environmental concern remain unclear, growing majorities see environmental problems as serious, worsening, and increasingly threatening to human well-being.*

Dunlap and Van Liere (1978) called this set of attitudes the "new environmental paradigm" that supports maintaining the balance of nature and rejects the notion that nature exists solely for human use. In many polls, younger respondents who are part of the baby boom generation expressed values more sympathetic with this perspective than did older respondents. Yaffee (1994) believed this stronger set of environmental values would likely be maintained as baby boomers age.

The causes for increased environmental concern have been reviewed by several researchers (Dunlap 1992, Dunlap and Van Liere 1978, Hendee 1989, Kanagay and others 1994, and Steel and others 1994). Among the contributing causes identified were generational differences, technological advances, urbanized lifestyles that detach people from settings producing demanded goods, many well-publicized events worldwide that demonstrated the risks of substantial human impacts to the environment, and beliefs that the world may not be able to support ever-increasing numbers of people competing for finite natural resources.

The *Times-Mirror* Magazine's National Environmental Forum Survey (Roper Starch 1994) conducted in 1992, 1993, and 1994 was used to describe recent environmental trends. In 1994, a majority of respondents (53%) believed that environmental laws and regulations had not gone far enough, compared to 16 percent who felt they had gone too far and 23 percent who believed the right balance had been met. Younger Americans (age 18 to 34) were more likely to feel strongly that regulations do not go far enough (64%), compared to just 36 percent of those age 65 and older.

In 1992, 63 percent of the respondents believed that environmental laws and regulations had not gone far enough, compared to 10 percent who felt they had gone too far and 17 percent who said the right balance had been met. Although the relative ranking of these three response categories did not change from 1992 to 1994, a slight shift in attitudes was apparent; in 1994, more people believed that there was a balance or that regulations had gone too far.

Values Regarding Natural Resources

Natural resource values can be categorized in many ways. The following list is one effort to categorize the types of social values relating to natural resources that were provided by the social assessment chapter of *Forest Ecosystem Management: An Ecological, Economic, and Social Assessment* (FEMAT 1993). In that document, social values were categorized as:

- Commodity values: timber, range, minerals.
- Amenity values: lifestyle, scenery, wildlife.
- Environmental quality values: air and water quality.
- Ecological values: habitat conservation, biodiversity, threatened and endangered species.
- Public use values: gathering, subsistence, recreation, tourism.
- Spiritual values: sacred places.
- Health values: medicines.
- Security values: sense of social continuity and heritage.

The CRB survey contained a query about values similar to those in FEMAT. From a list of 17 factors concerning the future of public lands in the Basin, respondents were asked to rank the 3 most important factors to them and their families. The wide range of factors included ecological health, resources for future generations, several types of commodity production, outdoor recreation and amenities, salmon, and wildlife habitat.

The most important factor of all four population segments was resources for future generations. The national sample's next most important factors were wildlife habitat and ecological health; the westside residents' next priorities were outdoor recreation, wildlife habitat, and ecological health. Next important factors for eastside residents were quality place to live (just 2% behind the top concern), followed by outdoor recreation, and wildlife habitat; wilderness and wild and scenic rivers were rated as less important than hydropower and agriculture. Project participants rated ecological health second, followed closely by quality place to live; more of this group included timber production (25%), livestock grazing (12%), and economic opportunity (15%) as one of their top three. Eastside residents, who potentially would experience the greatest immediate impacts of ecosystem management, expressed priorities similar to the national population.

Steel and others (1994) explored a value dichotomy that they believed was central to explaining conflicts about Federal forest management: an anthropocentric or resource conservation focus that advocates wise use of forests for the betterment of humankind; and a more biocentric orientation that assumes the natural environment has inherent worth apart from any human use. Sociodemographic characteristics, self or group interests, sociopolitical orientations, and geographical location (residence) are some of the variables influencing whether people hold the "more traditional anthropocentric view of forests" or the "emerging biocentric view."

To test the role of residence in value orientation and to better understand related attitudes and beliefs, Steel and others (1994) conducted a survey of two populations: the national public and Oregon residents. To assess value orientations, they used an eight-item scale of statements about the relationship of people to natural resources. People indicated their levels of agreement or disagreement with each item; scores were then combined to yield a total score for classifying respondents as anthropocentric, biocentric, or intermediate.

The authors concluded that Oregonians, and especially the Nation's public, strongly supported a less commodity-based, more ecologically sensitive approach to Federal forest management. Both the Oregon and national samples tended to be more biocentric than anthropocentric, but the national sample was significantly more likely to have stronger biocentric views toward forests than was the Oregon sample. Younger respondents, women, members of environmental groups, and liberals were more likely to have biocentric orientations toward forests than were older respondents, men, people dependent on the timber industry, and self-described political conservatives.

The authors reported that Oregonians and national residents both responded in an anthropocentric manner to only one of the eight items: "Forest resources can be improved through human management." This apparent agreement, however,

could have resulted from different interpretations of the question; agreement with this statement does not necessarily indicate an anthropocentric viewpoint. One could assume that humans have altered some forest environments to the point they cannot recover if left unmanaged. If the goal is to restore forest health, for example, human intervention would be necessary to eliminate exotic species and allow the return of native species.

Steel and others also asked about attitudes toward nine Federal forest policy statements regarding wilderness, clearcutting, old-growth forests, tradeoffs between timber workers and old-growth preservation, and the role of economic vitality of rural communities in decisions. The results were not surprising. People with biocentric orientations were more likely to support bans on clearcutting, creation of wilderness, and protection of old-growth areas. Anthropocentric thinkers were more likely to support setting aside endangered species laws to preserve jobs, or making economic concerns a higher priority in forest decision-making. However, differences emerged between the Oregon and national samples. Anthropocentric thinkers who were Oregon residents were more likely than their national counterparts to support human uses of forests. For instance, 80 percent of the Oregon anthropocentric respondents agreed that endangered species laws should be set aside to preserve timber jobs, compared to just 31 percent of the national anthropocentric thinkers.

The CRB survey (Brunson and others, n.d.) included five items taken from the eight-item scale discussed above in the Oregon and national survey. In general, the responses of all four population segments (national public, westside residents, eastside residents, and project participants) indicated a preference for biocentric over anthropocentric viewpoints. Eastside residents tended to be slightly less likely to reflect biocentric value orientations.

The Economic Assessment (chapter 6) suggested that estimating economic benefits is easier for market resources than for nonmarket resources, meaning that utilitarian values are more easily measured than biocentric ones. However, literature on natural resource and recreation economics is replete with technique examples to estimate dollar values of nonmarket resources, such as non-use values associated with knowing a resource is there (Duffield and others 1994). Dollar estimates associated with non-use or passive use values of natural resource settings are 3 to 20 times greater than those associated with direct recreational use, a notion supported in the policy arena as well (Allen 1985). Duffield and others (1994) suggest that motives for holding non-use values, often referred to as preservation and existence values, include general environmental concern, altruism, and past recreational use of natural resources.

A national values poll commissioned by the Forest Service (Hammond 1994) was designed to discover major trends and themes based on people's responses to broad statements about public forest and grassland uses. The results were used by the Forest Service's Reinvention Team in considering agency changes. Several major themes emerged from the values poll. First, respondents wanted to maintain healthy public forests and grasslands. This was called the overriding theme, because people were more concerned about reaching this goal than about who did it or how it would be accomplished. The authors stated: "Apparently, most people in America are convinced that maintaining healthy public forests and grasslands is somehow tied to the quality of life in this country."

Second, respondents wanted to create recreational opportunities on public lands. Although the poll did not ask for specific activity or setting of preferences, people rated recreation highly. Curiously, Hammond supported this point in part based on respondents' agreement with the following statement which seems to make a different point altogether: "The Federal Government should balance the wilderness and recreational use of public lands with logging, mining, and grazing uses."

People believed that maintaining healthy public forests should be a primary Federal management objective and that human intervention was necessary to meet this goal. They believed that Federal

agencies, such as the Forest Service, best represent their interests in forest management (47%), compared to 21 percent who said they are best represented by special interest groups, 13 percent by state agencies, and 5 percent by the Congress.

Respondents also valued not compromising the long-term health of public forestland for short-term gains. Explaining this theme, the author stated: "The people in this country also seem to realize that the public forests must be preserved for future generations and that what is done today will impact tomorrow...Any short-sighted excesses of the past will not be permitted in the present and the public expects the Federal Government to be responsible for conserving forests for those yet to be born." A related theme, that the consumer needs of the American public should not be satisfied at the expense of the health of public forests, indicated to the author that the general public wanted to place consumer interests within the context of long-term health of public lands.

Finally, people believed that the Federal Government should assist state and local government agencies and private landowners in managing forestlands. This theme indicated two types of responses: (1) people want the Federal Government to discover and disseminate information needed to solve resource problems; and (2) people feel that "those who live in closest proximity should play the primary role in the way public forests are utilized and managed." These responses suggest a preference for Federal agencies to work in partnerships with local governments and communities to reach decisions, a finding consistent with other surveys of both local and national publics.

Sense of Place

One value not considered uniformly in past forest and rangeland plans is sense of place, which includes the meanings and images that regions, areas, or specific locations on the landscape have for people. Ecosystems are the intersection of natural forces, social and economic relations, and sociocultural meanings (Williams 1995). Ecosystem management recognizes the social construction of nature; space becomes place when people create and attach meaning to it (Williams 1995).

Place is how people relate to and express an experiential understanding of geographic areas. People's perceptions of "place" or the physical area with which they interact, whether for a few minutes or a lifetime, give that area special meaning to them, their community, and their culture. Humans associate and interact with geographic areas, whether physically, spiritually, or through various media, and form long-term bonds of attachment with these places. Research shows that place attachment is customarily passed down through generations, becoming part of people's heritage. Place is an integral component of community life because collective definitions of socially important places help to form and maintain community bonds and priorities.

Galliano and Loeffler (1995) stated: "Perhaps one of the most significant characteristics of ecosystem management is its ability to substantiate the emotional and symbolic meanings of natural resources on our country's public lands." The values and meanings of the Basin's places serve as significant factors reflecting the human dimensions of ecosystems and serve as links between social experiences and geographic areas. Recognizing this important element, the *Framework for Ecosystem Management in the Interior Columbia Basin* (Haynes and others 1996) provides a strong alliance between ecosystem management and the social realities of place by having one of its five primary objectives be to "manage for the human sense of place."

The notion that people define landscapes based on their meaning, utility, and image is not new. Through their traditional subsistence economy, Indian peoples gained a very detailed knowledge of the land, including locations of each resource needed to sustain their lives and culture. Attachment to ancestral lands is reflected by the return to favored areas and campsites during annual subsistence rounds. Place importance is also reflected by language such as place names, which relay knowledge of the land by referring to a specific place's plants and animals, the actions of its people, its spiritual role, or other important site characteristics.

Understanding the concept of place in ecosystem management allows managers to more actively inventory and understand the meanings that people attach to the lands and resources within the manager's administrative jurisdiction. The notion of measuring and incorporating human sense of place into public land management is relatively new and has yet to be adopted uniformly by any land management agency. However, there is ample literature pointing to the importance of place that suggests ways to measure and manage for it (Andrews 1979, Brunson 1993).

Williams (1995) defined four different types of meaning attached to landscapes:

- Scenic/Aesthetic—Use of formal models from landscape architecture and environmental psychology to map physical characteristics, landscape themes, visual character, and scenic integrity of various landscapes. The current scenery management systems of the BLM and FS incorporate methods to measure and map these types of place meanings.
- Activity/Goals—Traditional utilitarian philosophy of natural resource management, which assigns meanings to geographic units by assessing their capacity to promote behavioral and economic goals. One example is the Recreation Opportunity Spectrum, which identifies recreational activity-oriented meanings. Such meanings, however, include other factors such as meanings associated with production of commodities. Typically, resource management agencies have developed extensive methods of identifying, mapping, and managing these types of place meanings.
- Cultural/Symbolic—Human emotional, spiritual, and symbolic identification with place, often referred to as the sense of place where natural resources are valued not only for functional purposes, but also places to which people, as a community, are attracted and become attached.
- Individual/Expressive—Potential for people to assign highly individualized meanings to places as a mechanism by which they construct and affirm a "sense of self."

Just as ecosystems must be viewed as hierarchies, so must places. The four approaches listed above can be viewed as different methods for assessing place meanings, ranging from the very broad and tangible (scenic/aesthetic) to the more familiar, often personal and intangible (individual/expressive). A BLM or FS unit manager may consider all four meanings when preparing a watershed or site analysis where the geographic area is relatively small and the desired level of specificity is high. At larger scales, such as the Basin ecoregion, where place inventories are comparably extensive, it would be unreasonable to attempt identification of individual/expressive place meanings. Because neither cultural/symbolic nor individual/expressive meanings can be easily mapped using geographic rule-based systems, these two meanings can only be identified through interactive processes such as those used by Galliano and Loeffler (1995).

Place assessment is a way to inventory the locations, names, and broad attachments that many peoples share for geographic areas within the Basin. Surveys of resource users and communities have demonstrated that the strength of place attachment can be quantified for multiple places and at multiple geographic scales (Williams 1995). Scenic/aesthetic and cultural/symbolic meanings of place were successfully mapped and defined at both a mid-scale (in the Yakima and Silvies basins) and at a Basin-wide scale (Galliano and Loeffler 1995). The issue of scale in defining places having special meaning is important (Tuan 1974). Although Galliano and Loeffler (1995) were successful at using ecological subsections as proxies in their effort to map place meanings in terms of scenic/aesthetic elements across the entire Basin, they recommended mapping places at a finer, more meaningful scale such as the community scale. The finer scale, which provides a positive basis for people and managers to understand the multiple meanings and values that can be attached to landscapes, is a sound basis and methodology for mutual learning and collaboration. Sense of place is particularly meaningful at the community scale; residents' common definitions of local places are the characteristics contributing to community cohesiveness and definition.

Attitudes and Beliefs Relevant to Ecosystem Management

Because understanding people's perceptions of ecosystem conditions helps to explain their attitudes toward ecosystem management, the following text describes both beliefs and attitudes. Many people believe there are problems with ecosystem health in the Basin. The CRB survey contained a question that first informed respondents: "Recently there has been a lot of talk about whether public lands in the western U.S. are deteriorating due to current management practices." Respondents were asked to indicate on a seven-point scale whether they believed that no serious environmental problems existed, or that serious environmental problems already existed in the western United States. The clear majority of respondents (between 70 and 78%) in all four samples fell on the "serious problems exist" side of the scale, with project participants expressing the strongest attitudes. Although the rather severely worded introduction may have influenced respondents, the results nonetheless suggest that the public supports reexamination of Federal land management practices.

Regarding beliefs about forest health, Frederick and Schneiders (1994) found that 58 percent of a national sample rated the Nation's forests as healthy, although just 13 percent of these rated forests as "very healthy" and 45 percent believed forests were "somewhat healthy." Of the 27 percent who believed U.S. forests were unhealthy, only 5 percent said they were "very unhealthy." Across every region, people tended to rate forest health conditions in their own part of the country as better than the Nation as a whole. For example, in the Pacific Northwest, 72 percent rated forests as healthy or very healthy, and 25 percent believed forests to be somewhat healthy or very unhealthy.

Comparable results were found in a poll of Idaho voters conducted for the Idaho Forest Products Commission (Moore Information, Inc. 1994); 58 percent rated forests in the state as healthy, and 32 percent believed they were unhealthy. Southwest Idaho residents, however, were either evenly divided in their beliefs or thought that the state's forests were not healthy. Men age 45 and older were less likely to believe forests were healthy (47%) than were younger men (60%) or women of all ages (62%).

Brunson and Steel (1994) found that "little research has examined public knowledge or beliefs about rangelands." Their study, one of the exceptions, found that "the public believes rangelands are overgrazed, seriously eroding, losing riparian vegetation, and that conditions are getting worse instead of better." Not surprisingly, this sample favored managing rangelands for broad ecosystem functioning rather than livestock production. They favored increasing fees to "fair market value" for grazing on public land, but wanted fees phased in to allow ranchers time to adjust. This desire reflects the broader trend of public concern to focus on restoring ecosystems, but in ways that consider and mitigate related socioeconomic impacts.

Although Brunson and Steel believed that the results "reflect a broad national trend toward increasing environmentalism." Respondents felt that a high priority should be given to the needs of affected local communities when making decisions about Federal rangeland management. The respondents distinguished communities from affected local industries, whose needs were perceived to have much lower priority. The authors noted that the results, in general, paralleled those of an earlier study on forest management, except for the increased proportion of respondents who were unsure about their feelings. This is consistent with other surveys, likely because range management issues and the BLM are less known to the general public than are forest management issues and the Forest Service.

Active and Passive Management Approaches

Brunson (1993) stated that ecosystem management would be most acceptable to people who believed it to be a more natural management approach. The challenge, he believed, would be to convince people that active human manipulation is more acceptable than letting nature take its

course. This issue was reflected in one Basin EIS issue statement about whether ecosystem and forest health restoration is possible and, if so, is it better to actively manipulate ecosystems and mimic natural disturbance regimes, or is it preferable to "let nature heal itself."

A national survey on forest management (Frederick and Schneiders 1994) found that 52 percent favored human management of forest areas, while 40 percent said nature should be allowed to take its course. This preference for human management was even stronger among Pacific Northwest residents (59% and 28%, respectively).

Ecosystem Disturbances

A major emphasis in ecosystem management has been to mimic natural processes, or at least to design activities based on knowledge of natural disturbance patterns. It is important to understand how attitudes toward such natural processes relate to attitudes toward management. Brunson (1993) hypothesized such attitudes may be one possible reason for people not to accept ecosystem management: "...natural processes being simulated (disturbance regimes) carry a negative label." This hypothesis has been supported in studies of people's attitudes toward many disturbances, including fire, diseases, and insects, as well as by public reactions to isolated Federal or state agency actions.

Much of the available research on people's attitudes toward specific ecosystem processes and management actions is summarized below to provide decision-makers with a better understanding of the public's attitudes, as well as factors influencing their attitudes, specific to fire, timber harvest, insect and disease infestation, and roads.

Fire—One national survey (Frederick and Schneiders 1994) found that 55 percent of respondents thought the Forest Service should attempt to extinguish all fires to preserve as much of the forests as possible, while 36 percent said more fires should be allowed to burn their course because fires are a part of the forest's life cycle. Pacific Northwest residents had similar opinions, but by a closer margin (46% and 39%, respectively).

The same survey found support for using controlled fire; 49 percent favored use of controlled fire by Federal agencies to thin forests so wildfires are less damaging, compared to 42 percent who opposed controlled fire use due to concern about potential for fire spread and air pollution from the resulting smoke. Support was stronger in the Pacific Northwest, with 54 percent favoring use of controlled fire compared to 38 percent opposed. Women were more likely to favor extinguishing all fires and were less supportive of controlled burns than were men.

The CRB survey informed respondents that "some people favor the introduction of fire in Federal forest lands to control disease, insects, and excessive fuel levels. Others suggest this use of fire is unnecessary and dangerous." This question was one of the few that the four samples agreed with completely. The top choice of all four samples, by a wide margin, was: "We should suppress wildfires in Federal forests managed for timber; however, controlled fire may be used to protect forest health." The second choice of all four groups was: "We should suppress wildfires in Federal forests only if they threaten human lives or property; otherwise, we should allow fire to resume its natural role in forests."

The third-ranked statement was: "We should suppress fire in all Federal forests managed for timber, and use pesticides or salvage logging if forest health is endangered." Although this statement was rated as significantly less attractive than the second choice for most samples, eastside residents ranked it only slightly lower. It may have been less attractive due to its reference to pesticides, based on other responses showing that chemical pesticides were opposed strongly by all groups. This statement's appeal to eastside residents may be related to its reference to salvage logging. Far behind the other options was: "We should suppress fire in all Federal forests." This was favored by less than 10 percent in each sample. Between 10 and 18 percent had no opinion.

Interpretation of these responses is hindered by the noncomparability of the various statements. For example, one statement included three separate elements, including one element that was not mentioned in any other statement. This noncomparability creates difficulty in determining to which aspect of the question people were keying their response. Nonetheless, the groups' rare agreement suggests that support for use of controlled fire to protect forest health may be acceptable to diverse publics.

Beliefs about the causes of wildfires can influence people's attitudes toward fire management. Moore Information, Inc. (1994) asked Idaho voters which of five factors they believed contributed most to the severity of forest fires in Idaho the previous summer. Fifty percent attributed fires to the drought, 19 percent to acts of nature, 12 percent to lack of forest management, 11 percent to over-dense timber stands, and 1 percent to insects and disease.

In a review of public perceptions of air quality in the Basin, Miller and Deller (1994) found that the public believed that wood stoves, traffic, dust from unpaved streets, and agricultural burning all contributed to air pollution. The specific location and purpose of the various surveys determined the nature and range of responses. The authors did not identify studies about perceptions of smoke from natural or prescribed fires, but did mention that providing the public with specific information about the reasons, location, timing, and effects of a prescribed burn results in a higher level of acceptance.

Timber harvest—Perhaps the most controversial of all forest management actions is timber harvesting on public lands. Moore Information, Inc. (1994) found that 76 percent of the Idaho voters who were surveyed were supportive of "thinning and other forest management techniques as a way to improve forest health and reduce the potential for catastrophic wildfires." Although the authors concluded that survey results indicate "widespread support for thinning among all voter subgroups," the question assumes that thinning always improves forest health and reduces fire risk. More important, use of the term "catastrophic" is likely to provoke support regardless of how people actually feel about the issue; nearly everyone is opposed to a catastrophe. We can still assume, however, that many Idaho voters support thinning practices. Thinning was also found acceptable in a survey of Blue Mountain area residents (Shindler and Reed 1996).

A related question asked people which of the following two positions did they agree with most:

- Thin forests to improve conditions for remaining trees and also for wildlife, provide jobs, reduce wildfires, and make forest conditions more similar to presettlement conditions.
- Allow nature to take its course in the forests by not harvesting timber under the assumption that logging can harm the scenic and recreational value of the forest area, the fisheries, and wildlife.

The first statement was the choice of 71 percent, and the second was chosen by 17 percent. Based on this ratio, the authors concluded that Idaho voters support thinning forests to improve forest conditions over allowing nature to take its course. They pointed out, however, that a nationwide survey posing the identical question found considerably less support for thinning (51%), compared to allowing nature to take its course (43%). Follow-up discussion with respondents would be valuable to determine which of the many attitudes and beliefs inherent in these complex statements led respondents to select one over the other.

In their nationwide survey, Frederick and Schneiders (1994) found divided views regarding salvage logging: 48 percent agreed that logging in burned-over areas should proceed rapidly to reduce the risk of further fire and that legal challenges should be limited so the trees do not decay and lose their value; 43 percent agreed with the statement that logging in burned-over areas should proceed only after comprehensive environmental review, public input, and resolution of legal challenges, even if the value of the timber is at risk.

A related question informed people that after forest fires, a considerable number of dead trees remain in the burned-over areas, and asked people to choose between two statements:

- Log some dead trees and use the timber sale revenue to help pay the cost of fighting wildfires and to restore the forest and wildlife habitats.
- Leave all trees in the forest to decay to provide nutrients and support for forest wildlife and the new plants that reestablish the forest following the fire, and lose revenue that logging would have brought.

The first statement was favored by 51 percent, and the second by 43 percent; support for salvage logging was stronger in the Pacific Northwest. The relatively narrow margin of support nationally suggests that people are persuaded by both arguments. One key term may be "some dead trees," which connotes very limited entry and impacts, compared to logging "most or all dead trees" to which people may have responded differently.

The CRB survey contained several questions related to logging practices that could be used to meet ecosystem goals, including selective logging, clearcutting in burned or insect-infested areas, selective cutting in burned or insect-infested areas, and selective harvesting to prevent forest diseases and infestations. Of the people who had an opinion, the greatest support among all four samples was for selective harvest methods to prevent forest diseases and infestations; the only opposition, which was slight (14%), was from project participants. All four samples also supported selective logging practices in general and were just slightly less supportive of selective cutting in burned or insect-infested areas, which was opposed by about 15 percent of the respondents in each sample. The greatest diversity of opinion was about clearcutting in burned or insect-infested areas; respondents in all samples were nearly equally divided, although eastside residents showed the strongest support.

Insects and disease—The CRB survey asked whether people agreed or disagreed that "insect outbreaks on public lands should be allowed to run their natural course." All four samples disagreed, at rates ranging from a high of 64 percent (eastside residents), to a low of 51 percent (westside residents). Except for the project participant group, more people were neutral than in agreement with the statement. This was especially true for the national group, 31 percent of whom were neutral, possibly due to their not understanding or having strong beliefs regarding the issue and its implications. The project participant group held the most extreme viewpoints, with just 12 percent being neutral. The widespread disagreement with the statement seems reasonable whether or not respondents understood the role of insects in forest ecosystems. When questions include the phrase "insect outbreaks," which has a negative connotation, disapproval is fairly assured in the absence of compelling information to the contrary.

Roads—Frederick and Schneiders (1994) asked national respondents to choose between two statements regarding managing forest areas where roads have not been built. Fifty-five percent did not favor building roads, stating roads create soil erosion and destroy the forest's wild nature; 40 percent favored building more roads to increase access for fighting fires, allow the forest to be thinned, and support recreational uses. Pacific Northwest residents slightly favored building more roads (48% to 46%). Women were more strongly opposed to constructing new roads than were men; Democrats and Independents were much more opposed to new road construction than were Republicans, who were evenly divided on the issue.

Another CRB survey question about roads asked people whether they supported road closures in ecologically sensitive areas where recreation occurs. Although all four samples supported this position as a strategy to improve conditions on public lands, about 26 percent from each of the eastside and participant samples opposed it.

Attitudes Toward Endangered Species

The Endangered Species Act has a history of broad public support. In a recent nationwide poll (Roper Starch 1994), 51 percent of the American public felt that regulations protecting endangered species of plants, animals, and insects have not been sufficient; 16 percent believed the regulations have gone too far; and 26 percent said the balance was right. The question was one of five elements of environmental concern; the others addressed air pollution, protection of wild or natural areas, protection of wetland areas, and water pollution. More people said that endangered species laws have gone too far compared to laws in the other four areas. Similarly, protecting endangered species was the least likely of the five areas to be viewed as not going far enough. In 1992, a higher proportion (31%) said there was a balance, fewer (11%) said laws and regulations had gone too far, and the same proportion (51%) said laws had not gone far enough.

A related question described the Endangered Species Act as requiring "the Federal Government to take whatever steps are necessary to prevent any type of plant, animal, or insect species from becoming extinct, even at a cost to landowners, businesses, or the local economies where species live." The question posed was: "Do you agree all endangered species of plants, animals, and insects should be saved regardless of the costs, or do you think the policy should take cost into consideration?" Nearly two-thirds (63%) said costs should be considered (compared to 50% in 1992); 29 percent agreed all species should be saved (compared to 38% in 1992), and 5 percent said it depends on the species.

In 1992, respondents were asked what they believed to be good arguments for saving species; 79 percent said the loss of life-saving medicines was a strong argument, 76 percent said that extinctions can upset the delicate balance of nature, and 63 percent said species have rights to exist and it is people's moral duty to help them. This reasoning describes some underlying values that lead people to support endangered species legislation.

A 1991 survey of Oregon residents (Market Decisions 1991 In: Duda and Young 1994) found that 66 percent of residents believed the Oregon Department of Fish and Wildlife "should operate a program to prevent fish or wildlife from declining to the point of becoming extinct, and protect and promote recovery of species that are already threatened or in danger of extinction."

The CRB survey also contained questions on endangered species management. One question asked respondents about their level of agreement with the statement "Greater efforts should be made to protect rare plant communities on public lands." In all four samples, more people agreed than disagreed. Agreement was strongest (65%) within the national sample and weakest (42%) for eastside residents. As with many other questions, the project participant group was the most polarized about providing more protection for rare plants on public lands; this group had the lowest level of respondents (13%) saying they were neutral, 49 percent agreeing, and 38 percent disagreeing.

Another CRB survey question was more explicit about potential tradeoffs: "Endangered species laws should be altered to maintain timber and ranching jobs on public lands." A majority (52%) of national respondents disagreed; just 29 percent agreed. Westside residents followed the same trend, but were more divided in their attitudes; 45 percent agreed and 39 percent disagreed. A majority of eastside residents (53%) agreed with the statement, while 30 percent disagreed. Again, ICBEMP participants were the most polarized; just 5 percent were neutral, 48 percent disagreed, and 47 percent agreed with the statement.

Overall, the results suggest that although remaining strong, support for endangered species laws and regulations may have decreased slightly over the past three years. This decrease may reflect that the public is increasingly concerned with seeking a balance between species protection and costs to society. This concern is especially strong among eastside residents.

One set of questions in the CRB survey was directed specifically toward salmon, many species of which are either listed or under consideration for listing. The four groups considered themselves to have very different levels of knowledge; 73 percent of the project participants, 43 percent of westside residents, 40 percent of the eastside residents, and just 13 percent of national residents said they were well informed about the status of salmon runs in the Pacific Northwest.

When presented with the general statement that greater protection should be given to fish, such as salmon, on public lands, all four samples agreed; the strongest level of agreement came from westside residents (72%) and national respondents (68%), compared to 55 percent of the project participants and 54 percent of the eastside residents. The project participant sample contained the largest proportion of people who disagreed (32%).

Respondents were presented with a list of 11 factors potentially contributing to the decline of salmon runs, and asked how much of a threat they believed each factor to be. National respondents were the most likely group to say they did not know. Three factors were perceived as the greatest threats by people both inside and outside the Basin: commercial ocean fishing by foreigners; water pollution; and dams. Habitat destruction on public and private lands was rated as a threat, but of less severity, and as a slightly higher threat on forestlands than on rangelands. Although patterns of response were fairly consistent across the four samples, project participants were far more likely to cite dams as a definite threat.

Moore Information, Inc. (1994) found that Oregon residents listed hydroelectric dams as the factor most responsible for declining salmon populations (39%), compared to too much fishing (19%), industrial and commercial development (18%), timber harvest activities (7%), and marine predators (7%). Idaho residents listed dams as the biggest factor in declines in Idaho's salmon populations (69%), followed by mining (40%), sport and Indian river fishing (39%), logging (35%), irrigation (31%), ocean fishing (29%), and grazing (19%). Just over half of the respondents (53%) agreed and 31 percent disagreed that there is adequate spawning habitat in Idaho rivers and streams to support increased populations of salmon and steelhead.

A follow-up question on the CRB survey asked about tradeoffs between recovery of salmon and issues such as employment, recreation, irrigation, and hydropower. The response format was a seven-point scale, with one end labeled: "Highest priority should be given to salmon, even if there are negative socioeconomic consequences," the other end labeled: "Highest priority should be given to socioeconomic considerations, even if there are negative consequences for salmon," and the midpoint labeled: "Salmon recovery and socioeconomic factors should be given equal priority."

About 40 percent of the eastside, westside, and national samples chose the midpoint response. Of the remainder, national and westside residents preferred giving priority to salmon by nearly a 3:1 margin, while eastside residents were equally divided on both sides. Project participants were again more polarized, with only 18 percent choosing the balanced viewpoint; 48 percent thought salmon should be given priority and 36 percent thought priority should be socioeconomics.

Attitudes Toward Tradeoffs in Public Land Management

As demonstrated above, one method of determining people's attitudes about natural resource issues has been to pose situations that represent tradeoffs between important values. However, one problem with many survey questions about tradeoffs is that they tend to set up dichotomies by asking people which is better, instead of exploring avenues of compromise or consensus. This approach casts the research and the policy issues being studied in a win or lose context, which may not represent actual true choices and can reinforce myths and stereotypes. In fact, most such debates do not really pit socioeconomic considerations against biological ones; they focus on conflicts about human values and priorities.

Despite this, one of the more common findings is that, when given the option, people will be optimistic that balanced solutions can be found. For example, a recent national poll (Roper Starch 1994) found that 90 percent of respondents agreed that: "We can find a balance that will allow economic progress and protection of the environment." However, more people agreed strongly with this statement in 1992 (58%) than in 1994 (49%). A related question asked people whether environmental protection and economic development could coexist or whether choices must be made; 66 percent believed the two could fit together, and 25 percent believed a choice was imperative. The response differences to these two questions are difficult to reconcile, pointing to the importance of subtle wording, such as asking people to choose between two options instead of asking for level of agreement with a single statement.

A follow-up question made the tradeoff more explicit, asking whether people believed economic development or environmental protection was more important when finding a reasonable compromise was impossible. Sixty percent thought environmental protection was more important, compared to 22 percent who gave more importance to economic development. When summarizing such results, it is important to distinguish very general questions such as this one from more specific questions that provide information on the type, location, purpose, costs, and methods of protection and development.

The Roper Starch survey also asked people whether they believed the only way to preserve wildlife, natural areas, and natural resources was to prevent development and restrict most other human activity in these areas, or whether these goals could be accomplished while being used to benefit the economy and the public. The first statement was chosen by 22 percent, and the second by 72 percent. This ratio may reflect another indicator that many people believe a balance can be found, or the ambiguous phrase "restrict most other human activity" could have been rejected as over-protection by many respondents.

The CRB survey contained several questions about tradeoffs, especially relative to salmon and endangered species. When asked about their agreement with the statement: "Survival of timber workers and their families is more important than preservation of old growth forests," national respondents expressed the highest levels of disagreement (54%) and eastside residents the lowest (36%). Eastside residents were the only sample that had a higher proportion of respondents agree with the statement than disagree. Somewhat surprisingly, the eastside residents had the highest proportion of people professing neutrality (25%). The sample of project participants again demonstrated their polarization; this group had the most people who strongly disagreed (30%), as well as the most who strongly agreed (22%).

Attitudes Toward the Federal Government

The continuing debate about the appropriate role of the Federal Government in shaping our society is a prominent political issue. For example, people who favor minimal government intervention in many arenas may oppose the active nature of ecosystem management, as well as the Federal Government's involvement.

Concern about the role of the Federal Government is reflected by county rights movements, which claim that Federal administration of public land is illegal. Starting with Catron County, New Mexico, in 1991, about 70 counties have enacted or are considering similar measures to change administration of public lands. In recent years, there has also been increasing social discussion about returning Federal lands to the states, or to American Indian tribes. However, an alternative reflection of county concerns and attitudes toward the Federal Government was the establishment and direction of the Eastside Ecosystem Coalition of Counties, a group created to provide input to the ICBEMP. The Coalition seeks to represent community interests, rather than individual viewpoints, and to provide a forum for discussing the public's opinion on community values. It is

specifically stated that the Coalition is not an advocate for special interests, nor a forum that trades one use for another, nor a forum for advocating elimination of the role of the Forest Service, Bureau of Land Management, or other federal agencies.

People's trust in the Federal Government is a major issue, because trust is an important type of belief influencing people's attitudes and behaviors about ecosystem management. It is therefore important to measure people's trust in the agencies and other institutions having roles in ecosystem management, such as other federal agencies, scientists, local governments and communities, national and regional publics, and the Congress. Attitude toward these institutions is another reflection of the ease or difficulty expected in obtaining public acceptance of ecosystem management.

Brunson (1993) pointed out that some people may be skeptical of ecosystem management, believing it to be a guise for finding "a level of timber harvest that reduces dissent to tolerable levels while adhering as closely as possible to the status quo." He concluded that public acceptance or preference for ecosystem management will be based partly on people's beliefs about its probability to actually produce desired conditions. Because ecosystem management is a new concept, people may not yet have formed beliefs about its effectiveness. Their beliefs may therefore depend more on past experiences with public agency attempts to mimic or work with natural events, which have had mixed success.

To many people already skeptical about the motives of the Federal Government, ecosystem management connotes attempts by the Federal Government to regulate private land uses. One reason for this concern is that, because ecosystems do not begin or end at public land boundaries, the assessment addresses resources on all lands within the Basin, not just Federal lands. Although the ICBEMP charter and other descriptive materials emphasize that the intent is only to apply ecosystem management to public lands managed by the FS and BLM, the act of inventorying resources on non-Federal lands makes many people suspicious that the next step may be increased regulation of those resources.

Level of Trust in Various Institutions

A fundamental issue affecting how the public perceives ecosystem management is the public's level of trust that agencies have the knowledge, willingness, and ability to implement required programs and activities. Many public participants in the ICBEMP have expressed skepticism about agencies' abilities. However, in one national survey (Frederick and Schneiders 1994), 74 percent of respondents gave the Forest Service favorable ratings compared to 8 percent unfavorable; favorable ratings were strong in every region across the Nation. The BLM was perceived less positively, with favorable ratings from 33 percent and unfavorable from 25 percent. The two agencies were rated by different numbers of people, because 43 percent of the national public either had not heard of the BLM or didn't know enough about the agency to state an attitude, compared to just 19 percent for the Forest Service. In the Pacific Northwest, where more people are familiar with the BLM, ratings remained about the same (42% favorable and 36% unfavorable).

Although the national sample had positive attitudes toward environmental organizations (64% favorable compared to 21% unfavorable), ratings by Pacific Northwest residents were lower (49% favorable and 46% unfavorable). Timber companies were viewed positively (36% favorable and 21% unfavorable), especially in the Pacific Northwest (57% favorable and 24% unfavorable). The same survey also asked about state forest agencies; although many respondents did not express an attitude, nationwide 47 percent (and 60% in the Pacific Northwest) gave favorable ratings compared to just 6 percent unfavorable.

Another national survey (Roper Starch 1994) found that 15 percent said they had a highly favorable opinion of most environmental groups, an additional 59 percent had moderately favorable opinions, and 23 percent had unfavorable opinions. Fifty-five percent had never contributed money to any environmental group, and 41 percent said they were unlikely to do so in the near future.

Moore Information, Inc. (1994) asked Idaho voters which of the following two groups did they agree with more about logging and the environment: forest products companies "who say that modern logging practices are an ecologically sound component of forest management plans," or environmental groups who say "logging is generally destructive to Idaho's forest environment." Fifty-six percent said forest products companies, 20 percent said environmental groups, 12 percent said both, and 7 percent said neither. However, the introduction to the question and characterization of each group's position really questions whether Idaho voters are supporting the statements or the respective groups.

When asked about the relative roles of the Congress and the Forest Service, 74 percent believed that the Congress should give agencies such as the Forest Service more flexibility to manage Federal forests in response to changing conditions; only 17 percent said the Congress should closely regulate such agencies because they cannot be trusted to manage forests wisely.

Finally, the survey asked about trust in scientists. Nationwide, university scientists were the most respected (by 43% of respondents), compared to environmental group scientists (21%), Federal forest agency scientists (16%), and timber company scientists (7%). However, in the Pacific Northwest, timber company scientists were twice as likely to be judged as credible than were scientists working for environmental groups. The authors concluded that trust in Federal agencies was strong and that the public takes a balanced approach to forest management issues: "The survey's findings provide encouragement for those who would attempt to educate the public and raise awareness of these issues, in order to promote better-informed public participation in the decisions which must be made in guiding forest management policy" (Frederick and Schneiders 1994).

The CRB survey obtained different results in querying about people's level of trust in institutions. Trust levels in government agencies were generally low in the Basin. For example, 42 percent of the eastside residents, 37 percent of the westside residents, and 31 percent of the project participants had moderate-to-great levels of trust in the Forest Service. Comparable figures for the BLM were lower: 31 percent, 26 percent, and 27 percent, respectively. The U.S. Fish and Wildlife Service received high ratings of trust from the eastside (47%) and westside (46%) residents, but was rated low by project participants (29%). Another survey (Roper Starch 1994) of Idaho, Oregon, and Washington residents showed very low levels of trust in government as well, but did not query about specific agencies. In the Roper Starch survey, the Federal Government as a source of information about the environment was rated fifth, after environmental groups, industry, the media, and university scientists.

In the CRB survey, other entities such as the Army Corps of Engineers, Bonneville Power Administration, and Native American governments uniformly received even lower ratings, moderately or greatly trusted by just 11 to 28 percent of respondents. Urban communities in the Basin, national public opinion, and federal courts also were less trusted, with most ratings in the 20 percent range. However, the distinction of least-trusted of all institutions was the Congress, in which just 8 percent of the eastside residents, 7 percent of the westside residents, and 6 percent of the project participants had moderate-to-great levels of trust.

The authors concluded that the general public places its greatest trust in local residents, the western United States public, the U.S. Fish and Wildlife Service, Forest Service, and university scientists. Rural community residents and university scientists were the only entities trusted more than distrusted by project participants. The project participants generally had higher levels of distrust than did other samples, which could be viewed as discouraging by the agencies, who would hope that increased familiarity would increase trust. However, project participants tended to have the most polarized views of any of the samples, suggesting that they began the process with strong viewpoints and, perhaps, were motivated by their lower levels of trust in the agencies.

A study of Idaho residents provided additional evidence for a relative lack of trust in the Federal Government, with 33 percent of respondents claiming the greatest confidence in local governments, 33 percent in state governments, and 20 percent saying they had no confidence in any level of government (Boise State University 1992). About 50 percent of respondents said that local government was the level most responsive to their needs.

Brick and others (1995) conducted a survey of residents in five counties surrounding Hells Canyon National Recreation Area (three northeastern Oregon counties: Wallowa, Baker, and Union; and two Idaho counties: Nez Perce and Idaho). They found that respondents reported having "some" to "a lot" of trust in community residents, local landowners, and locally owned businesses to manage the region's natural resources. This compared to "a little" to "some" trust in county commissioners, the FS, BLM, scientists, and state fish and wildlife departments, and to "no" or "little" trust in trade unions, non-profit environmental organizations, and out-of-state corporations.

People's beliefs about the trustworthiness of various institutions should correlate with their beliefs about assumed roles for institutions in influencing decisions about public land management, which would mean the greater the trust, the greater the influence. This hypothesis is only partially supported by available data. For example, the CRB survey found that eastside and westside residents, as well as project participants, believed that rural communities in the Basin, the western United States, public opinion, and university research scientists—all of whom they trusted—should have a moderate-to-great deal of influence in public land management.

The FS and BLM received much higher ratings on the measure about influence than on trust, with 46 to 56 percent of respondents from each population segment saying the two agencies should have a moderate-to-great deal of influence. The biggest difference, however, was the U.S. Fish and Wildlife Service (USFWS): 56 percent of eastside residents, 62 percent of westside residents, and 82 percent of project participants said USFWS should have a moderate-to-great deal of influence. These ratings may reflect people's acknowledgments of the agencies' legal responsibilities and authorities.

Respondents generally agreed that the Congress and Federal courts should have much less influence than Federal agencies or more-trusted institutions. This stance should be viewed as a positive finding and also as people's preference that the public and managing agencies work together to resolve issues, rather than relying on Congress to legislate solutions or the courts to make the ultimate decision. In other words, this could reflect a willingness to work in a collaborative fashion.

Steel and Brunson (1993) asked a national and an Oregon sample to whom government officials should be most responsive when making decisions about Federal rangelands. Both samples believed that government should be most responsive to affected local communities. National respondents believed that governments should then give the most attention to the following, and in the priority listed: national public opinion, government natural resource agencies, environmental groups, local affected industries, states' public opinions, and global and international opinion.

Oregon respondents believed governments should then give the most attention to the following: states' public opinion, local affected industries, national public opinion, government natural resource agencies, and environmental groups. Comparable results were reported in a national and Oregon survey regarding Federal forests (Shindler and others 1993). Respondents in the survey of five Hells Canyon area counties (Brick and others 1995) strongly agreed that "national forests belong to all Americans, but local people living near the forests should have the most say in management of the forests."

These findings appear to indicate that people favor downplaying the role of special interest groups. Perhaps this reflects agreement with a viewpoint expressed by Yaffee (1994) that while interest groups are important elements of our collective choice processes, their dominance is problematic in several ways: "Since they are primarily single-interest oriented, they promote the fragmentation of values and public purposes...that help agencies and decision makers craft effective policy direction."

These results show some of the similarities and differences between regional and national publics. Most interesting is the agreement that local communities should have a strong voice in decisions about Federal forests and rangelands. These results demonstrate the public's clear interest in having a greater role in natural resource decision-making. This involvement role is consistent with the public participation philosophy of ecosystem management, which requires close and frequent collaboration with the public and stakeholders in public land management (see following discussion on role of the public for more detail).

Attitudes Within the Forest Service

Several recent surveys of Forest Service employees provide a portrait of agency culture and the attitudes, beliefs, and values of agency employees (comparable studies of BLM employees were not found). A 1991 study examined value orientations of 1,900 Forest Service employees (Cramer and others 1994). A central finding was that "employees of the USFS tend to believe that the traditional priorities on timber and grazing are greater than their own values and the values of the American public. Furthermore, they believe that a greater priority ought to be given to recreation, wildlife, and water management rather than the traditional priority of timber." Employees believed that agency priorities were slowly aligning with the ecosystem values held by themselves and the public.

A 1992 survey of Forest Service line officers and staff (Mohai and others 1994) asked respondents to list the most important positive changes the agency had made over the last 10 years. Line officers and staff alike gave high ratings to increased responsiveness to the public; increased emphasis on noncommodity uses; workforce diversification; better working conditions, communications, and openness; and increased environmental sensitivity and awareness. However, the single most important change needed was one of the same ones: increased emphasis on noncommodity uses and decreased emphasis on commodities. The authors stated that the "vast majority of FS employees, both line and staff, feel the agency's policies have changed over the past 10 years. The vast majority see the agency headed in the right direction. However, they also feel the FS still has further to go."

Implications for Ecosystem Management

Discussions about ecosystem management clearly take place in a broad context; the role of the Federal Government, society's values about endangered species, and rights associated with private lands are all being actively debated. Although often stated as jobs versus the environment, commodities versus amenities, or species versus trees, the issues actually represent differing values regarding what benefits society should receive from public lands. Values are really the subject of debate, not just ecosystem management. Understanding and addressing people's values adequately is key to public and agency acceptance of ecosystem management.

Although people express concern about public land management, they look to science to provide many answers and seem willing to trust credible analyses of existing conditions and potential cures and results of scientific study of ecosystems. There are, however, varying levels of trust in scientists employed by different institutions. Although it is recognized that science can provide many types of data and analyses, the people and the institutions with management responsibility decide the use of those results. Science provides the information, not the decision. In other words, science is appropriate for describing problems, proposing techniques for resolving them, and measuring the associated impacts and risks. However, the conditions to be achieved are not decided by science, but are political decisions based on values. Ecosystem management's explicit attempt to blend science and values is both its strength and greatest challenge.

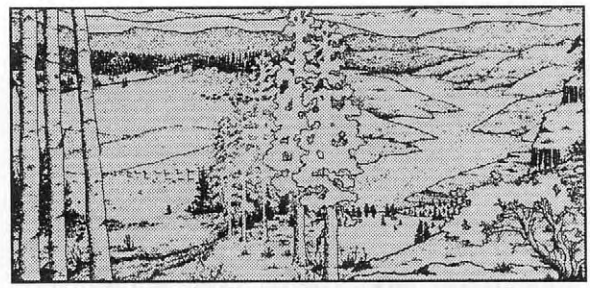
Survey research can help identify barriers to public acceptance of ecosystem management. For example, support for salmon recovery and a willingness to accept resulting socioeconomic impacts seem to be stronger than for endangered species in general. However, most people perceive that the major barriers to salmon recovery are dams and overfishing, rather than lack of suitable habitat. Given this perception, measures that just improve habitat on public lands may be viewed as ineffective and opposed by many if the impacts are perceived as too great.

Defining public lands in public terms such as sense of place, as well as scientific terms, has many advantages. First, incorporating human definitions and meanings about public lands into day-to-day management activities reflects that people are part of the ecosystem. Second, the process of defining and mapping places serves as a new and valuable way of seeking knowledge from the public in a systematic manner. Defining places and their meanings at a community scale extends well beyond traditional forms of public involvement (Williams 1995). Third, considering place in management activities could result in implementation of activities that are more acceptable and more easily communicated in terms that people understand.

Implementing ecosystem management involves continuous learning about people, their attitudes, beliefs, and values. Learning more about people's perceptions of public land and natural resource management and the reasons for those perceptions is a cornerstone of ecosystem management that explicitly includes people, as noted in the *Framework for Ecosystem Management in the Interior Columbia Basin* (Haynes and others 1996). Only a few relevant values are discussed here, which for some affected populations is just a start. People's tastes and preferences change, their perspectives on natural resources are influenced by knowledge, and their acceptance of differing management practices may shift as experience is gained with ecosystem management. One important way that ecosystem management integrates attitudes, beliefs, and values is in describing desired conditions. Development of ecosystem management alternatives requires developing alternative visions of social, physical, biological, and economic conditions that are desirable, and/or alternative ways of achieving those conditions.

Scientific research will improve managers' understanding of the values and interests that may be either adversely affected or positively enhanced by specific actions. Science enhances this understanding by providing a test for the acceptance of practices and the effectiveness related to various techniques, including public participation. Just as science plays an important role in helping to understand biophysical processes, science also has an important function in explaining the social and cultural aspects of decisions.

AMERICAN INDIAN PEOPLES: THEIR PLACE IN ECOSYSTEMS AND THEIR ROLE IN ECOSYSTEM STRATEGIES



The discussion of American Indians in the Basin focuses on their relationships with the natural environment and the trends regarding agency relations with the Basin's affected American Indian tribes. These topics have particular significance for Federal land managers for two reasons: (1) FS and BLM management actions affect resources and areas of concern to American Indians; and (2) the Federal Government holds certain trust responsibilities and obligations to tribes based on various legal agreements, including treaties, which have implications for ecosystem management. Although many ecosystem management issues are common to American Indians and the general public, the legal status of American Indians, the sovereignty of tribal governments, the nature of reserved tribal rights, and the unique concerns of tribes merit separate attention.

As members of both our collective society and frequently also of an Indian society, Native American peoples are well known to their neighbors. As described earlier in this chapter, American Indians comprise a higher proportion of the total population within the Basin (2.5 percent) than of the national population (just less than 1 percent). These populations are not evenly distributed across the Basin, but tend to be located either in association with Indian reservations or with large urban centers such as Boise, Idaho and Spokane, Washington (map 7.2).

There are 22 federally recognized tribes and numerous off-reservation traditional Indian communities whose aboriginal territories or reserved treaty rights are within the assessment area. Traditional Indian communities are communities either under the jurisdiction of a tribe or with cultural affiliations to one or more tribes and therefore lack federal recognition. An Indian person may be an enrolled member of a federally recognized tribe from the Basin or elsewhere, a member of a non-federally recognized traditional community, or someone with Indian lineage cultural ties to the Basin. For many Indian people, self-identity is based on familial ties and other associations that often include a large number of extended family relations. Such family connections provide socially acknowledged individual roles and the social cohesion that typically characterize tribal and traditional community life in the Basin.

Cultural History

Prior to non-Indian arrivals in the region, Basin peoples had successfully resided here for at least 12,000 years. Their cultures permitted adaptation to changing climates, environments, species distributions, and socio-political circumstances. Settlements were distributed across the region, each a member of a diverse array of indigenous cultures.

Map 7.2 - Indian reservations in the Basin.

The political autonomy of these communities and their relatively loose organizational structures meant that primary collective identity was based on village associations, shared lands, kinship ties, linguistic affiliations, and integrative political and economic systems.

Larger groupings of native peoples were later established by researchers based on shared cultural traits and language groups (families). Basin culture areas include the Plateau, which encompasses the Basin's northern half; and the Great Basin, which covers much of the Basin's southern half and a small area of California located just south of the assessment area's southwest corner. Language families included Sahaptin, Shoshonean, Paiute, Kootenai, Interior Salish, Chinookan, Lutumian, Pit River, and Shasta. Although these cultural groupings reflect and hold static the conditions that existed just before non-Indian contact, their influence extends into modern times and serves to bind certain tribes together.

Major population losses, due to introduced European diseases and then relocation of Indian nations onto reservations in the 19th and early 20th centuries, resulted in geographically isolated and distinct rural communities. These newly created communities were formed under federally imposed political structures called "tribes" and consisted of one or more Indian nations. Some federally recognized tribes, such as the Nez Perce and the Spokane, had to settle on a small area of their homelands. Other tribes had to share a reservation in a portion of their homeland with other Indian peoples, including some who may have been traditionally hostile, such as the Confederated Tribes of the Warm Springs and the Wind River Reservation. In other cases, Indian nations (such as the Kootenai, Paiute, Bannock and Shoshoni) were formally separated onto more than one reservation, usually in a small area of their homeland.

History of Legal Standing

Most American Indian tribes and bands were independent and self-governing societies long before their contact with non-Indian peoples or relations with the Federal Government. However, the degree and kind of socio-political organization varied. Consistently, first by European nations and later by the Federal Government, Indian nations have been formally recognized as distinct and independent political communities qualified to exercise powers of self-government by reason of their original sovereignty (Cohen 1971).

The relationship of the Federal Government with American Indian tribes is based on legal agreements between sovereign nations, federal recognition of their dependent sovereign status, principles of jurisprudence, international law, prevailing views of society, and government policies toward American Indians. The body of this formal relationship involves the whole span of United States history, ties with European culture, and conventions in law.

The United States inherited from England two important, albeit conflicting, policies that recognized Indian sovereignty within the context of the "right of discovery" concept, giving title to the discoverer, and made that title subject to Indian peoples' "right of occupancy." These policies are reflected in early documents. The Northwest Ordinance of 1787 (1 Stat. 50) reaffirmed federal recognition of Indian nations' sovereignty, as did the U.S. Constitution. Both policies also stipulated that only the Federal Government could negotiate treaties for cession of lands.

A series of Indian trade and intercourse acts, initiated in 1790 (1 Stat. 137) and permanently adopted in 1834, became the cornerstone of Federal Indian policy. Another significant early contribution to Indian law, known as the Marshall Trilogy, involved three Supreme Court decisions [*Johnson v. M'Intosh* (1823), *Cherokee Nation v. Georgia* (1831), and *Worcester v.*

Georgia (1832)]. These decisions established that: (1) only the Federal Government has the preemptive right to procure Indian land; (2) the Federal Government has trust responsibilities toward American Indian tribes; and (3) treaties take precedence over state law.

Treaty-Making Period

When the Oregon Territory was created in 1848, provisions of the Northwest Ordinance were extended to the new territory, confirming Indian title to land and recognizing lands not expressly ceded to the United States by ratified treaty or agreement as Indian Country. Soon after, an aggressive policy of securing land for non-Indian settlers motivated treaty-making efforts west of the Cascade Mountains. However, the Oregon Donation Act in 1850 provided patents (7,437 claims in Oregon and 1,018 in Washington) to land totaling 2.8 million acres to new settlers of the Territory prior to ratification of any Pacific Northwest treaties for tribal land cessions. This action, taken contrary to established United States policy, created considerable tension in the region.

The period between 1840 and 1870 was one of increasing tension between Indians and non-Indians in the region for a variety of reasons: large and dramatic declines in Indian populations due to recurring epidemics; non-ratification of Indian treaties negotiated with western Oregon tribes in 1851; encroachment upon and seizure of Indian lands authorized by territorial leaders and Congressional acts despite legal agreements with tribes; rapid loss of access to and destruction of Indian food resources; and persistent antipathy toward, and mutual fear between, both societies (Beckham 1984).

Treaties with Indian nations of the region sometimes addressed the United States' interest to maintain peaceful relations and to secure rights to travel through Indian lands (Treaty with the Eastern Shoshoni 1863; Treaty between the United States and the Blackfoot Nation of Indians 1865). The purpose of other treaties was more comprehensive and addressed land title status, creation of reservations, and Federal obligations to tribes.

In 1855, some Indian nations within the Basin entered into treaties with Isaac Stevens, then Governor and Superintendent of Indian Affairs for Washington. These ratified treaties provided for apportionment of land and natural resources and still serve that purpose today. Tribes affected by these treaties include the Confederated Tribes of the Colville and the Umatilla reservations; Confederated Tribes and Bands of the Yakama Nation, Nez Perce Tribe; Kootenai Tribe of Idaho; and the Salish and Kootenai Tribes of the Flathead Reservation. The Blackfeet Tribe, located adjacent to the assessment area boundary, also made treaties with Governor Stevens in 1855. These various treaties contain similar language reserving tribes' existing rights, such as this example from the Flathead:

> *The exclusive right of taking fish in all the streams running through or bordering said reservation is further secured to said Indians; as also the right of taking fish at all usual and accustomed places, in common with citizens of the Territory, and of erecting temporary buildings for curing; together with the privilege of hunting, gathering roots and berries, and pasturing their horses and cattle upon open and unclaimed land.*

In other Basin treaties and agreements, similar preexisting tribal rights were recognized, such as the right to access and use water sources, trap animals, cut and gather noncommercial wood, or engage in water power uses. While the scope and intent of the Stevens' treaties concerning rights to fish at all usual and accustomed stations and grounds in common with citizens of the Territory has been addressed through numerous court decisions, the geographical limits on other treaty-reserved rights have remained largely unexplored. Such terms in legal documents as "open," "unclaimed," "public lands," and "unoccupied" lands carry the implied condition that rights reserved on such lands could be exercised until the lands were closed, claimed, or occupied by United States citizens under the public land disposal statutes.

Lands ceded by treaty to the United States were typically delineated by non-Indians and were not accurate representations of tribal homeland areas;

customary land-uses routinely extended beyond the homelands of any particular Indian group. These reserved rights and treaty obligations are a significant factor in public land management. Tribes and traditional Indian communities have areas of interest that are based on prehistoric and historic land-use patterns; these extend beyond reservations boundaries and also often extend beyond lands that tribes ceded to the United States.

The explicit reservation of rights through treaty constitutes an assurance by the Federal Government that traditional lifeway-based land uses can be sustained. What is reserved are the activities that support an Indian community's way of life, not simply a resource use (Hunn 1990). Through historic legal agreements, tribes received promises of Federal protection for their lands, resources, and people. These promises constitute fiduciary responsibilities, also called trust responsibilities and obligations. Considerable benefits were gained by the Federal Government by establishing legal rights to Indian lands and providing a basis for economic, political, and social development in the Northwest.

Development of Federal Indian Policy

For more than two centuries, Federal policy toward Indian peoples has vacillated between two conflicting themes: (1) self-determination and an acceptance of cultural plurality; and (2) assimilation of Indian peoples into American culture and weakening of tribal governments. For example, those reservations set aside by treaty, executive order, or agreement, though sizable in the beginning, were systematically and significantly reduced in area as a policy of reservation consolidation and reduction prevailed between 1871 and 1928.

Passage of the Dawes Act in 1887 (24 Stat. 389) led to dramatic reductions in tribally owned lands, if not elimination of reservations in some cases. "Surplus" lands were identified on reservations and allotment plans were developed and implemented over the next few decades, leaving tribes dispossessed of much of their lands (Cohen 1971). Nationally, tribes lost 90 million acres, from 138 million acres down to 48 million acres, and the remaining Indian Country was severely fragmented. Effects of this Act and the allotment policy can be seen in the land ownership patterns of many reservations.

The allotment process was terminated in 1934 with a basic shift in policy away from forced assimilation to one of cultural and ethnic pluralism. The Indian Reorganization Act of 1934 (48 Stat. 984) provided an opportunity for tribes to adopt provisions for self-determination. The Act facilitated major revisions to federal policy by ending the allotting of Indian lands, extending the trust status to lands allotted, restoring unsold "surplus" lands from the allotment period to tribal ownership, ceasing the sale of Indian lands to non-Indians, promoting acquisition of lands for Indian use, establishing tribal enterprises, encouraging tribes to incorporate, providing revolving loans, and enhancing management practices for Indian forests and range (Cohen 1971).

This policy sought to promote reservation autonomy and self-determination and to preserve Indian cultures and values. For example, under the Indian Reorganization Act, the Quartz Valley Indian Community was established; also, the Fort McDermitt Paiute Tribe received economic assistance, allowing a grazing cooperative for tribal members to be developed through the Bureau of Indian Affairs. Although many Basin tribes accepted the Act and its provisions, some were not receptive due to concern about possible adverse effects to their legal rights and interests.

The Act fostered changes in many Basin tribal governmental structures. Constitutions and bylaws were adopted by tribal members and approved by the Secretary of the Department of Interior. These written laws were then implemented by elected officials who replaced the traditional tribal headmen or recognized chiefs. Elected councils were responsible for establishing economic development and resource management policies for reservation timber, rangeland, and farm lands.

The period between 1943 and 1961 marked another era of major changes and setbacks for tribes. With the Termination Act of 1953, a forced assimilation policy was again introduced. Reservations of selected tribes were terminated and lands sold, often to third parties. Federal recognition and services to these tribes ceased, and tribal sovereignty was terminated.

Often, however, much more was forfeited through the termination process. The Klamath Tribes, one of the Basin tribes affected, lost its federal recognition and its land base; their land base subsequently became the eastern portion of the Winema National Forest. The Quartz Valley Indian Community and the Northwest Band of Shoshoni Tribes were other Basin tribes terminated under this Act. Subsequently, all three tribes have been reinstated as federally recognized tribes. However, as for most tribes targeted for termination, effects on community and social well-being are ongoing. Little of their lost land base has been recovered, and the tribes are struggling to re-establish their governmental organizations and economic self-sufficiency to provide needed services for their members.

By the early 1970s, the termination policy had been rejected and was being replaced by one that promoted a renewal of tribal self-determination. Tribal communities across the Nation greatly benefited from actions of the Nixon administration that resulted in the Self-Determination and Education Assistance Act of 1975 (88 Stat. 2203). The Act provided substantial funding avenues for the tribes and granted authority for tribes to acquire lands adjacent to reservations. The Act also enabled tribes to pursue economic growth and to effectively assert a political role in the region.

Indian Case Law and Federal Administrative Policy

As tribes developed sophistication in dealing with states and Federal agencies, moving away from Bureau of Indian Affairs' domination in tribal government operations, they began to address issues relating to their legal interest and cultural relationship with natural resources; this sometimes involved lengthy and controversial court cases. The interpretation of tribal rights and property interests and the nature of the tribes' legal relations with state and federal agencies have developed into a large body of Indian law. Cases involving Basin tribes, dating from the late 1800s, often revolve around interpretations of treaty-reserved fishing rights.

One early Supreme Court case, *United States v. Winans*, 198 U.S. 381 (1905), addressed the right of Yakama tribal fishermen to fish at a well-known usual and accustomed fishing station when their access had been effectively denied by construction of a commercial fishing operation. In this case, the court's opinion stated in part:

> *...the treaty was not a grant of rights to the Indians, but a grant of rights from them - a reservation of those [rights] not granted [away to the United States government]...*
> *The contingency of future ownership of the lands, therefore, was foreseen and provided for—in other words, the Indians were given a right in the land—the right of crossing it to the river—the right to occupy it to the extent and for the purpose mentioned [such as fishing].*

The implied right of access to usual and accustomed fishing places extends to both private and public lands. In 1974, a U.S. Washington District Court (upheld by the Supreme Court in 1979) reaffirmed off-reservation fishing rights and their priority over other uses. Tribes were allowed up to a 50 percent share of harvestable fish passing by accustomed traditional fishing places. That case also recognized the sovereign right of tribes, rather than States, to regulate their off-reservation treaty rights. States regulate tribal use for conservation purposes only. An important aspect of this decision is the surmised right of tribes to take part in the protection of fish habitats and to help ensure that the resource persists and in quantities available for fishing. The case has been allowed to stand open, as does the similar *United States* v. *Oregon* case that began in the late 1960s, to resolve other disputes concerning exercise of treaty-reserved rights.

Numerous Federal regulatory acts passed in recent decades have increased the roles of tribes in public land management decision-making processes. These acts include:

- National Environmental Policy Act of 1969 (NEPA) (83 Stat. 852).
- American Indian Religious Freedom Act of 1978 (AIRFA) (92 Stat. 469).
- Archeological Resources Protection Act of 1979 (ARPA) (93 Stat. 721).
- Native American Graves Protection and Repatriation Act of 1990 (NAGPRA) (104 Stat. 3048).
- National Historic Preservation Act of 1966 (NHPA) (80 Stat. 915) as amended in 1992.
- Religious Freedom Restoration Act of 1993 (107 Stat. 1488).
- 1994 amendments to the Self-Determination and Education Assistance Act of 1975 (108 Stat. 4272).

The portion of case law pertaining to off-reservation tribal interests and federal agency land management is reflected in recent federal administrative policy and guidance. Interior Secretarial Order No. 3175, issued in November 1993, requires all bureaus and agencies to conduct trust responsibilities of the Federal Government, assess the impacts of their actions on Indian trust resources, and consult with tribes when impacts are identified. A White House memorandum issued in April 1994 emphasized the importance of government-to-government relations with tribal governments and the need to consult tribes prior to taking actions that may affect tribal interests.

The close of the 20th century bears witness to an extended period of increasing tribal political and economic involvement in mainstream regional society. Recent Congressional acts, executive orders, and federal court decisions have provided a basis for tribal renewal. The region's tribes have become active in seeking cooperative opportunities with states, federal agencies, and private landowners to address shared concerns about ecosystem issues and specific resource strategies. In keeping with each tribe's unique legal and cultural history, Indian people are forging individual paths toward socioeconomic development. The Federal Government is responsible for assisting tribes while still recognizing their sovereign standing.

The trust relationship between the U.S. Government and Indian Tribes is a part of the very fabric of federal Indian law. There are stringent fiduciary standards of conduct imposed on federal agencies in their relationships with Indian Tribes and Indian-owned assets. Meeting the Federal Government's trust responsibility is consistent with, although not the same as, meeting Federal obligations to all users, which are to protect and restore habitat necessary to maintain resources at healthy, sustainable, usable levels for present and future generations.

Place in Basin Ecosystems

The intense interest of Indian peoples and their tribal governments in the region's ecosystems and natural resources is founded in their long-term relationship and spiritual attachment to the land. Although many differences exist among the region's Indian communities, the various tribes hold a common belief about their relationship with the land and water (Dick 1990). All tribes understand that placement of their peoples in this landscape was by the Creator. Therefore, the Indian ancestry in the Basin extends from "time immemorial," a long-term attachment reflected in modern Indian culture.

Indian peoples are part of a large, loose social web strengthened by their shared experience of the Basin and associated ecosystems (Hunn 1990). Traditional subsistence economies were broadbased and included fishing, fowling, hunting, trapping, livestock grazing, and gathering of terrestrial and aquatic resources over very large geographic areas and a diverse range of important places (Walker 1993). The full range of resources needed to sustain families and Indian cultures was found in the socially and culturally important

ethno-environments and ethno-habitats of their homelands and traditional use areas. Living cultural traditions are embedded in these older understandings of the land, resources, landforms, ethno-habitats, and landscapes. Consequently, Indian peoples have accrued a "detailed, encyclopedic knowledge of their environment" through the millennia (Hunn 1990).

The intimacy and length of attachment to the land and the totality of landscape importance have contributed to a strong sense of place for Indian peoples. Lands sacred to Indian peoples and all the natural components of such lands participate together in a system of complex interrelationships. As such, places of significance are created by an intersection of natural systems, cultural uses, social systems, and cultural meanings. Knowledge of places is passed to each succeeding generation through oral storytelling, various performed rituals, and personal experiences. The importance of cultural places is embedded in the regional, although now somewhat melded, Indian cultures of the Basin. This "symbolic link" to the land is the context for maintaining community and cultural identity.

The world view of tribal communities is complex and includes both traditional native values and belief systems along with common Christian-American values. In general, traditional community values assert an interconnected natural world that includes people and the important interactions between Indian people and the land. Indian peoples may consider themselves caretakers of the lands, especially within their homelands, seeking protection of all resources (natural and cultural) and recognizing their collective significance.

Traditional peoples typically feel privileged to be able to eat native foods, be respectful of the Creator, enjoy the bounty of a diverse natural world, and listen to their elders and their teachings. In traditional belief systems, all life in the ecosystem shares the world's past existence and, with people, has intelligence and possesses moral rights and obligations. The benefits of a balanced and moral human society are extended to the entire local ecosystem.

Today, as in the distant past, tribal members and their governments hold considerable natural resource information in the form of both academic (many tribes employ resource professionals) and "indigenous" knowledge (DeWalt 1994). Elders have kept traditions alive through the practice of traditional culture and their counsel to younger generations. Besides providing cultural continuity and a form of sustenance and comfort for those who follow the traditional ways, these traditions help to sustain social cohesion and well-being. This extensive knowledge base is beginning to gain consideration in public land management, in part as a means to consider American Indian interests and public land-use needs.

American Indian cultural values toward public lands have tended to be subsumed under general categories, such as nonconsumptive or recreational land uses as understood for the general public. The primary cultural activities commonly include harvest of natural resources and associated activities: fishing, hunting, noncommercial wood cutting, gathering, resource processing, scouting for ethno-habitats and camping. Other public land-uses include religious practices or observances such as spirit quests, visiting unmarked graves, rites of passage, livestock grazing, and cultural tours.

Many American Indian cultural uses (such as camping, wildlife viewing, hunting, fishing, and berry picking) follow use patterns similar to recreational uses for the general public. However, differences in the purposes and social context (how such uses contribute to community social well-being and cultural integrity) often distinguish them. Resource acquisition activities such as fishing, hunting, and plant and mineral gathering are usually done within the context of traditional socio-cultural and economic systems. For many Basin tribes, a series of spring and summer root, salmon, and berry feasts mark high points on Indian religious calendars (Hunn 1990). In addition to these substantial feasts, numerous other occasions and events occur throughout the year

(often held in community longhouses, shorthouses, Indian Shaker churches, or private homes) that are supplied with traditional foods. These native foods are usually collected from a tribe's or traditional community's ethno-environment (area of interest or homeland) and its socially and/or traditionally significant ecological places (ethno-habitats), typically on reservations or public lands.

In 1805, Lewis and Clark observed that thanks were ritually offered to the first spring Chinook by the whole community (Spier and Sapir 1930). The mixture of religious, social, subsistence, and economic values for a variety of aquatic and terrestrial resources found then continues today. The degree that individuals and families participate in this lifeway often brings them esteem from the community and generally acts to provide cultural continuity, social cohesion, and individual well-being. Cultural relationships with aquatic species are reflected in the folk taxonomy and nomenclature of Sahaptin speakers, who classify fish on the basis of both their physical attributes and their Indian cultural uses (Hunn 1990). Fish, such as the Pacific lamprey and sculpin, while of little interest in American society, are still desired and respected by Indian peoples. Living cultural traditions in the Basin are exemplified by the fishing done from wooden platforms with dip nets just below The Dalles Dam on the Columbia River or on southern Washington's Klickitat River, and the traditional gaff-hooking at fishing stations on the John Day River and Catherine Creek in Oregon.

People's diets have become largely supplemented with other foodstuffs from American culture, but native game animals are still very much desired and consumed. Hunting as an activity also serves a greater socio-cultural role. For example, the taking of a youth's first game animal becomes the focus of a rite of passage in many tribes. Leadership roles may be aligned in traditional religious arenas based on the knowledge, skill, and proficiency of men who hunt for their communities.

In the past, principal meat sources were derived from wildlife, including deer, pronghorn, bighorn sheep, moose, elk, bison, bear, rabbit, and groundhog. These and other animals may still be considered powerful and able to help or hinder a person's ability to progress through life. The power to cure diseases often comes from animal spirits (Fowler 1986). Their importance in diet, economy, or religion varied by culture and was influenced in part by the natural range and population density of a species and people's cultural values for them.

Non-Indian fish and game laws may sometimes be viewed as meshing well with traditional Indian laws that prescribe the respectful taking of game life. At other times, when considering a man's community or family obligations and his right to exercise aboriginal and/or treaty-reserved rights, they mesh poorly. At times throughout this century, there have been public misunderstandings concerning tribal takings of fish and wildlife, which have resulted in complex and extensive Federal court adjudications in recent decades.

The importance of native plants has received relatively little recognition compared to other native resources. Yet, use of plant resources as food during the ethno-historic period was at least equal to, if not greater than, use of fisheries (Hunn 1990, Fowler 1986). In fact, food-plant resource locations, not fishery ethno-habitats, have been considered the critical variable for determining the placement of historic settlements in the Nez Perce region (Ames and Marshal 1980).

Plants and their communities and habitats continue to be valued. Plant parts are used for purification, ceremonial, subsistence, commercial, and medicinal purposes and for creating objects of personal use, trade, gift-giving, or sale (Fowler 1990, Schlick 1994, Wilke 1988). Plants play special roles in the physical and spiritual cleansing or purifying of a person, and may be found at various life-event ceremonies including daily sweats, funerals, and disciplinary actions. Like fish, plants are used commercially and for subsistence, ceremony, and trade.

Traditional use of plants reflects the resilience and persistence of common cultural themes in the Basin (Hanes 1982, Hunn 1990). In recent years, there has been renewed interest in traditional plant use by Indian people in parts of the Basin. Such an interest is seen as socially rewarding and important for maintenance of traditional activities, which provide cultural continuity and reaffirm Indian identity (Coulture and others 1986). For some Indian families and tribes, the practices and relationships associated with plants and plant ethnohabitats have continued unabated throughout this century.

Some plants identified by the ICBEMP as of tribal interest are characterized as habitat generalists and are associated with terrestrial community types found widely distributed in the Basin. However, plants are considered significant in a given culture on the basis of people's recognition of the plants and the values and/or uses assigned to the plants. As a result, many plant species are more significant than may be recognized by either the native folk biologist or American naturalist. For example, a plant such as camas may be known to live in several habitat types, but the plant normally occurs in the quality and quantity appropriate for harvest in only a few of those types. Also, a plant may occur in abundance in one tribe's area of interest. Though considered highly valued by a second tribe, the plant may not be valued in the same way, or to the same degree in the two different cultures.

Cultural activities occur frequently outside the purview of both the public and the land managers. The public's understanding of cultural plants or any competition for them has been restricted to a few plants, such as huckleberries, morel mushrooms, or beargrass. As a consequence, some plant ethnohabitats have not been recognized or valued in a shared way by the general society or the tribes.

Scablands are one example, with their characteristic areas of shallow rocky soils, sometimes interspersed with large mounds of deep soils. Agencies have often dismissed scablands as non-productive timber lands with limited range values, and even considered them unattractive or desert-like. Scablands have been used as convenient road locations or borrow pit sources. Most Basin tribes have a very different perception; to them, scablands are places high in biomass, which produce highly valued foods that are part of the traditional springtime focus in Indian life.

The cultural significance of the environment is much more complex than simply a source for food or medicine. It involves social values and meanings that interlace traditional societal, political, religious, and economic areas of modern native cultures (Hunn 1981). The culturally familiar natural world and its life forms support individual, family, community, tribal, and regional Indian identity, socioeconomic well-being, and quality of life.

Like most traditional societies, Indian communities have preserved a well-established tradition of close-knit groups. Individuals are recognized through kinship ties and roles, usually in the context of extended family structures. In general, communally controlled uses of lands and resources have evolved over the past century. For some tribes, such uses were greatly altered during the allotment policy period, when families and lands were separated into discrete areas across Indian Country. For those lands remaining in tribal ownership (not privately held), tribal laws and traditional laws prevail. On public lands still visited by traditionalists, communal values and traditional laws commonly dictate appropriate resource uses in addition to tribal, state, and federal laws.

Community health is affected by numerous factors, including economic opportunity; pursuit of traditional uses of the land; effective trust relationships with the Federal Government; and freedom to practice cultural, religious, and social customs. Shortfalls in any of these factors can potentially lead to various effects on the well-being of Indian communities. Accumulative, and at times substantial, adverse effects have been observed in the social history of Basin tribes. These effects have been reflected generally in social measures such as family cohesion, drug and alcohol abuse, depression, low self-esteem, suicide rates, crime, and physical health.

Implications for Ecosystem Management

In casual conversation and in substantial tribal government expenditures, the natural biophysical world still pervades Indian life. The continuance of American Indian/tribal land-based lifeways and Indian people's dependence on natural resources are expected to draw multiple Federal land management agencies into dialogue with affected tribes well into the future.

Tribal governments have an increasing influence on the formulation of public land policy because of their legally reserved and established rights, as well as their unique trust relationship with the United States Government. In recent years, there has been an increased understanding of the sovereign status of tribes and an increase in government-to-government relations between tribes and agencies. This has resulted in increased participation by tribes in all agency planning levels (policy, program, and project) as a consultation strategy. Also important are early involvement in project planning and opportunities to contribute to implementation and monitoring stages of projects.

Agency decision-makers should be familiar with potential effects on tribal interests and rights early in the planning process. Federal agencies are obligated to use their authority in safeguarding tribes' reserved rights and trust properties that are under their jurisdiction. Federal agencies cannot renegotiate or narrowly interpret the historic agreements between the Federal Government and tribes either in the consultation process, or through management decisions and actions.

Recognition of the uniqueness of each tribe has placed the burden on agencies to become knowledgeable of, and sensitive to, Indian interests on an individual tribal basis. There is great variation in demographic characteristics, and the nature of rights, interests, and dependence on public land resources between tribes. One implication is that an ongoing dialogue would benefit agency-tribal relations if established locally, over and beyond the notification and consultation requirements associated with NFMA, NEPA, NHPA, ARPA, NAGPRA, and other regulatory acts. Frequently, agencies have communicated with tribes largely in the context of stringent timeframes derived from statutes that apply to agency undertakings, rather than in desirable tribal consultation processes.

In addition, with passage of the Self-Governance Act late in 1994, increased emphasis is being placed on involving tribes in Federal management processes, including development and implementation of land-use plans, preparation of budget proposals, and conducting of other activities on public lands on behalf of the agencies. Tribes also now have the option of considering the incorporation of programs or functions (otherwise under federal agencies) into their tribal responsibilities if they are interested and can provide justification.

Use of the "ecosystems" concept essentially serves as a social "tool for holistic and empathetic thinking about nature," which takes into account the culturally based perceptions of science and society toward landscapes (Ingerson 1994). Whereas "science" is based on observable elements and processes of nature visible to anyone, the nature, significance, and importance of Basin landscapes for Indian peoples are prescribed by the full benefit of cultural systems and values. The natural world is "sacred" and seen in a manner that is both physical and spiritual, not subordinate to, nor dependent on, scientific analysis. Federal agencies consider the natural world in a linear way, with decision-making that relies on traditional hierarchial and compartmentalized thinking.

One implication of differing world views between agencies and tribes is that agency data collections are commonly performed in the language of natural or social scientists, which may not sufficiently accommodate the general complexity of human behavior or differing cultural world views and sensibilities. An important element in efforts to address these differences is maintenance of meaningful and ongoing dialogue. Ecosystem management provides a sound framework for incorporating traditional environmental knowledge into decision making, but the mechanism for accomplishing this needs to be developed.

Meaningful dialogue through an effective consultation process is an important issue among tribes. Consultation among federal agencies, tribes, and American Indian communities has its basis in Federal law, court interpretations, and executive orders. Consultation is not a single event, but a process that leads to a decision; consultation serves at least four purposes:

- Identify and clarify the issues.
- Provide for an exchange of existing information and identify where information is needed.
- Identify and serve as a process for conflict resolution.
- Provide an opportunity to discuss and explain the decision.

Consultation means different things to different tribes; it can be a formal process of negotiation, cooperation, and policy-level decision-making between tribal governments and the Federal Government, or a more informal process. Consultation can be viewed as an ongoing relationship between one or more agencies and one or more tribes characterized by consensus-seeking approaches to reach mutual understanding and resolve issues. It may concern issues and actions that could affect the government's trust responsibilities or other tribal interests. Developing a consistent approach to consultation that meets tribal needs is one of the challenges of ecosystem management.

The ongoing nature of consultation suggests that it is not appropriate to solve the issues of treaty rights by providing American Indians with sufficient land, resources, and access to sacred sites, with the assumption that the problem will then go away. Many tribal issues are based upon tribal needs, interests, and rights, which are taken from their histories, living cultural traditions, and modern lifeways. As agencies seek to consider and accommodate human needs in land management decisions, an understanding of the shared and unique relationships that both tribes and the general public have with landscapes will emerge. Ecosystem-appropriate decisions in land management would tend to follow from including these human values and cultural rules.

As agencies recognize that American Indians use places and resources largely because they are among those limited number of places and ethnohabitats shown and interpreted to them by elder relatives, land management may be able to better prioritize and meaningfully consider American Indian needs. Similarly, as agencies incorporate this understanding with tribal interests in healthy ecosystems, and the restoration or conservation of ethno-environments and habitats, apparent conflicts and lingering frustrations may be resolved.

Fundamentally, tribal governments and traditionalists have a well-established history of compromise and acceptance of changes to their homelands, even when changes have affected those places and aspects of their lifeways of most significance. American Indians struggle with many of the same issues in today's society that others face. As described by Bordewich (1996):

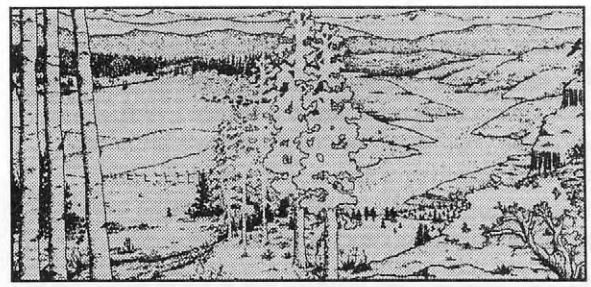
> *The Indian story does not end, of course, with an intellectual accommodation with the past or even a moral coming of terms. Indeed, the story does not end at all. Until now each age has imagined its own Indian: untamable savage, child of Nature, steward of the earth, the white man's ultimate victim. Imagining that we see the Indian, we have often seen little more than a warped reflection of ourselves; when the Indians have stepped from the roles to which we have assigned them, we have often seen nothing at all. There will be not an end to history, but an end may be put to the invention of distorting myth. With that may come the recognition that Indians are not, at last, poignant vestiges of a lost age, but men and women of our own time, struggling to solve twentieth-century problems with tools of our shared civilization. To see Indians as they are is to see not only a far richer tapestry of life than our fantasies ever allowed but also the limitations of futile attempts to remake one another by force. Stripped of myth, the relationship between Indians and other Americans may yet remain an uncertain one, an embrace that permits neither consummation nor release, but that is, nonetheless, full of hope.*

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COMMUNITIES: FROM DEPENDENCY TO RESILIENCY



Social and economic transformations that have characterized the Nation for the last two decades are particularly striking in the Basin because they are a stark contrast to traditional images of the American West. Technological advances, a growing population, improved transportation systems, and an ever-expanding set of global relationships lead to visible changes in the everyday lives of people in the Basin. Where there were saw shops there are now espresso bars; mountain bikes have replaced locomotives on old railroad grades; and recreational vehicles, not logging trucks, clog the roads. The overarching character of the Basin remains rural, however, with a population residing within a natural environment that, in a comparative sense, retains much of its original quality. Environmental issues, many of which are intertwined with the central social changes occurring nationally, confront the region's citizens directly on a daily basis. These issues also affect people living elsewhere that benefit from the natural resources and values in the Basin.

Change is intrinsic in both biophysical and human systems, and many changes in environmental policy result from shifts in public preferences for managing the environment. Rural communities in the Basin have been linked traditionally to natural resources, giving cause for people to be deeply concerned about what will happen to the places where they live. Concern about the future of rural communities, especially those with high employment in industries that utilize Federal resources, was reflected at a July 5, 1995 Congressional hearing held in Grangeville, Idaho. The Forests and Public Land Management Subcommittee conducted the hearing; its subject, "Endangered Communities," explained the subcommittee's concerns.

A key debate about ecosystem management is the role of the FS and BLM in promoting community well-being. There are questions about how to make tradeoffs when objectives for communities conflict with those for achieving desired conditions of other ecosystem components. There is also a need to know how the agencies can best assist communities in their own unique efforts to achieve and maintain social and economic health. Community well-being as a social goal needs to be better understood in relation to the health of other ecosystem components.

Community Definition and Relation to Ecosystem

The term "community" can have several definitions (Society of American Foresters 1989). Communities can be groups of like-minded people who gain strength from their relationships and associations. Communities of interest, as these groups are called (Sirmon and others 1993), can be people employed in a similar profession, people who participate in the same activities, or those who share a set of values; examples are the ranching

community or the whitewater boating community. People within these communities are linked because of their interests or concerns and may live in a wide variety of locations (Bates 1993). These different communities are important units of analysis for impact assessments because social and economic impacts are unlikely to be evenly distributed across diverse interest groups.

In this chapter, community has a more traditional definition: a spatially defined place such as a town. Community is an important scale for ecosystem assessments because communities are where people socialize, work, shop, and raise their children; communities are the focus of people's social lives. In public meetings conducted by the ICBEMP Science Team and in scoping and other meetings held by the EIS teams, people have repeatedly expressed concern that conditions and functions of communities and related places used and valued by residents be identified and considered alongside other ecosystem components. Although counties are an important political scale to consider, leaving the discussion at that level would mask the many differences among communities within a given county.

The Bureau of Census recognizes 476 communities within the project area, including 29 cities larger than 10,000 in population and 49 Census-Designated Places, which are locations that are unincorporated but have an identity to the local population. Of the other almost 400 small rural communities, 68 percent are communities of 1,500 or less, which is the smallest size class. These communities range in size from 22 to 1,500 people, with an average population of 520.

The Interior Columbia Basin Ecosystem Management Project collected many types of information about Basin communities, particularly the nearly 400 communities with populations less than 10,000. Harris and others (1996) have a complete description of this information, including community self-assessments consisting of interviews with 1,350 community leaders and residents in nearly half of the Basin's communities. In addition, because social and economic conditions in communities are intertwined, a profile of the economic structure of each community was developed (Harris and others 1996).

The following discussion describes Basin communities and their relationships to lands administered by the FS and BLM. It begins with an overview of the types of fundamental socioeconomic changes that Basin communities are experiencing, many of which parallel those occurring in rural areas nationwide. This is followed by a review of law and policy that allow the FS and BLM to address community issues and promote community well-being. Basin communities are then described in terms of their resiliency, which is their ability to effectively respond to change, along with the primary ways that FS and BLM management actions currently affect resiliency.

Economic and Social Changes Affecting Communities

Basin communities are affected by the social, economic, and political trends and conditions occurring in much of North America near the close of the 20th century. Although the history of human interaction with natural resources in the Basin has numerous stories of cultural adaptation to changing conditions, the rate of change has accelerated in the present era. Several changing elements are described below, along with implications for community development, expectations about Federal land management, and community relationships with the natural environment.

As described in the Economic Assessment (chapter 6), the region's economy has experienced significant change over the last three decades. In terms of job production, the Basin's economy has grown much faster than the Nation as a whole, although not quite as fast as the West's overall, while the importance of some industries that manage and extract commodities from the environment has declined over the last 30 years (Krannich and others 1994). For example, Rasker (1993) found that nearly all job growth in the Yellowstone Ecosystem in the period 1970 to 1990 was in industries other than traditional resource commodity sectors.

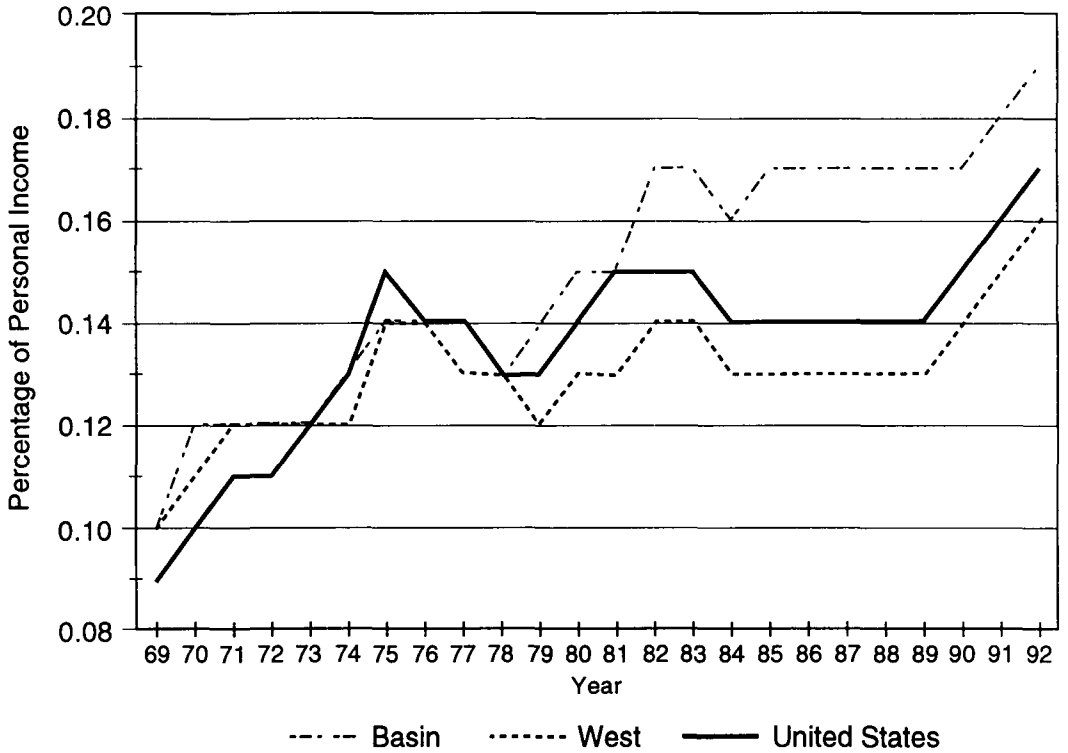


Figure 7.3 - Transfer payments have become increasingly important sources of personal income since the late 1960s. This trend is particularly pronounced in the Basin. (Source: Bureau of Economic Analysis, Regional Economic Information System).

Service industries have become more important at all scales and, along with retail sales, finance, insurance, and real estate, account for 61 percent of the Basin's job growth since 1969. Service industries and people receiving "nonlabor income" in the form of retirement annuities, interest, dividends, and other transfer payments have increased significantly. Figure 7.3 shows how transfer payments have increased in significance since 1969 for the Nation and the West. Although the Basin has followed those trends, the importance of transfer payments varies significantly. Rasker (1993) and Rasker and Glick (1994) suggest that the growth of transfer payments and service sector industries in rural areas is strongly related to environmental quality, an issue explored more thoroughly later in the section on amenities.

Except for urbanization, rural communities in the Basin have been subject to national social-demographic changes (Krannich and others 1994), as have larger cities in the Basin that have also seen increased growth recently. These changes include an older population, migration to smaller communities, increasing diversity of household types, increased poverty, and the shift toward occupations in service industries. Increased population growth from in-migration poses a whole set of challenges to rural communities, as well as to public land management.

There is a growing perception that decisions affecting the viability of local communities tend to be increasingly more remotely located from the community, producing a feeling of powerlessness.

Warren (1978) stated that "local communities are being engulfed by forces which they cannot control...less and less of what goes on locally is subject to the collective decisions of local people." During the latter part of the 20th century, the focus of control for many industrial and retail sectors shifted away from local and rural communities, resulting in increased dominance of nonlocal decision-making in local affairs.

Blatner and others (in press) suggested these trends result "in a double bind in which rural communities appear to be more linked to urban centers for economic survival, yet are being left behind as a result of uneven growth in the global economy." External changes are significant in the sense that they impact people, their communities, and their interactions with the natural environment. These changes are powerful, dynamic, unpredictable, and generally uncontrollable at the local level, although how communities deal with change within their domain is subject to discretion.

The discussion on attitudes, beliefs, and values described many of the expectations of Basin residents and other members of the public for FS and BLM management of public lands. Demographic changes within communities have shifted expectations about forests and ecosystems and their management. That discussion also addresses sense of place and its measurement at the community level. One way communities define themselves is by the places and meanings shared by residents and others who care about the Basin. The social and economic changes discussed above, and their effects on particular pieces of land that people care about, is an important consideration for communities. Attachments to places on public land and the ability to use those places in traditional ways contributes greatly to the quality of life of many Basin residents.

Legal, Policy, and Social Context

The FS and BLM do not have specific legal mandates to improve the health of rural communities, but existing law and policy permits and encourages consideration of economic benefits when planning and implementing Federal actions. The political support for thriving rural communities traces back to Jeffersonian ideals of a democracy based on the independence of "yeoman" farmers. Federal rural policies have a lengthy and complex history of subsidizing farm families. The legislative signals for supporting communities that have traditionally extracted timber is mixed, however, and Federal obligations to rural communities in grazing or timber producing zones of the West remain the subject of political debate.

Use of the National Forests for national and regional growth and development was policy when the Organic Act was passed in 1897 and remains important today. Early policy represented a belief that resources existed for the benefit of the local residents who needed them. Individual uses were determined largely by local demands and needs of users and the larger community living in and near Federal lands. The Forest Service's 1905 "Use Book" listed "protecting local residents from unfair competition in the use of forest and range" as a principal objective of the forest reserves, apparently in response to concern about the influence of big industry. The Bureau of Land Management received a comparatively strong legislative mandate in the Taylor Grazing Act (1934) to stabilize the livestock industry dependent on public range, which also reflects concern for community economic health.

The Sustained Yield Forest Management Act of 1944 linked timber supply to community stability by providing authority to establish cooperative sustained yield units. The purpose of these units was to "promote the stability of forest industries, of employment, of communities, and of taxable forest wealth." Although this concept has been experimented in the Basin, its success has not been demonstrated. The National Forest Management Act of 1976 added substantially to community stability policy by solidifying an even-flow timber supply strategy. Section 14 (e)(1) of NFMA addressed community stability by requiring bidding methods for timber sales to "consider the economic stability of communities whose economies

are dependent on such National Forest materials." In 1977, and again in 1987, the Forest Service developed lists of timber-dependent communities to receive special consideration for bidding on Federal timber sales.

The primary authority for Forest Service involvement in rural development comes from the 1990 Farm Bill in Title XXIII, Subtitle G, "Rural Revitalization Through Forestry" (P.L. 101-624). It directs the Forest Service and other Department of Agriculture agencies (Cooperative Extension Service and Natural Resources Conservation Service, among others) to assist rural communities in diversifying their local economic bases. Through coordinated assistance with local institutions, the agencies support "action-oriented," locally developed plans and projects (USDA 1992). For example, the Winema National Forest contributes to diverse projects in communities within the Klamath Basin in south central Oregon. Although contributions tend to be small ($2,000 to $15,000), they often serve as catalysts to initiate projects (Haugen 1994).

The National Forest-Dependent Rural Communities Economic Diversification Act in the 1990 Farm Bill also sought to provide assistance to rural communities located near national forests that fit a specified definition of "economically disadvantaged" due to the loss of jobs or income derived from forestry, the wood products industry, or related commercial enterprises such as recreation and tourism in the national forest" (Ashton 1995).

In examining community economic stability, the distinction between the business needs of industry and community economic needs is often overlooked (Society of American Foresters 1989). Although employing local residents, industry interests inevitably differ somewhat from the communities in which they are located. Both communities and industry are substantially affected by forces beyond their control. The community has little influence on decisions made by the business firms operating in its area, and the firms may have little influence on macroeconomic forces that influence their operations. Because of these factors, rural communities often find themselves vulnerable to boom-and-bust cycles, commodity price fluctuations, and national and regional recessions.

Past agency efforts designed to maintain community stability have centered on providing stable, high flows of commodities, especially timber. However, the Economic Assessment concluded that "the literature is ambiguous at best regarding the relationship of sustained timber yields and community stability, as measured by employment in the timber industry." Many factors undermine the potential use of an even-flow supply of timber to stabilize rural communities regarded as timber dependent. Aside from the macroeconomic forces that are beyond local control, federal managers have been unable to deliver an even flow of timber according to projections because of the need to manage for other uses and meet changing public desires. In addition, Federal timber can be purchased and transported long distances rather than purchased locally and used to provide jobs in the community. Stabilizing an industry is not the same as stabilizing a community.

Contemporary guiding legislation (NFMA and FLPMA) for both the Forest Service and the Bureau of Land Management, respectively, is oriented toward planning methodology rather than specific economic or social policy goals (Dana and Fairfax 1980). However, many citizens believe that the agencies have established a social contract with rural timber communities based on past practices. Observers such as Lee (1994) have suggested that sudden departures from past practices have resulted in feelings of abandonment, violation, and helplessness by people in timber-dependent communities. Such beliefs undoubtedly influence the many current attitudes toward the agencies discussed earlier in this chapter.

Relative to rangelands, holders of Federal range allotments often experience gains in property value stemming from their access to Federal forage (Frewing-Runyon 1995) although grazing permits are not a property right. This expectation reasonably evolved from past relationships and land uses,

yet changes in Federal grazing allotments could result in decreased value of base properties that are not compensable. The intense social and political debate over rangeland reform reflects the difference in beliefs and values regarding management of grazing on Federal lands.

Community Resiliency

Many social scientists documenting the challenges facing rural communities throughout the Nation have recently concluded that stability is just one way to achieve the broader goal of healthy, prosperous, interesting, and vital communities. Just as stability may not be a better goal than growth or diversification, even-flow resource outputs and volumes are not necessarily the best path to healthier communities:

> *Community adaptability may be more useful than community stability in assessing which communities will prosper in a rapidly changing world reflected by such factors as imagination of community leaders, the ability to access information, and the availability of a diverse resource base (Beckley 1995).*

Mindful of the destructive boom-and-bust cycles that accompanied 19th century forestry, the Forest Service argued that the non-declining even-flow policy was necessary to assure community stability. Their analysis assumes, first, that stability is an accepted goal, as opposed to, for example, growth, diversification, or reorientation of a community's economic base; second, that the Forest Service has a mandate and a capacity to contribute to that goal; and third, that even flows of timber volumes from Federal lands contribute to that goal. None of these assumptions is broadly accepted as a working assumption (Dana and Fairfax 1980).

Social scientists have used several terms to describe community health. Flora (1995), Jakes and Harms (1995), and various works in progress by rural development councils throughout the United States have referred to "community vitality" as a measure of community well-being that incorporates generation of wealth; condition of surrounding biophysical resources; economic diversity; strategic preparedness for the future; organizational connection; and the skills, initiative, and confidence of community members.

FEMAT (1993) defined "community capacity" as the ability of community residents and institutions to meet local needs and expectations, based on physical infrastructure, human capital, and civic responsiveness. Some previous definitions of stability were extremely close to those concepts: "Community stability is best defined as a process of orderly change within those political and geographical areas that are significantly affected socially or economically by forest resources...community stability concerns the prosperity, adaptability, and cohesiveness of people living in a common functional geographic area and their ability to absorb and cope with change" (Society of American Foresters 1989).

Harris and others (1996) used the term "community resiliency" to refer to a community's ability to respond and adapt to change. This term is essentially an expansion of the community capacity definition, further defined through primary research conducted specifically to learn more about small, rural communities in the Basin (Harris and others 1996). Using community resiliency in assessment moves the discussion from the previous goal of maintaining timber-dependent communities by supplying an even flow of timber, toward a broader social goal of maintaining healthy communities throughout the Basin, and gives special attention to towns that rely on opportunities provided by public lands managed by the FS and BLM.

This chapter focuses on "community resiliency" as the preferred term. However, resiliency in this context does not equate to the traditional definition of resilience, which is the capability of a body to recover its original shape after deformation. Instead, resiliency as applied to ecosystem management reflects the ability of people to manage personal and community transitions with some degree of comfort and confidence in the face of powerful forces of change. Selection of the term "community resiliency" does not mean that

definitive measurements of many of its components have been obtained, nor that all of the attributes contributing to community resiliency have been measured. These factors make it clear that additional conceptual development is needed to assess these terms and their predictive capabilities.

Components of Community Resiliency

In their literature review of conditions that contribute to community health, Harris and others (1996) identified numerous characteristics that could help determine a community's resiliency: community character, cohesiveness, services, and infrastructure; autonomy; economic diversity; resource dependence; attractiveness to business; quality of life; leadership; effectiveness of community government; and preparedness for the future. Based on this information and the work of other social scientists researching community issues, five factors are identified for closer inspection because of their key links to assessing community resiliency: population size, economic diversity, civic infrastructure, amenities, and location. Although each factor is discussed separately below, additional research of these factors is needed in other settings and for other data to validate the significance and interactive effects of these and other variables relevant to public land management.

Population—Harris and others (1996) identified population size as a global indicator of resiliency; much like the resiliency of many biophysical ecosystem components, community resiliency is affected by scale. Communities having larger populations possess greater amounts, and wider diversity, of human capital than smaller towns and tend to show higher levels of resiliency as a consequence. Larger communities also tend to have higher levels of economic diversity, which cushion job losses in times when industries decline; in other words, their economy does not depend heavily on a single industry or business firm. Also, in a larger economy, less money leaks from the local economy to pay for goods purchased outside the community.

Participants in community self-assessment workshops held in approximately 200 communities throughout the Basin during 1995 (Harris and others 1996) viewed larger towns more positively. Smaller towns tended to be viewed as less attractive, less friendly, and less vital to business. Among the exceptions of these viewpoints were representatives of intermediate-size communities (3,000 to 5,000 population) who viewed their communities as more autonomous and friendly than did representatives from either smaller or larger towns.

It is not likely that land-use decisions of the FS or BLM will substantially affect the resiliency of the communities having larger populations and economies, although certain members of these communities whose occupations are tied to natural resources may be deeply affected.

The converse is generally true for communities with small populations having fewer industries and business firms per economic sector. Even where many industries are represented, each may include only a few businesses. A decline in one industry or loss of a business firm, especially a major employer, can mean high job loss in the community until adjustments are made. This can be especially disruptive if the community is geographically isolated and has limited alternative employment opportunities. This situation describes many rural communities with a high proportion of employment in agriculture and natural resource commodity industries. It is reasonable to expect that land-use decisions of the FS and BLM could affect industries important to communities with smaller populations near lands administered by these agencies, especially in the geographically isolated areas. However, as will be discussed below, resiliency cannot always be predicted from a community's population size.

Economic Diversity—Harris and others (1996) created employment profiles for more than 450 communities in the Basin, which they used to develop indices of economic diversity at the com-

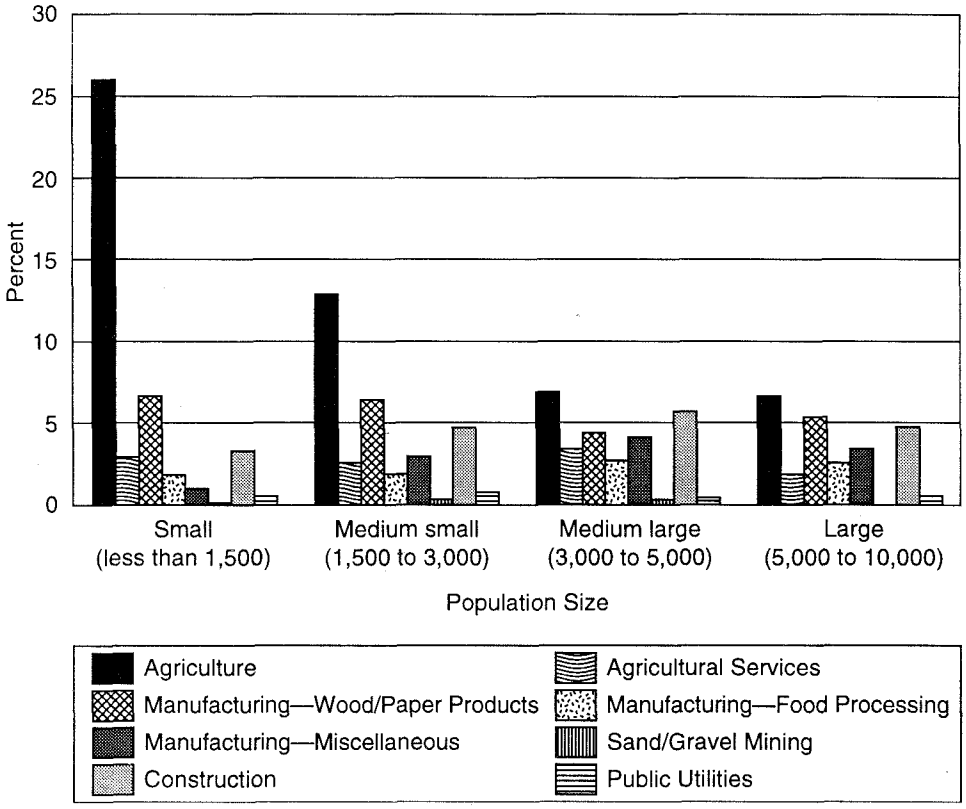


Figure 7.4a - Community employment profiles by size of community. (Note: The scales for figures 7.4a-c are not identical relative to percent of total employment.) (Source: Harris and others 1996).

munity level. The resulting economic diversity values represent a relative index of the employment structure based on the number of industries reported in a town and the proportion of the workforce working in any single industry. The greater the number of industries and the higher the distribution of the workforce across industries, the higher the index value.

Although larger towns tend to have a higher degree of economic diversity than smaller towns, a greater population does not always guarantee a more diverse economic structure (figs. 7.4a-c). Employment comparisons by industrial sector show that many smaller communities are as diverse as larger ones. An exception includes agriculture (farming and ranching), which comprises a larger proportion of employment in the smallest towns (26%) than in the largest ones (7%). Larger towns also contain higher proportions of employment in business, personal, and medical services.

As part of the community self-assessment workshops (Harris and others 1996), participants were asked for perceptions of their community's economy. People perceived farming and agriculture as most important in terms of community dependence on natural resources, followed by grazing and ranching, outdoor recreation and tourism, forest products, and mining and minerals. People perceived that most towns' economies were linked to a mix of natural resources; only 9 percent of the communities were perceived as highly independent of farming and ranching,

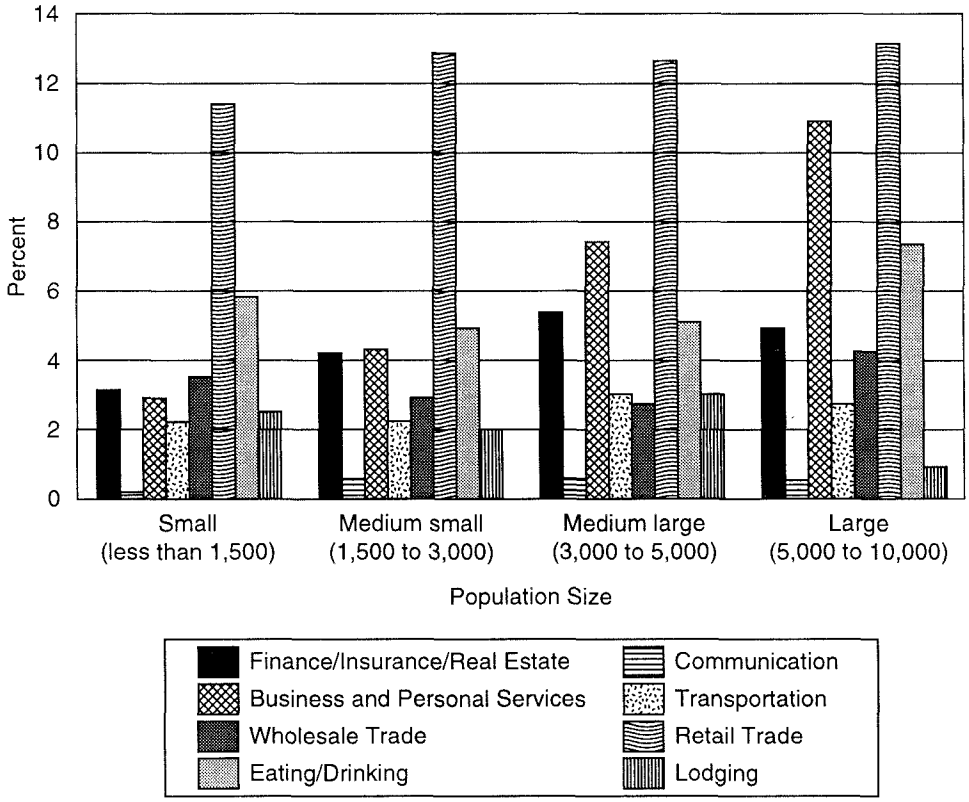


Figure 7.4b - Community employment profiles by size of community. (Note: The scales for figures 7.4a-c are not identical relative to percent of total employment.) (Source: Harris and others 1996).

13 percent independent of tourism and recreation, and 37 percent independent of timber. About 25 percent of all communities were viewed as having a mixed economy, with no particular dominant industry.

These perceptions were compared with the actual economic profiles of each community. Overall, people were fairly accurate in their perceptions, but they tended to underestimate the diversity of their economy and overestimate the importance of traditional industries. For example, 71 of the communities in the Basin were determined to have high employment (10% or greater) in wood products industries; of these, 37 were among the approximately 200 communities studied in detail. People were very accurate in recognizing timber dependence; 92 percent of the participants from these communities said timber was an important component of the economy. However, of the 161 communities studied in detail in which less than 10 percent of employment was in wood products, 37 percent were perceived as highly dependent on timber.

As another example, 321 of the Basin communities were determined to have high employment (10% or greater) in agriculture; of these, 138 were among the approximately 200 communities studied in detail. People were very accurate in recognizing the importance of agriculture; 91 percent of the participants from these communities rated their town as highly dependent on agriculture. However, 58 percent

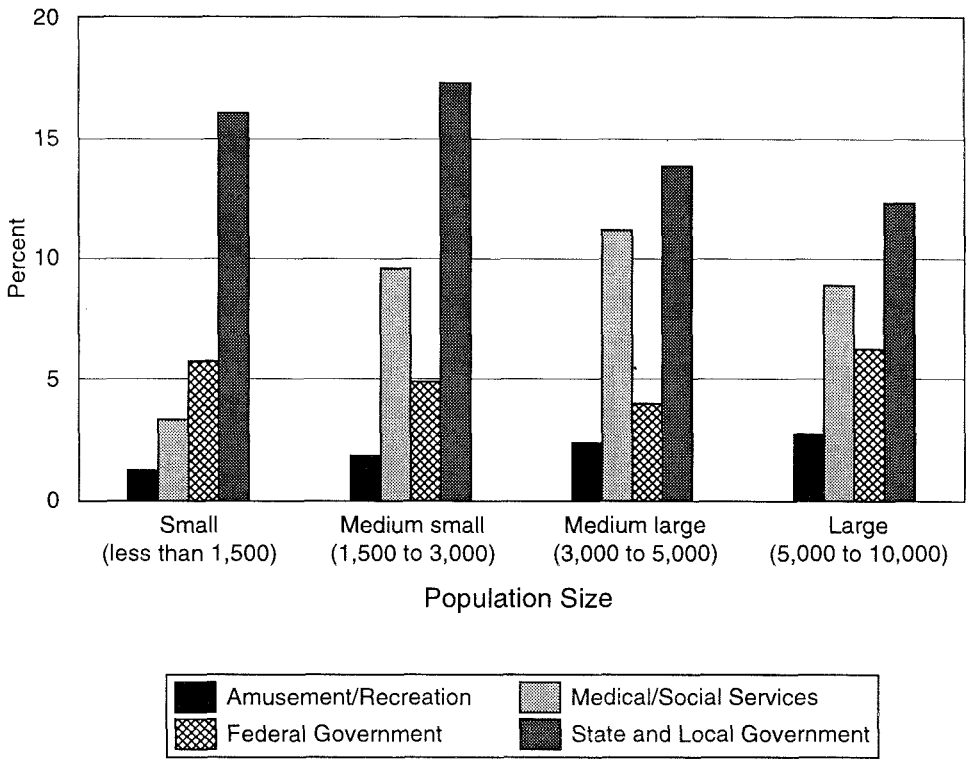


Figure 7.4c - Community employment profiles by size of community. (Note: The scales for figures 7.4a-c are not identical relative to percent of total employment.) (Source: Harris and others 1996).

of the 60 communities that had below 10 percent employment in agriculture were perceived as highly dependent on this industry.

There could be several explanations for these differences between perceptions and the empirically measured economic structures: people could simply be overestimating dependence on timber or agriculture; people could be basing their perceptions on income effects or social influence instead of percent of employment; or the use of 10 percent as a threshold for employment could be inappropriate. Regardless of the explanation, it is clear that the debate over resource dependence in the Basin will continue, and that perceptions may not always match actual conditions.

When considering the significance of wage levels (income) to community members, using economic diversity as a measure of community resiliency may only tell part of the story. Although economic diversity may show greater opportunities in employment options, it does not show the effect of wages on the lives of community residents. Lower-wage jobs in communities may result in greater stress on families; both parents may be forced to work, or one may have to take multiple jobs. These types of pressures, along with an increasing number of single parent households, may negatively affect both community resiliency and quality of life for individuals and families.

Civic Infrastructure—Unlike population size and growth, employment and wages, and economic diversity, the human imagination and energy that contribute to community resiliency are difficult to measure. Human initiative is believed

Table 7.2—Self-assessment of communities' preparation for future.

Category of Response	Number of Communities	Percent
Community has plans and projects identified that will allow them to stay the same.	7	3.5
Community has plans and projects identified that will allow them to change and achieve a desired future.	61	30.8
Community has discussed and identified future directions, but not identified any actions.	78	39.4
Community has had little discussion about the future, and wants to stay the same.	36	18.2
Community has had little discussion about the future, but is willing to change to endure into the future.	16	8.1
Totals	198	100.0

to be a significant consideration for community adaptability (Flora 1995). Institutional features of civic responsiveness (such as community leadership, planning operations, and local government effectiveness) and individual characteristics that would support a "civic culture" (levels of education and professional employment) are likely variables to consider.

An objective of the community self-assessment workshops was to identify civic and cultural attributes important to communities. Based on these workshops and assessments of 10 case-study communities that have experienced significant change in the past decade, three elements emerged as important components of the factor called "civic infrastructure":

- Strong civic leadership—A high commitment of individual leaders and groups to community and active involvement in creating and/or responding to change; a strong sense of local control regardless of external events or influences.
- Positive, proactive attitude toward change—Residents either promote change and thus vitality in community development or, if change is occurring on its own, residents respond positively and create a desirable future.
- Strong social cohesion—A high degree of consensus in values and goals for a desired future; working together to achieve goals.

Communities vary across the Basin in their self-evaluations of these three attributes, yet no strong relationships emerge among the above civic infrastructure variables nor any other characteristics of community resiliency. Levels of perceived community leadership, preparedness toward change, and social cohesion appear to be independent of community size, population growth, amenities, or economic diversity.

Preparation for the future varied among communities across the Basin (table 7.2). Although approximately 75 percent of the communities have discussed the future, only about half of those have identified actions for meeting future needs. Of communities that have considered the future, the planned projects are overwhelmingly oriented toward managing themselves toward something new; only a small proportion expressed "staying the same" as a future objective.

These results show that potential may exist for additional dialogue between community members and other potential cooperators about possible actions for addressing changing conditions. The two-thirds of the communities that lack specific plans or projects for addressing change have opportunities to explore alternative strategies and to communicate with other communities about successful projects. The BLM and FS are active participants in many of those efforts, but not in any systematic manner across the Basin.

Individual capabilities of community members may be considered an additional component of civic infrastructure because they may reflect a capacity to contribute toward community plans and projects for the future. Indicators of individual skills, such as education level, could be used as proxies to estimate these capacities. Under the hypothesis that higher levels of education and professional work experience produce a positive effect on community resiliency, data collected at the county level by Force and others (1995) on amount of college education and proportion of the work force in professional occupations were reviewed for any evident patterns. Counties that are urban, contain universities, or have larger towns had generally higher proportions in these educational and skill categories, yet the highest levels of all in Oregon were in the very rural counties of Gilliam and Sherman. In addition, rural counties in western Montana had relatively higher levels of college graduates and professional occupations than other rural counties in the Basin.

The problem with applying these data to communities is that one town in a county with high levels of personal skills may mask the levels in other communities within that county. However, the frequent occurrence of relatively high levels of education in some of the more rural counties indicates that this type of human capability may be well distributed across the Basin.

Amenities—A high degree of physical amenities, such as the historic character and attractiveness of a community's downtown, the attractiveness of the community's setting relative to scenic and recreational opportunities, and the lack of negative elements such as air or water pollution appears to be another important component of resiliency (Harris and others 1996). In general, Basin residents found their communities to be highly attractive. In ratings made during the community self-assessment workshops, the distribution for community attractiveness tended to be on the high (attractive) end of the scale, and there was little overall variation across communities. Although these uniformly high ratings of local perceptions of community attractiveness may reflect the difficulty of community members in providing an objective evaluation of features within or around their communities, scenic integrity of the Basin is generally high as discussed in the section on amenities.

The presence of desirable environmental amenities, and especially the types supplied by public lands, can contribute to an area's population and economic growth. Tourism and recreation, retirement settlement, and other opportunities supported by Federal lands can be significant sources of jobs and income, as well as personal enjoyment (Society of American Foresters 1989). Some evidence to support this relationship is the high population growth occurring in areas of high recreation importance (Johnson and Beale 1994). Recreation counties tend to diversify more rapidly than others, due to Federal land multiple-use policy that provides an environment for attracting both tourists and permanent residents, such as retirees (Ashton 1995).

Location—Communities are embedded in a biophysical setting of climate, physiography, vegetation, and other features, but also are located within the context of a modern transportation and communication infrastructure that supplies variable levels of service, depending on location. Communities in the Basin were sited based on a number of historical factors such as access to river systems, location of mineral resources, placement of military installations, and location of railroad routes. In today's economy, the ability to be connected to other places and markets presents comparative

advantages for some communities. Towns located next to major highways or regionally important airports that carry high volumes of passengers have obvious advantages in attracting visitors and trade. High speed phone lines and access to information services may also contribute to the relative status of a community's attractiveness for new growth.

A community isolated from centers of growth may have lower resiliency due, in part, to having fewer opportunities to keep businesses and services from consolidating for efficiency. Small communities are more deeply affected by these consolidations because they may have only one outlet, or very few, for a particular type of service. Banks, hospitals, schools, state and federal agencies, and other important service institutions are centralizing operations. Due to this centralization, residents of small communities must travel to larger towns to receive services, forcing smaller communities in the Basin to become increasingly reliant on regional centers. Considering these factors, the Economic Assessment used trade regions as an important scale for economic analysis.

Shopping, culture events and entertainment, doctor and medical treatments, employment, and other general services are main reasons that people connect to larger towns outside their own (Bales 1995). The 10 most frequently mentioned centers providing these services within the Basin are: Spokane and Kennewick (Tri-Cities) in Washington; Boise, Idaho Falls, Lewiston, Coeur d'Alene, and Rexburg in Idaho; Missoula, Montana; and Ontario and Bend in Oregon. Medium-size towns such as Grangeville, Idaho, with an approximate population of 3,200, provide a more restricted range of important services to some nearby outlying communities, such as White Bird and Cottonwood with approximate populations of 110 and 850, respectively.

Reliance on other places would seem to make small communities less autonomous and, perhaps, less resilient as a result. However, Harris and others (1996) identified a strong sense of community autonomy as a contributor to community resiliency, so the relationship between isolation and resiliency is not clear. Isolation also requires that people act more independently to meet their needs, and this self-sufficiency may bolster creativity and an internal cohesion that could help a community face adversity.

Measurement of Community Resiliency

In an attempt to establish a broad measure of resiliency that could be compared across Basin communities, Harris and others (1996) developed the community resiliency index (CRI). The index is a single number computed by combining scores on each of four aggregated resiliency factors (economic structure, civic leadership, social organization, and regional amenities) for each community studied in the self-assessment workshop process. Based on available literature and statistical analysis, each factor received a weight before computing the overall resiliency score; civic leadership was weighted the highest, followed by social organization, economic structure, and amenities. Each community was assigned a score based on this composite variable, which was a relative rating of that community's resiliency compared to resiliency of other communities in the Basin. Harris and others (1996) listed Basin communities and their CRI scores, which were combined to form four CRI classes: high, moderately high, moderately low, and low.

The CRI scores demonstrated that there is no one common formula to achieving community resiliency, but that many strategies have proven successful. Yet, some common characteristics emerged; more-resilient communities tended to:

- Be larger.
- Have an economy based on a mix of industries.
- Be autonomous.
- Have a government rated by its residents as responsive to its public's wants.
- Have plans for adapting to change.

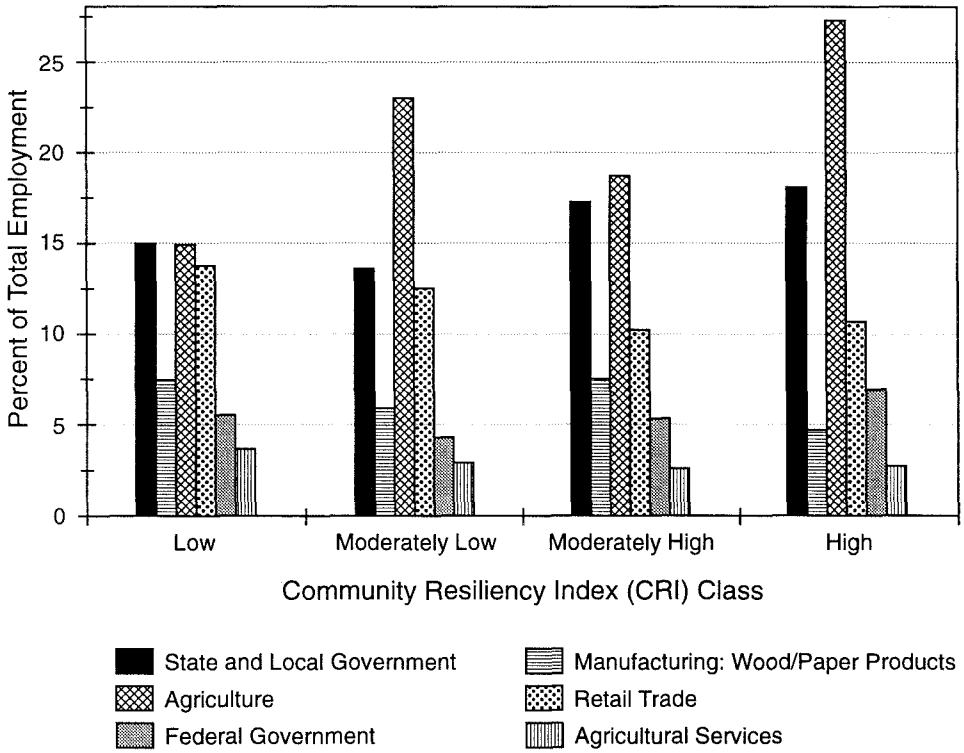


Figure 7.5a - Community employment profiles by resiliency of community. (Note: The scales for figures 7.5a-c are not identical relative to percent of total employment.)

Data relating resiliency class to economic structure suggested few direct relationships (figs. 7.5a-c). Many communities in the most resilient class have high proportions of employment in agriculture, but so do many communities in the moderately low class. Many communities perceived as timber-dominated by community leaders ranked among the highest on the index of community resiliency. Communities confronted with major social and economic changes tended to have higher levels of resiliency. Many on the high resiliency list were communities which had resource processing facilities that had either closed or had production substantially lowered. For example, in Wallace, Idaho a major hardrock mining and processing industry closed in the early 1980s.

The approximately 200 communities studied in detail span all 13 Ecological Reporting Units (ERUs) in the Basin. In general, the Southern Cascades, Upper Clark Fork, and Central Idaho Mountains ERUs had the highest proportion of communities in the high resilience class. Many of the communities with high resilience are in or near mountainous regions that have high amenity values; these communities are responding constructively and proactively to change and, in some cases, are growing in population. The Blue Mountains, Lower Clark Fork, and Upper Snake ERUs had the next highest proportion of communities in the high resilience class; these ERUs also had amenity resources and increasingly diversified economies (Harris and others 1996). The Columbia

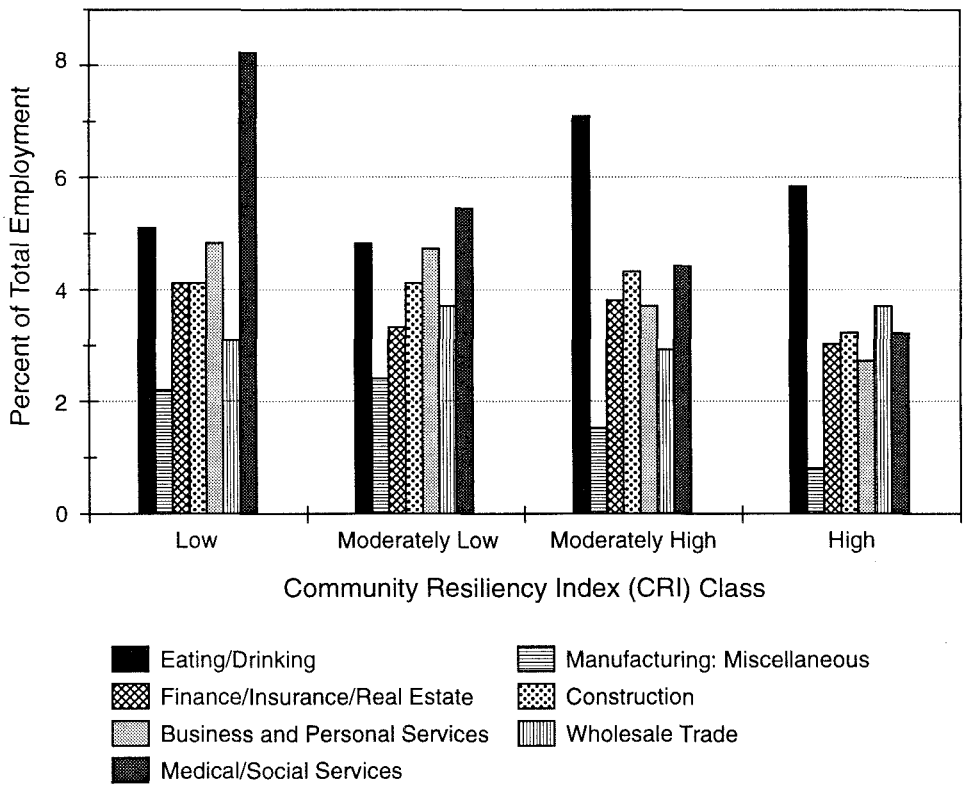


Figure 7.5b - Community employment profiles by resiliency of community. (Note: The scales for figures 7.5a-c are not identical relative to percent of total employment.)

Plateau, Snake Headwaters, and Owyhee Uplands ERUs contained higher proportions of communities in the low resilience class; these were farming and ranching communities perceived as having comparatively fewer amenities. In the Northern Glaciated Mountains, Upper Klamath, Northern Great Basin, and Northern Cascades ERUs, there was either no particular trend in resilience or the number of communities was too small to characterize.

Although the CRI showed the relative resiliency of Basin communities, the index masked the many different ways communities can become resilient. It would be useful to be able to group communities, based on the individual scales used in defining resiliency, for the purpose of identifying different paths to achieving resiliency and of making implications for adapting to change. As a preliminary start in this effort, ICBEMP staff conducted a series of cluster analyses that grouped communities based on similar patterns of resiliency (SPSS Inc. 1989).

The results of the cluster analyses suggested it is useful to think of three types or groups of communities with respect to resiliency. The first group had the highest scores on all five factors comprising the resiliency index; these were communities viewed by their leaders as attractive, economically diverse, and socially cohesive, with strong civic leadership. These communities also tended to have larger populations and exhibited the greatest

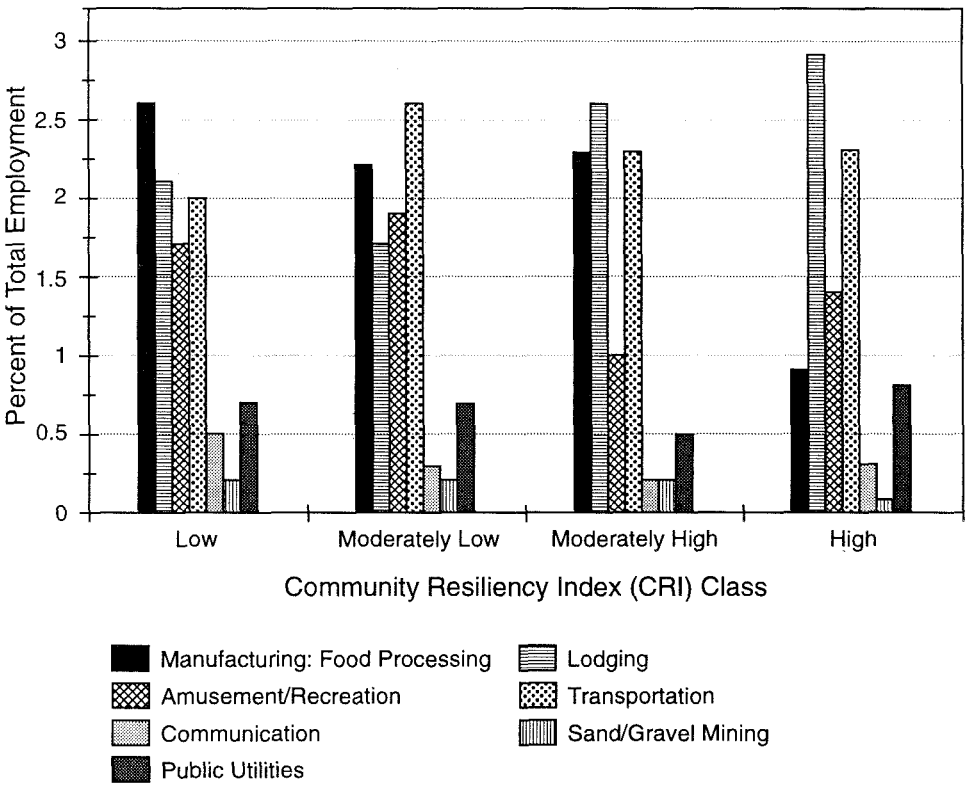


Figure 7.5c - Community employment profiles by resiliency of community. (Note: The scales for figures 7.5a-c are not identical relative to percent of total employment.)

economic diversity. This group tended to contain a larger number of communities than the other two groups. These communities presumably had several different characteristics that would allow them to meet new challenges successfully.

The second group of communities had comparably high scores on civic leadership and amenity values, but much lower scores on social cohesion and economic diversity. Towns in this group were considerably less populated than those in the first group. The number of towns in this group was slightly lower than the number in the first group. Although this type of community may lack the economic base to adapt to change successfully, this shortcoming could be compensated by progressive-thinking civic leaders and the presence of amenities.

The third community type identified tended to have the lowest scores on all measures, although amenity scores were only slightly lower. Intermediate in population, these communities were closer in size to the smallest rather than the largest towns. These communities may have difficulties coping with change because they have few current strengths on which to build. From a Basinwide perspective, this group was by far the smallest, containing just a handful of communities.

Quality of Life

A concept closely related to resiliency and of long-term interest to sociologists is quality of life. Machlis and others (1994) identified numerous indicators of social conditions regularly monitored by various agencies that provide indirect measures of quality of life. Usually collected at the county level, these indicators include conditions such as crime rates, income and employment levels, pollution, and voting rates. Only employment and income can be linked closely to uses of land administered by the FS and BLM.

Because quality of life is subjective, people's perceptions are critical. Relevant perceptions include the attractiveness and aesthetics of the local environment (Pulver 1989) and the quality of services such as infrastructure, medical care, education, and commercial services (Rojek and others 1975). Many of these characteristics could be summarized in the Basin as "small town values." Many local residents who participated in the Interior Columbia Basin Ecosystem Management Project suggested that other factors were meaningless if people did not have jobs.

One measure of baseline conditions for quality of life in rural communities was provided by participants in the community self-assessment workshops (Harris and others 1996). These community leaders and residents generally rated the quality of life in the Basin as high; 80 percent believed their community was "safe, friendly, and a good place to live; few rural communities can match its quality of life." These data also suggested that factors predicting the quality of life include how interesting a community is perceived to be, the level of social problems, community safety, social cohesion, and the attractiveness of the surrounding region. Community population size, however, was not related to perceptions about the quality of life; this perception suggests that increases in a town's size may not, positively or negatively, affect its quality of life (Harris and others 1996).

FS and BLM Roles in Promoting Community Resiliency

The FS and BLM affect the health and resiliency of small, rural communities in the Basin in four main ways:

- Provision of opportunities for *employment and income* through the management of commodities, rangelands, and recreation opportunities, and support for related lifestyles.
- Support of community *attractiveness* through the provision of high quality scenery, healthy forests, clean air, wildlife, and clean water.
- Support of infrastructure and community institutions through *revenue sharing* from the extraction of commodities.
- Support of skills and human capabilities by the *placement of federal employees* in community settings.

The following text on promoting community resiliency focuses on three of these factors (employment and income, Federal revenue sharing, and federal employees); attractiveness is included in the social amenities discussion later in this chapter.

Employment and Income

The Economic Assessment chapter describes employment and income in the Basin and the current roles of the FS and BLM in providing economic opportunities for Basin residents. Its discussion of communities focuses on timber dependency:

> *The Forest Service has implemented specific policy only with respect to timber...Although there is a general sense that the Federal agencies have responsibility toward local economies where they manage a lot of land, not much is known about range dependence...The lessons from the discussion here can be applied to BLM and range-dependence by inference, and other types of resource dependency as well.*

Timber dependency is an issue deeply entrenched in the conventional wisdom of Federal land-use in the West and frequently mentioned by members of the public when addressing agency planning. The issue of community dependency on rangelands generally has not received the same attention as timber dependency. Research on natural resource-dependent communities has focused on timber because of its greater perception of economic value compared to other resources and the resulting social and political concerns. This focus may be changing, as research is beginning to explore effects of amenity management and other nontimber resources on local communities (see later discussion on amenities in this chapter).

There has been much debate about the definition and meaning of timber dependency. Definitions of timber dependency generally stem from two factors: (1) size of the community, and (2) percent of employment associated with timber harvest and processing. In 1977, the Forest Service identified 57 communities in Idaho, Montana, Washington, and Oregon thought to be dependent on National Forest timber, as required by the NFMA. The list, updated and revised in 1987, identified 66 communities in the four states thought to depend on National Forest timber, but also acknowledged there was not a widely accepted definition of "timber dependency." Towns were identified as timber dependent if greater than 10 percent of their workforce was in timber processing and at least 50 percent of their mill supply was from National Forest lands. A community could be labeled timber dependent under current criteria with only a small percentage of employment associated with Federal timber; some have argued that supply must account for much more than this before the production can claim a meaningful impact on an area (Boyd 1989).

The Economic Assessment chapter revisits the timber-dependent list, eliminating communities within 50 miles of one or more towns of at least 10,000 in population and communities in recreation counties. The result was a list of 23 communities deemed to be worthy of attention when developing Federal land-use plans because they are isolated and located in slower-growing parts of the Basin, in addition to being timber dependent.

Burchfield (1995) also re-examined the concept of timber-dependent communities to assess changes since the release of the 1987 Forest Service report. He modified the list by adding communities that Harris and others (1996) found to have more than 10 percent employment in timber processing, as well as 89 communities identified as having timber mills during the data collection for the ICBEMP economic research effort. He also reported other relevant factors of the communities' relationship to Federal lands and timber processing, such as nearby major recreation attractions and average stumpage values. Some communities that appeared on the 1987 list, such as Boise, Idaho, or Missoula, Montana, do not fit today's profile of timber-dependent communities, as both are rapidly growing urban areas with diverse economic bases. Other communities showed changes in their relationship to timber processing by virtue of mill closures or other emerging economic opportunities.

Burchfield's analysis revealed that some communities maintained a high proportion of their workforce in timber processing, and that their locations in close proximity to Forest Service lands argued for closer inspection of the significance of Federal flows of timber in each specific case. Burchfield concluded that several communities (18 in Oregon, 8 in Washington) have greater than 10 percent employment in timber processing. Idaho's Clearwater Valley is another concentration of towns relying on timber. Several of these communities also had populations less than 1,000, possibly suggesting lower resiliency. Both sets of these additional criteria are certain to enter into the debate about timber dependency and the broader issue of links between communities and public land management.

Timber dependency is a social issue as well as an economic one that has many implications for community resiliency. For example, Cook (1995)

examined relationships between poverty and timber dependency in western Washington between 1980 and 1990. She concluded that, "Restructuring of the timber industry during the 1980s coincided with a substantial decline in several indicators of well-being in timber-dependent areas in western Washington, even before the northern spotted owl was listed as an endangered species." She found that poverty in timber-dependent areas rose dramatically compared to rates in nontimber-dependent areas (aside from metropolitan areas). In timber-dependent areas, wage and salary incomes not only continued their importance as a component of household income (in contrast to nontimber-dependent areas, where it declined), but failed to keep pace with inflation. Poverty rates also increased among families with females as heads-of-the-households.

The social effects of economic hardship in natural resource-dependent communities are not unique to timber issues; similar challenges face communities that serve as offshore oil and commercial fishing ports (Freudenburg and Gramling 1994). This finding led those authors to "ask whether natural and human resource preservation and conservation represent a more realistic path to rural community well-being than traditional natural resource extraction activities as we approach the 21st century" (Humphrey 1995).

Regardless of a person's views on the issue, timber harvest today is an important component of economic diversity in some Basin communities. Further reductions in harvest independent of cause would likely lead to negative social consequences that, for some communities, may be difficult to overcome. One reason for this difficulty is that economic opportunities resulting from natural resources on public lands are not just an economic issue, but a social issue that involves chosen lifestyles for many Basin residents:

People bought homes, invested capital, and formed attachments to town communities on the basis of the government's promise of sustained yield in wood production. People in timber dependent communities trusted the government to maintain its commitment to providing continuous wood supplies. A sudden departure from anticipated harvest schedules will force the government to break this trust. Investments in jobs, homes, and attachments to places will be disrupted. Since people have been dependent on the parental good will of their government, they will experience a sense of abandonment, violation, and helplessness that will contribute to the already heavy burden of stress (Lee 1994).

The lifestyles of many Basin residents are linked to their natural-resource-based occupations. People who work in the woods, on rangelands, or on the Basin's many mountains and rivers develop special attachments to the land that can extend across generations. Communities of interest typically develop among people who share a natural-resource-based livelihood and lifestyle. Studies by Carroll (1984) and Carroll and Lee (1990) found that members of occupational communities spend much of their free time with others in the occupation, and look to each other as a primary reference group. While this type of socialization occurs in many groups, the authors believe that occupational communities tend to develop distinctive values and world views centering specifically around their occupation and its culture.

The communities of interest mentioned in this social assessment are a special concern for three reasons:

- They are likely to be impacted by changes in Federal policy, such as ecosystem management, which focuses on achieving desired physical and biological conditions rather than target levels of outputs such as timber harvest.
- The individual identity and lifestyle of these communities are often linked directly to occupations.
- Employment already is shifting downward in many of these industries (logging, mining, ranching, and farming) due to external economic or other factors (Krannich and others 1994), so any additional restrictions could have strong local impacts.

Hovee (1995) described lifestyle characteristics of five natural-resource-related, occupational communities of interest: miners, ranchers, farmers, loggers, and commercial anglers. While each of these occupational interests has somewhat different values, Hovee listed several shared orientations such as hard work, independence, conservative political viewpoints, a utilitarian view of natural resources, and an orientation toward hunting and fishing as forms of outdoor recreation. These occupations tend to be male-dominated, although women are greater participants in operating farms and ranches.

Loggers and ranchers who have a strong lifestyle affiliation with their occupations may be particularly affected by ecosystem management strategies. Hovee (1995) indicated that loggers' values include the following: trees are a renewable resource and are to be harvested as any other agricultural crop; the beauty of the environment and the sustainability of the resource is important; the government is often an impediment to free enterprise and personal freedom; and independence, self-reliance, hard work, and hard play are a sign of good character.

Hovee reported similar values for ranchers: ranchers are caretakers of the environment; stewardship involved in ranching enhances rather than detracts from the environment; ranchers have a sense of intimacy and attachment to the land that "outsiders" cannot achieve; ranchers have an appreciation for peace, quiet, and remoteness coupled with a concern about population growth and encroachment on the resource base; predators present a threat to livestock; and the land defines one's home, identity, and lifestyle. While not all people employed in these occupations share this particular set of values, such descriptions do provide insight into communities of interest.

Carroll and Lee (1990) stated that "identity and shared meanings are key factors in the logger's ability or inability to adjust successfully to dramatic shifts in the demand for labor." This statement suggests that the question of resiliency for communities of interest is also a valid issue. Blatner and others (in press) stated that such occupational communities feel "disenfranchised" in environmental issues, which possibly makes them less able to adapt to policies and leads to unemployment. Therefore, understanding how Federal land-use policies affect communities as a whole is only part of the picture.

Federal Revenue Sharing

County governments provide many community services in rural areas. Local school districts, which operate as independent units of government in each of the Basin states, are institutional fixtures within communities. The schools they administer not only provide education, but offer highly important focal points for community cohesion, supplying community educational needs as well as cultural and athletic events that draw the community together. The condition of schools and roads is a key element that contributes to the quality of life in small, rural communities.

County governments and school districts in the Basin receive Federal revenue sharing payments based on the amount of Federal land in the county and the value of commodities extracted in a given year. Federal revenue sharing in the Basin occurs under the Mineral Lands Leasing Act of 1920, the Taylor Grazing Act of 1934, the Twenty-Five Percent Fund, and Payments in Lieu of Taxes (PILT), with the latter two being most important to county governments and school districts.

Under the Twenty-Five Percent Fund, 25 percent of the revenues from sales of Federal commodities are returned to the states, with stipulations that it be expended for roads and schools. The states decide the proportional distribution to each; Montana and Idaho each give about two-thirds to roads and one-third to schools (Schuster 1995a). PILT payments are revenues returned to counties as compensation for tax-exempt Federal lands (Shuster 1995b); these monies are distributed to counties based on a payment formula that includes consideration of the amount of Federal land within the county boundaries and county population levels.

A major incentive for local government officials to support timber harvest on national forests is the linkage between the value of timber harvested (based on price and volume) and the amount returned to counties (for roads) and school districts under the Twenty-Five Percent Fund. The higher the harvest value, the greater the local share. The Economic Assessment chapter describes many other factors that influence Federal payments and also points out that recreation, which generates greater economic value than other land uses, does not contribute to revenue sharing payments because recreational opportunities on Federal lands generate little Federal revenue.

Schmit (1995) found that nearly one-third of Basin counties receive additional benefits due to added revenues from the Twenty-Five Percent Fund; the majority of counties receive baseline PILT payments of $0.75 per acre regardless of harvest revenue (table 7.3). The largest per acre benefits accrue to counties on the far western edge of the Basin that have moist forest environments with high timber volumes per acre.

Important benefits also accrue to counties such as Grant County, Oregon; Lincoln County, Montana; Shoshone County, Idaho; and several others with small communities that are losing population and have a high percentage of the workforce in timber processing. In these communities, Federal timber harvest could be important to community resiliency for the support given to community institutions such as schools or civic projects, as well as the direct employment benefits. Recent decreases in Federal timber harvest levels have led to 50 percent cuts in revenue-sharing payments in eastside counties. Even in counties where the per acre benefits of the Twenty-Five Percent Fund payments are only slightly higher than the PILT baseline, there may be a large amount of Federal land that presents a significant increment of revenue.

As mentioned above, the value of payments to counties from the Twenty-Five Percent Fund is also greatly affected by the price of timber. Between 1987 and 1994, when the price of timber increased by 75 percent on the Basin's national forests and harvests dropped by 64 percent, the higher price of timber sustained the value of revenue sharing payments at near constant levels (Schmit 1995).

Federal Employees

Another way the FS and BLM affect communities is placement of staff in rural areas to implement management activities. Data collected by the ICBEMP in 1995 show that the Forest Service had just over 8,000 field employees (approx. 63% permanent and 37% temporary) and the BLM 900 field employees (approx. 82% permanent and 28% temporary) in the Basin, with most located in smaller communities. In some of these communities, one or more agency offices can comprise a significant portion of the local economy.

The diverse backgrounds and disciplinary specialties of FS and BLM personnel offer communities highly valued skills for planning, engineering, design, communications, and other skills that have value in small, rural communities (Rodriguez 1995). The contributions of FS and BLM staff in rural areas demonstrate a solidarity with communities and the rural environment that is not well demonstrated by the behaviors of professionals in other occupations. As Lasch (1995) observes, there is a general trend for well-trained "elites" to abandon small towns and the traditional "middle class culture" for the allure of urban centers and fast-paced lifestyles, leaving few skilled "symbolic analysts" to remain in rural areas and small towns to assume the tasks of a technologically dependent society.

Table 7.3—Counties receiving extra benefits from timber harvest (1992).

County	Payment per Entitlement Acre (In dollars)	Total Payment (Prior year + PILT) (In dollars)
Wasco, Oregon	$9.37	$1,954,157
Hood River, Oregon	9.21	1,931,000
Skamania, Washington	6.30	5,240,749
Klamath, Oregon	4.77	10,227,422
Grant, Oregon	4.76	8,324,100
Yakima, Washington	3.39	1,804,986
Wheeler, Oregon	3.16	958,883
Crook, Oregon	3.09	2,903,190
Deschutes, Oregon	2.32	3,317,533
Jefferson, Oregon	2.31	676,619
Umatilla, Oregon	2.28	948,201
Morrow, Oregon	2.28	352,391
Klickitat, Washington	2.17	90,479
Lincoln, Montana	1.95	3,466,497
Shoshone, Idaho	1.79	2,197,770
Union, Oregon	1.71	1,062,945
Wallowa, Oregon	1.61	1,882,010
Boundary, Idaho	1.58	747,176
Bonner, Idaho	1.58	691,398
Lake, Oregon	1.35	5,007,538
Baker, Oregon	1.27	1,295,348
Columbia, Washington	1.24	203,987
Garfield, Washington	1.21	122,385
Kittitas, Washington	1.16	505,685
Benewah, Idaho	1.15	60,007
Sanders, Montana	1.11	1,009,943
Pend Oreille, Washington	1.08	505,685
Asotin, Washington	1.07	70,549
Ferry, Washington	1.01	503,300
Stevens, Washington	0.95	234,243
Chelan, Washington	0.89	1,263,354

Source: Schmit 1995

Implications for Ecosystem Management

The current pace and nature of changes in the Basin suggest that the manner in which the FS and BLM interact with communities be carefully reviewed. Old behavior patterns that characterized land management priorities may no longer serve the interests of many community residents. Policies to promote community stability may be inappropriate under conditions where there is little stability in the social system.

Many communities have long-standing social, cultural, and economic ties to FS- and BLM-administered lands in the Basin. Numerous Federal laws, regulations, and policies refer to this relationship, but few systematic attempts have been made to inventory the meanings of important places on public lands. Conducting place assessments at the community level would be one way to address this important ecosystem feature, as well as to begin meaningful community involvement. Public interactions with Federal managers, planners, and lawmakers at every level of government clearly show concern for Federal land uses and communities, and is an issue often cast as community "dependency" on Federal lands. Presenting the relationship of Federal lands and communities as "dependency" connotes an image of powerlessness among those dependent communities, and yet, as demonstrated by the discussion on community resiliency, communities have considerable capacity through their civic infrastructure and other factors to direct their own futures.

Traditional descriptions of dependency focus most attention on the provision of employment based on timber production. Others (Haynes and Horne, chapter 6; Rasker 1995) have shown that recreation supplies higher levels of employment than timber management in the Basin, and other social factors (macroeconomic relationships, growth, and family structure) have greater effects on the well-being of rural communities in the Northwest than does timber production (Heberlein 1994). Even though it is difficult to predict any direct effects that timber harvests in a given National Forest may have on a given community, inferences can be made about geographically clustered communities in areas having high proportions of Federal land. Lower levels of timber harvests on National Forests in these areas may diminish the resiliency of these communities by reducing the number of timber-related jobs and income that support individual families, community businesses, and civic infrastructure. The wood products industry contributes to economic diversity in communities across all Basin states.

Notable among the groups of communities in the Basin that appear to be most vulnerable to change are:

- Clearwater Valley in Idaho, where communities are already experiencing population decline and reduced timber harvests from FS-administered lands (Harris and others 1996).
- Isolated communities in western Montana that are outside the growth hubs of Kalispell and Missoula.
- Isolated, small communities in eastern Oregon that are not receiving the growth of the region's medium-sized towns.

The relationships of these towns to Federal resources could be more closely examined at the Forest Plan decision-making level. This level can give a better understanding of the opportunities to mitigate potentially negative consequences of further reductions in timber harvests from national forest lands. Economic analyses are important not just at the regional scale, but at county and community scales as well. Each level of analysis has its own most appropriate uses, with a different story at each scale because each is a crucial part of the ecosystem. Issues and concerns emerge at one scale that may not be present at another. In addition, agencies could develop a better understudy of how resource management decisions affect employment in other industries.

Although the resiliency concept is useful, it deserves additional attention to be fully developed. As stated above, there are many ways in which a community may be resilient. A community may have small population size but strong civic leadership, therefore having the ability to maintain itself through creative solutions to problems. A highly cohesive community may be able to overcome limited economic diversity by cooperating together to attempt new business endeavors. Even though a community may be resilient, its interests should be considered in ecosystem management.

Measuring community resiliency presents problems for researchers, because it involves complex interactions between personal skills and institutional behaviors. The CRI must be viewed as provisional; humans and the communities they inhabit have proven through history to be remarkably adaptable, and the multiple, interacting factors that affect this adaptability make prediction highly uncertain. If people's ties to their communities are strong enough, they often make surprising sacrifices (commuting hundreds of miles for employment or accepting lower pay, for example) to continue to reside in their homes. Adversity often motivates people to be resourceful, and as Harris and others (1996) observed, Basin communities that have undergone some of the most severe shocks have successfully restructured their economic and social relationships. Therefore, attempts to classify communities based on resiliency must be viewed with considerable restraint, as the procedure itself may have negative consequences for communities that are rated as less resilient or healthy than others (FEMAT 1993). For this reason, this social assessment does not describe individual communities and their resiliency.

Social impact assessment can consider resiliency as both an independent variable that determines how communities will respond to effects and as a dependent variable that can be affected by Federal and other policies and projects. The community self-assessments have been a valuable information source about communities for this social assessment, as well as for the Draft EISs. This process was welcome in nearly all communities. Although participation was limited to a few people from each town, the process served as a starting point for a new interaction approach with communities. While many FS and BLM employees who live in the Basin's small, rural areas participate in community affairs in various capacities, these relationships could be formalized and structured to meet mutually desirable objectives for the relationships between public lands and communities.

The outcome of the old-growth controversy west of the Cascades provided a recent precedent when the Federal Government helped ameliorate the impacts to timber workers whose jobs were lost by the need to protect habitat for the spotted owl. "Jobs in the Woods" and other specialized transition programs were authorized over a three-state area, and a special White House Office on Forestry and Economic Development was established in Portland, Oregon, to oversee Federal, State, and local efforts to support people and communities in the affected area. The high visibility of this federal response elevated expectations that the Federal Government would act to buffer changes caused by reductions in flows of commodity product from FS- and BLM-administered lands even though the overall impacts on job losses in the region have been less than anticipated (Sleeth 1995).

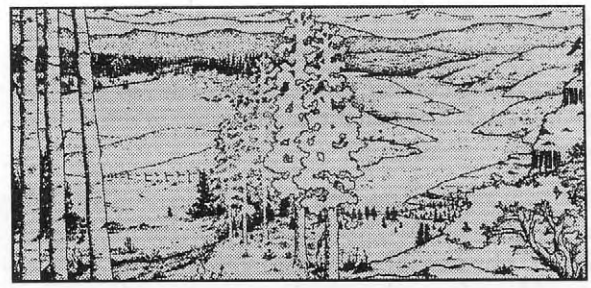
Although efforts by agencies to support economic diversity may also be important, the demands of the marketplace and the operation of the economy on a larger scale may make attempts at increasing resiliency more difficult. Economists, as well as members of the public, differ with respect to the acceptability of agency activities such as sustained yield units, special provisions for certain contractors, and other attempts to manipulate the market to achieve social and economic objectives. Monitoring these efforts to assess their long-term social, economic, and environmental effects will help to identify characteristics of the most useful approaches.

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SOCIAL BENEFITS OF AMENITIES ON PUBLIC LAND



The environmental amenities of the Basin are significant components of not only the region's identity (Angus-Reid 1993), but the quality of life for current and future residents. The principal motivation and source of satisfaction for many visitors are the extensive wildland-based sceneries that typify the Basin (Christensen and others 1995). The environmental amenities that tourists find attractive are also appealing to the region's residents, and are reasons that people either remain in, or migrate to, the Basin.

The term "amenities" has been used in many ways. In the context of ecosystem management, "amenities" refers to environmental aesthetics and opportunities to appreciate them. This includes scenery and associated opportunities to recreate in natural-resource-based settings in areas both with and without roads. In the past, the use of amenity resources has been called "nonconsumptive" compared to timber harvest, grazing, and mining, which were typically viewed as "consumptive." However, all land uses are consumptive in a social sense; using land in one way may make it less available for other uses and may also emphasize the importance of some ecosystem conditions and processes over others.

By emphasizing restoration of ecosystem health and functioning, ecosystem management may lead to changes in landscape conditions that could enhance some forms of recreation but limit or alter others. For example, it is reasonable to expect increased concern about the effects of roads, particularly in sensitive areas such as riparian systems. This issue is complex because roads provide recreational access essential for some types of activities and experiences, but can detract from others. Some restoration treatments, such as thinning and prescribed fire, can be expected to have mixed effects as well, both on recreation opportunities and scenic quality. It is therefore important to have an overview of amenity resources in the Basin, both to better understand this component of the ecosystem and to serve as a baseline for measuring change.

This discussion on social benefits of amenities describes the principal amenities and sites in the region, with an emphasis on recreation opportunities and scenery measured at the broad scale. Some information is summarized from the Economic Assessment (chapter 6), which contains a complete discussion of recreational opportunities. The discussion on amenities concludes with implications for ecosystem management and recommendations for future assessments at finer scales.

Recreation Opportunities

Recreational opportunities contribute significantly to the quality of life for Basin residents, as well as people who visit the Basin. Lee and Driver (1992) identified four major types of benefits derived from recreation participation:

personal, social and community, economic, and environmental. As discussed in the Economic Assessment (chapter 6), recreation settings on public lands also benefit people who do not actually visit the sites.

Recreation, tourism, and related industries are among the fastest-growing economic sectors in the Basin. The Economic Assessment (Chapter 6) provides information on the economic values associated with Basin recreation opportunities, estimated annually at $1.2 billion. More than 80 percent of this value stems from opportunities on lands administered by the FS or BLM. Recreation also supports at least 200,000 jobs Basinwide.

The Basin provides a diversity of outstanding, nationally known recreation settings. Many of the most important opportunities that are based on natural resources are located on lands administered by the FS or BLM. These existing local, regional, and national resources can be affected in many ways. For example, population growth increases not only the demand for ecosystem goods and services, but also the land and resource requirements. Such growth also affects the environment directly through conversion of vegetation and open space to residential, commercial, industrial, and transportation uses.

Supply of Recreation Opportunities

Counties in the Basin have, on the average, substantially greater amounts of available recreation resources compared to the national average. Aside from the central Rocky Mountains and the Colorado Plateau, the Basin is among the richest regions in the Nation for environmentally based amenities. The Yellowstone Ecosystem on the Basin's eastern edge, the birthplace of the national park system, contains an ecologically outstanding and economically important set of amenity resources. To the northeast lies the area surrounding Glacier National Park, a spectacular demonstration of geology, vegetation, and ecological processes. Both areas show the need for ecosystem-based strategies that cross agency boundaries.

The northwest portion of the Basin contains equally well-known mountains, forests, rivers, and wildlife in the northern Cascades. The southwest portion of the Basin contains Crater Lake National Park and the Klamath Basin, a vegetatively complex region of natural resources.

Near the Basin's center are the Frank Church River-of-No-Return and Selway-Bitterroot Wilderness Areas, both uncommonly large unroaded areas that retain some of the Nation's most significant wildlife populations. Hells Canyon, located on the Idaho-Oregon and Idaho-Washington boundaries, is one of the deepest canyons in North America. It provides outstanding whitewater recreation opportunities, as do the Snake River in Wyoming, the Salmon and Selway River systems in Idaho, the Deschutes in Oregon, and many other Basin rivers.

On a comparative basis, the Basin has abundant amounts of protected areas, which equate to about four acres of Wilderness Areas, National Parks, or National Recreation Areas per person; this ratio is nearly seven times the national average. The project area contains 70 percent of the unroaded areas that are 200,000 acres or larger in the lower 48 states. These areas provide not only important habitat for wildlife, but singularly distinctive opportunities for people to experience primitive recreation. The combination of large-scale protected areas and low population density provides much of the regional identity.

The Recreation Opportunity Spectrum (ROS) inventory described in the Economic Assessment (Chapter 6) found that about 60 percent of Federal lands in the Basin provide roaded natural opportunities, 40 percent are considered primitive and semi-primitive, and less than 1 percent are rural. A large amount of the supply of the semi-primitive class is not currently in a protected status. Semi-primitive opportunities are the most scarce and also those most at risk in terms of potential changes due to development, especially of roads.

The ROS is a convenient way to inventory and display recreation settings based on access, level and type of development, and other social and managerial characteristics. ROS does not, however, consider the main attractions that draw people to recreation settings, such as specific recreational facilities, water, fish, and wildlife. Many destination ski areas located on FS-administered land are part of a package of amenity resources that create tremendous attraction among both residents and nonresidents.

The presence of water has been, and will continue to be, the most important attractor for recreation visitors. Among recreational resources, free-flowing rivers stand out as "a nonrenewable and rapidly disappearing feature of the American landscape" (National Academy of Sciences 1979). One resource advantage for the Basin over the surrounding area is wild and remote water environments; the average for Basin counties is nearly three times the national average, and more than double the average of adjacent counties. The Basin contains some of the Nation's best fishing and whitewater streams. The River Information Digest (American River Management Society 1992) identified whitewater river segments that were at least 10 miles in length or that were designated as components of Federal-, State-, or local-protected river programs as small subsamples of unique recreational river segments in the Basin. The digest described 46 outstanding rivers for recreation in Idaho, 15 in Montana, 29 in Oregon, and 19 in Washington.

In the future, the Basin is expected to continue to have substantially more available recreation resources than the Nation as a whole. For most recreation environments, the resource base for the western United States is expected to grow more rapidly, or decline more slowly, than the eastern portion of the country (English and others 1993). Similarly, the Basin should continue to have greater availability of most recreation resources than surrounding areas.

Demand for Recreation Opportunities

As described in the Economic Assessment, between 1991 and 1993, about 200 million recreation activity days per year occurred on federally administered public lands in the Basin. Roaded natural settings received about 75 percent of all activity days. Activities most frequently measured by activity day include day use and motor viewing, camping, fishing, trail use, and hunting.

Just more than six million people were estimated to have participated in wildlife-oriented activities within the four main Basin states. Wildlife viewing, photography, and related wildlife activities were more popular than hunting and fishing in all four states. Many of these visits were made by people residing outside the Basin. For example, 22 percent (1.4 million) of Basin visitors who engaged in wildlife-oriented activities were nonresidents of the four major states comprising the Basin.

A significant portion of the overall nonresident visitation originated from the nearby metropolitan areas of Seattle, Portland, and Salt Lake City. The Basin also is an international destination; more than three million Canadians visited the Basin's four main states. International visitations to the Basin from countries other than Canada totaled about 123,000 visits, and most of these visitors were from western Europe or Japan. Projected international visitation in the Basin's four main states for the year 2000 is almost seven million visitors.

As noted in the Economic Assessment, the following social and economic characteristics of the United States population influence participation trends:

- An aging population with older-aged individuals having much leisure time.
- Increasing population levels.
- Increasing ethnic diversity, resulting in a greater variety of recreational demands.
- Population migration, from urban areas to more rural areas.
- A narrowing of the middle class.

All of these characteristics greatly influence the types of activities in which individuals participate, the length and season of recreation participation, and the frequency of participation.

Although lack of consistent data among land management agencies prevents calculating an annual percent change in participation levels for the entire Basin, recreation participation has been steadily increasing over the past 15 years. The BLM indicated a slight decrease in participation in 1995, but otherwise had been experiencing a steady increase in visitation the last 10 years. Nationwide, the five fastest-growing outdoor activities between 1982 and 1995 included birdwatching, hiking, backpacking, downhill skiing, and primitive camping (Cordell and others 1995). Projections made by the states of Oregon, Washington, Idaho, and Montana in their Statewide Comprehensive Outdoor Recreation Plans showed that trail use, a majority of which takes place in less developed settings, is expected to be one of the fastest-growing activities in all four states.

Nationally, the greatest shortages in recreational opportunities are expected to be for primitive camping, backpacking, hiking, horseback riding, nature study, and wildlife observation (Cordell and others 1990). The Economic Assessment described this national shortage as a comparative advantage for the Basin and one that will increase in value. Within the Basin, demand for developed camping, family gatherings, visiting museums, bicycling, running and jogging, and outdoor-pool swimming is anticipated to increase at least 250 percent in the next 50 years (Cordell and others 1992). Although all activities are expected to increase in participation, gathering firewood and collecting berries are expected to have relatively small increases in demand.

Scenery

Scenery, the general appearance of a place and the arrangement of its individual features, is another type of Basin amenity. Scenery consists of both *biophysical* and *cultural* elements. Biophysical elements include land forms, water, and vegetation; cultural elements include buildings, rock walls, and fences. Scenery is the product of both natural processes and human culture, combined in varying proportions (Eckbo 1969). Therefore, it is a resource vulnerable to change because virtually everything humans do in terms of management activities has an effect on the appearance of an area.

Human intervention in natural processes has been a major force in shaping landscapes within the Basin. Of the Basin's more than 144 million acres, over 37 million acres (26%) have been transformed by the agricultural and industrial undertakings of humans to the degree that their overall images are no longer near-natural in appearance but are culturally dominated.

Landscape appearance and scenery are important environmentally based amenities, not just as settings for recreation, but as components of the Basin's image to residents and nonresidents. Basin residents consider the scenic quality of Federally managed lands to be important. FS- and BLM-administered lands often serve as backdrops for communities and residences in both rural and urban settings scattered throughout the Basin, offering a large area of wildland-viewing opportunities. These same lands also provide settings for a variety of occupational and recreational activities serving a wide diversity of people living both inside and outside the Basin.

Attempts to define and measure public perceptions of scenery and aesthetic values began in the 1960s, gained momentum in the 1970s (Elsner and Smardon 1979), and continue today. One of the many interesting findings is that, although beauty is in the eye of the beholder, members of the public tend to have common perceptions of what constitutes natural scenic beauty (Zube 1976). One study, for example, measured how members of 26 different user, interest, and professional groups perceived 6 areas representing a cross-section of forest management in northern Arizona (Zube 1976). The most striking finding was the level of agreement in scenic preferences among these diverse groups. Taken as a whole,

these and related findings suggest that scenery is not just a strongly held value, but one held in common by a broad range of people.

Many people who hold value for the Basin's scenic resources realize that landscape settings are dynamic and that these settings may change over time whether humans alter them or not. People do not prefer to see drastic changes in the character or condition of geographic areas of importance to them (Galliano and Loeffler 1995). Resource managers are interested in the integrity of these landscapes, specifically about visual changes resulting from human alterations.

Supply of Scenery

In an effort to systematically inventory and protect the aesthetic quality of public lands they administer, Federal agencies have tested, adopted, and applied scenery management systems nationwide over the past quarter century. The ICBEMP measured the supply of scenery in the Basin using two related but distinct concepts, Landscape Themes and Scenic Integrity. The full analysis is described in Galliano and Loeffler (1995).

Landscape Themes—Every place within the Basin has an identifiable visual image that can be expressed in terms of a theme. Themes range from an essentially natural landscape such as a wilderness, to one that is highly developed such as an urban area. Themes indicate how people perceive the Basin's environments in a very general sense. Themes are images formed by combined landscape character (natural attributes) and scenic condition (human or cultural attributes). They are not goals for future management, but merely show what currently exists within a broad spectrum of degrees of naturalness or development. For the ICBEMP, landscape themes were defined based upon ecological subregions at the subsection scale. This scale provided the appropriate level of detail necessary for such a large assessment, yet remained fairly manageable.

The Basin's landscapes were described with five themes:

- Forest and shrub/grasslands (naturally evolving): Lands that have a vegetative cover of either forest species or shrub, forb, and grass species that are in a naturally evolving state or condition. Human intervention (such as manipulation or development) is at a very minimum or nonexistent level; natural processes dominate visually.
- Forestlands (natural-appearing): Lands that have a vegetative cover of forest species (large trees creating the walls and ceilings of visual space) that are in a natural-appearing state or condition. Human intervention may be evident or may have occurred, but does not dominate the natural landscape.
- Shrub/grasslands (natural-appearing): Lands that have a vegetative cover of shrub, forb, and/or grass species (small trees and plants that may create small walls of visual space, but an overhead plane or ceiling is absent) that are in a natural-appearing state or condition. Human intervention may be evident or may have occurred, but does not dominate the landscape.
- Agricultural lands: Working landscapes with geometric patterns that visually dominate the landscape, usually due to fencing and/or monocrop planting and cultivation patterns. The theme includes managed timber lands that have a cultivated appearance.
- Developed areas: Lands that have gridded street patterns, commercial areas, and suburban residential areas. These range from small developed areas with a gas station, a general store, or restaurant and surrounding homes, to larger towns or cities with gridded street patterns, commercial hubs, and numerous residential developments.

Naturally evolving forest and shrub/grasslands cover 7 percent of the area in the Basin; natural-appearing forestlands cover 37 percent; natural-appearing shrub/grasslands 30 percent; agricultural lands 20 percent, and developed areas 6 percent

Table 7.4—Existing landscape themes in the Basin.

Landscape Theme	Current Situation (hectares)	Current Situation (acres)	Percent of BLM- and FS-managed Lands in Basin	Percent of total Basin
Naturally-evolving forest & shrub and grasslands	3,913	9,666	10	7
Natural-appearing forestlands	21,561	53,256	46	37
Natural-appearing shrub and grasslands	17,826	44,030	34	30
Agricultural lands	11,540	28,503	8	20
Developed areas	3,632	8,971	2	6
Not classified	19	47	<1	<1
Basin Total[1]	58,491	144,473	100	100

[1]Total areas may be slightly different from other Basin totals because vector data from variable sources were used in this analysis.

(table 7.4). Current levels of landscape themes in the Basin lean heavily toward natural-appearing forestlands and shrub/grasslands. BLM- and FS-administered lands, as expected, contain higher proportions of less developed lands. Map 7.3 shows the primary landscape themes for the 394 ecological subsections in the Basin. Similar maps were generated for secondary and tertiary themes.

Scenic Integrity—This is a measure of the visual "wholeness" or intactness of the landscape (Galliano and Loeffler 1995). It was developed by combining data from the computerized Geographic Information System (GIS) on vegetative structure, landform, and road density. Scenic integrity was described using five categories, ranging from very high to very low:

- Very high scenic integrity: Settings where the landscape is visually intact with only minor deviations, if any. The visual harmony of the existing landscape character and sense of place is expressed at the highest possible level.
- High scenic integrity: Settings where the landscape appears intact. Scenic deviations resulting from human activities may be present but repeat the form, line, color, texture, and pattern common to the landscape's character so completely and at such scale as not to be evident.
- Moderate scenic integrity: Settings where the landscape appears slightly fragmented, but deviations remain visually subordinate to the "valued"[8] landscape character.
- Low scenic integrity: Settings where the landscape appears fragmented. Scenic deviations resulting from human activities dominate the valued landscape character. Scenic deviations are often unlike any natural occurrences within the landscape viewed.
- Very low scenic integrity: Settings where the landscape appears heavily fragmented. Deviations resulting from human activities strongly dominate the valued landscape character.

[8] "Valued" landscape character refers to scenic components that are expected and/or preferred by constituents and are obtained through questionnaires, interviews, and other survey techniques.

Map 7.3 - Primary landscape themes.

For the broad-scale assessment, scenic integrity was summarized by watersheds at the 6th field hydrologic unit code (HUC), which generally range from 10,000 to 12,000 acres, a scale consistent with that used by the agencies for viewshed analysis.

Existing scenic integrity was mapped for all lands within the Basin managed by the Bureau of Land Management, Forest Service, U.S. Fish and Wildlife Service, and National Park Service (map 7.4). Less than 1 percent of the acreage in the Basin was rated as very low in scenic integrity, 11 percent as moderately low, 38 percent moderately high, 31 percent high, and 14 percent very high. BLM- and FS-administered lands contain much larger proportions of acreage at the high end of the scale. Areas with the least alteration are located primarily in congressionally designated Wilderness and national recreation areas administered by the FS or BLM, or in unroaded areas. Unprotected and unroaded areas that have little alteration are the areas of scenic integrity at greatest risk from vegetation modification.

Demand for Scenery

According to the Resources Planning Act (RPA) 1990 program update, viewing scenery has a high participation rate relative to other recreation activities in the United States, with about 20 percent of the Nation's population and Basin residents participating. About 20 percent of the Nation's population and the Basin residents each participate in recreational activity. Although participation rates may change over time, it can be assumed that viewing scenery will remain among the highest ranked recreational activities in the Pacific Northwest.

Demand for natural-appearing landscapes is expected to outpace the demand for modified landscapes; Washington and Oregon State Comprehensive Outdoor Recreation Plans identified a need for nearly 19 million acres of natural-appearing landscapes to meet projected recreational demands by the year 2000, compared to about 5 million acres of heavily modified landscapes (FEMAT 1993). This demand is not limited to people who are only viewing scenery. Significant numbers of people who hunt, fish, and participate in other so-called "consumptive" recreation activities value scenery highly and choose where to recreate based not just on abundance of fish and game, but on scenic and aesthetic qualities (Allen 1988a, 1988b).

One component of scenic quality not captured by landscape themes or scenic integrity is air quality, which is important to people who hold value for places within the Basin. Clean air and good visibility contribute to the quality of life for people living in the Basin and may contribute significantly to the quality of the experience for people who come to the Basin to recreate or earn a living. Human perceptions of the scenic characteristics of a place are dependent on clean air. During most of the year, the vast majority of landscape settings within the Basin have excellent air quality. The Basin's relatively dry air, occasional cleansing breezes, and predominantly sunny days provide long-range views that are uncommon in other parts of the Nation.

Amenities and In-migration

The precise role of amenities in population growth, although a topic of much research, is not clear. There is increasing evidence, however, that the presence of amenities attracts both businesses and families to the Basin and its quality of life.

Recent studies and commentaries indicate an increasing importance of amenities in attracting and retaining businesses. For example, Rasker (1994) and Rasker and Glick (1994) discussed how the economy of the Yellowstone Ecosystem had dramatically changed. Rasker and others (1994) concluded that both long-time business people and those who have recently moved to the region claim amenities to be important reasons for staying in or moving to the area. A survey of residents of the 100-county ICBEMP assessment area (Rudzitis and others 1995) found that reasons other than employment, including landscape, scenery, and outdoor recreation opportunities, were important in people's decisions to move to the Basin.

Map 7.4 - Scenic integrity classes.

Rudzitis and Johanson (1989) link population growth in the northern Rocky Mountains to the presence of Wilderness Areas, noting that people often cite "wilderness" as an attraction in making decisions on where to relocate. Wilderness Areas, present in 46 of the 100 counties in the Basin, total 10.3 million acres. National Recreation Areas, National Parks, and other areas administered by the National Park Service are located in 28 of the 100 counties and total 3.3 million acres. Table 7.5 shows the amount of acreage of these protected areas in the 10 fastest-growing and 10 stable or declining counties in the region. These data support, although not conclusively, the notion of wilderness as a factor contributing to in-migration.

Economic development in the region increasingly depends on environmentally based amenities. This kind of economic development does not depend on the environment for raw materials, but rather establishes a quality of life dependency important in retaining and attracting a labor force. Factors other than traditional site-selection criteria become important considerations. Service- and knowledge-based industries, which comprise most of the national economic base, are relatively "footloose," meaning their location is relatively independent of natural resource commodities. While the Basin's economy is relatively more dependent on agriculture and manufacturing compared to the Nation as a whole, the fundamental changes occurring nationally are mirrored in the Basin. The growing reliance on information, services, and transfer payments as the economic base of the region suggests that quality of life factors will gain in importance in business location decisions.

Environmental quality factors such as clean air, pure water, the presence of recreation areas, wildlife, and appropriate balances between development and open space can constitute economic assets, acting to retain existing people and business, and to attract potential entrepreneurs (Rasker 1994).

The environmentally oriented lifestyles that outdoor recreation resources provide are important to people living in the Basin, as well as for attracting migrants. This lifestyle is difficult to describe but generally consists of an outdoor orientation; relatively easy access to the region's undeveloped forests, mountains, rivers and wildlife; and appreciation of the relatively clean air and water and open spaces of the Basin. One measure of this interest is the relative rate of participation in outdoor recreation, which as described in chapter 6 is significantly higher among Basin residents than among people living in other regions of the nation.

Rasker (1994), Power (1994), and others have emphasized the role of a high quality natural environment, scenic beauty, and recreation opportunities in influencing population growth and shaping the emerging economy of the Basin. For example, Rasker (1995), writing about the Basin, stated that:

> *As we approach the twenty-first century, there is a striking change in how the region's forests, mountains, streams, rivers, and grasslands contribute to the economic life of its residents. Once, settlers were attracted to the region by the promise of logging, ranching, mining, and farming. Now, the magnet that draws new residents and holds the region's existing inhabitants is environmental quality: clean air and water, handsome scenery, and native wildlife...the region's economy is growing less dependent on resource extraction and more dependent on less tangible qualities: environmental quality, education, entrepreneurship, and capital.*

While there is clearly a need for additional research about environmental factors relative to social assessment, the available research indicates a growing importance of environmental amenities in migration and business location decisions.

Implications for Ecosystem Management

Environmentally based amenities managed by the Federal Government play many social and economic roles in the Basin; they contribute to the quality of life of Basin residents, attract new migrants, and provide recreational settings for residents and non-residents. Despite the importance of amenities, such as recreation opportunities and scenery, systems to map and inventory these values are not well integrated into current agency planning systems at ecoregion scales.

Table 7.5—Wilderness acreage for the 10 fastest growing and 10 stable/declining rural counties in the Basin.

County	1990-94 Growth Rate	Wilderness Acreage	Percent of County
Growth Counties:			
Boise, Idaho	28.2	66,273	5.4
Kootenai, Idaho	25.5	0	0.0
Valley, Idaho	25.0	722,905	30.2
Teton, Idaho	24.1	0	0.0
Ravalli, Montana	22.8	286,700	18.7
Deschutes, Oregon	21.3	108,400	5.5
Elko, Nevada	20.7	0	0.0
Bonner, Idaho	19.8	89,455	7.3
Humboldt, Nevada	18.8	0	0.0
Adams, Idaho	18.2	22,437	2.6
Stable/Declining Counties:			
Silver Bow, Montana	2.6	0	0.0
Lake, Oregon	2.0	18,119	0.3
Columbia, Washington	1.9	79,787	14.3
Grant, Oregon	1.1	186,155	6.4
Madison, Idaho	0.3	0	0.0
Whitman, Washington	0.2	0	0.0
Harney, Oregon	-0.1	0	0.0
Shoshone, Idaho	-0.4	0	0.0
Deer Lodge, Montana	-0.5	56,231	11.8
Custer, Idaho	-3.6	382,508	12.1

Assuming the population continues to increase with in-migration, there will be a multiplying effect on demand for recreation opportunities resulting from the changes in population and lifestyle. Area residents may find themselves increasingly in conflict with nonresidents who also find amenities within the region attractive as places to recreate, thereby accelerating potential conflicts with the tourism industry. As lifestyles change and the population ages, recreation demands are expected to shift from consumptive types of recreation to the more appreciative experiences.

The data on recreating participation by lifestyle, coupled with projected population increases, also suggest a multiplying effect on demand for outdoor recreation opportunities traditionally found on Federal lands within the Basin. These increases may intensify long-held conflicts, not only between recreation and commodity uses, but among recreation activities as well.

The lack of both uniform Basinwide data on the supply of recreation opportunities and a field-based inventory of existing scenic condition hampers efforts to assess the extent to which Federal agencies can meet demands for important social values. To address increased demand for amenities, such as

recreation and scenic quality, land management agencies may find it helpful to accelerate their inventory processes, map areas, and use GIS technology for integration of these data with other natural resource information.

Changes in the region's economic structure and the growing importance of amenities and quality of life considerations in business location decisions create challenges to traditional economic development models that are based on natural resources. The forest and range, while still sources of commodities, are also sources of environmental amenities upon which many local economies are increasingly dependent. Amenity-rich areas will likely continue their role as centers of growth, increasing the need for intergovernmental cooperation and coordination in growth management to mitigate impacts.

Assuming the Basin will continue to have not only increasing numbers of people, but at least relatively constant recreation participation rates and an overall aging population, demand is expected to increase for high quality, nature-dominated scenery within the Basin. While some developed portions of the Basin will continue to offer outstanding scenic landscapes, the greatest opportunity for meeting expected increasing demand for scenery in the Basin lies in the amount of undeveloped and partially developed settings.

An emerging opportunity already being capitalized in the Basin is ecotourism. Ecotourism is a special type of tourism, having some of the same characteristics as tourism: people leave their home, travel to a recreation setting, engage in a package of activities designed to produce a desired set of experiences, and, presumably, return home with a set of benefits. Adding the "eco" prefix defines tourism more sharply:

- The natural environment is the central attraction.
- Any development is designed to provide better access to, and awareness of, the main attraction.
- It is active participation and appreciation (for example, participating in an archaeological dig), rather than passively watching someone else do something in a classroom setting.
- There is an element of adventure and romance.
- People learn interesting aspects of the natural and cultural environment through outdoor recreation.
- The tourism opportunity fits well into the existing ecosystem.

Ecotourism opportunities must be sustainable socially, economically, and environmentally. For example, the tourism opportunity is developed in concert with, and supported by, local and regional residents. The tourism opportunity is financially self-sufficient; earned revenues or other sources of financial support cover all capital and operations costs over the long term. Local and regional economics benefit from increased numbers of tourists and associated expenditures. Two primary goals of construction, management, and visitation associated with tourism are to minimize energy usage and encourage all people involved with the tourism opportunity to be environmentally sensitive.

Several current recreation issues were identified from the most recent Statewide Comprehensive Outdoor Recreation Plan (SCORP) for each of the four main states of the Basin. Issues common to all areas of the Basin include:

- Cooperation and coordination among land management agencies.
- Funding.
- Maintenance and development of facilities.

Several other common issues, though not among all state SCORPs, include access, education/information, and liability.

Restrictions on use levels and visitor behaviors are increasing as pressures increase on finite resources such as wilderness trails located near population centers or to which access is good. Limiting visitor numbers through some kind of rationing and allocation system is usually viewed as a last resort for resource protection. Any recreational use has

some impact on the natural and social environment; the question is what types will be acceptable, and to what extent and how. Managers of Wilderness Areas, Wild and Scenic Rivers, and other resources where protection of the environment and quality of the experience are paramount often conduct studies to determine a balance between recreational uses and impacts.

Because impacts tend to be more a function of visitor behavior than amount of use, it is important in devising programs for habitat restoration to understand what aspect of recreation use is causing impacts, make decisions about what levels and types of impacts are unacceptable (Stankey and others 1985), and suggest appropriate remedial mechanisms. Unfortunately, there is little research documenting the impact of recreation use on key ecosystems such as riparian and aquatic habitats. The lack of research hampers the ability to develop appropriate, scientifically based actions to restore habitats, particularly for threatened and endangered species and for anadromous and inland freshwater fisheries. For example, interim direction for management of anadromous fisheries in the region (PACFISH) suggests closing many recreation sites located in riparian areas. Such closures would have dramatic impact, particularly on camping opportunities, because people prefer to camp near water. Closer examination of the relationship between recreation and impact on fish and riparian habitats would help managers better understand the costs and benefits of such proposals.

Perhaps the biggest recreational issue is financial. Without investment in recreational resources and facilities, the supply and quality of recreation opportunities will decline as population levels increase within the Basin. FS and BLM budgets for recreation are declining, making it difficult to adequately staff and maintain existing facilities and settings. While reduced Federal staffing and maintenance can inspire a spirit of volunteerism, providing many benefits to agencies, user groups, and the public, relying on volunteers may not be a sustainable strategy.

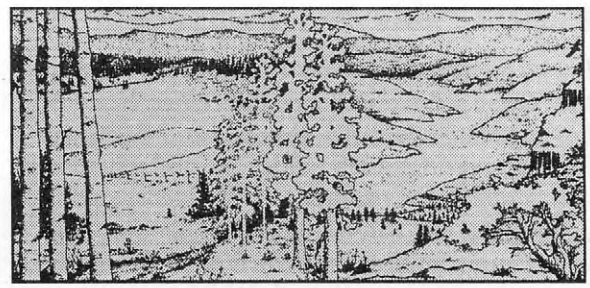
Programs that charge the public for recreation on public lands may be one answer. Research suggests that people are willing to pay as long as fees are reasonable, equitable, and are used to improve recreation at the site. Agencies should pay careful attention to the cumulative impacts of fee systems.

Federal land managers are contracting increasingly more recreation operations, from large-scale recreation and wilderness planning efforts to management of campgrounds and reservation systems. Information gathered from observing the private sector in providing recreational opportunities on public lands can be used to develop new programs. However, there appears to be a large, growing gap between the value of recreation on public lands and the ability of the FS and BLM to successfully accommodate demands for recreation opportunities.

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ROLE OF THE PUBLIC IN ECOSYSTEM MANAGEMENT

A basic tenet of ecosystem management is that people are active and involved in all phases of planning and decision-making (Jakes and Harms 1995). This is a common theme in the ecosystem literature, expressed in terms such as partnership, collaboration, consultation, involvement, power-sharing, and participation (Grumbine 1994, Lee 1993, Moote and others 1994).

The underlying goals of public participation include not just informing the public and soliciting opinions on proposed actions, but integrating people's concerns into decisions responsive to the public. Public participation can bring together the multiple partners involved in ecosystem management in settings where common goals can be identified and a basis for negotiation can commence.

Because public values are not static, public participation helps managers understand changing public needs. This information, coming in the form of interactive processes, can help institutions such as the BLM and FS to stay updated in both the issues addressed and the mechanisms employed to resolve them (Stankey and McCool 1995). This is especially true for ecosystem management, which strives to respond to an evolving set of social values. Social change is rapid; institutions and processes must be adaptable and sensitive to public needs to stay relevant (Moote and others 1994, Stankey 1994).

Another challenge for public participation is that society's demands on natural resources have diversified. There has been a significant shift in emphasis from commodity uses of public lands to amenity and cultural uses, which are difficult to define in strictly economic terms (Gale 1991). Instead of a simple planning problem of one objective, there are now multiple and frequently competing objectives. In the words of Allen and Gould (1986), managers are confronted with "wicked" problems that cannot be solved through mathematical models. Public participation in planning can help articulate what noncommodity and commodity values are important, and to whom.

Interaction with affected publics can help managers understand the various values and definitions of ecosystems that exist in the population and identify the distribution of preferences about public land management. People who know the land best are valuable sources of information. Friedmann (1973) argues that action in society requires actors at all levels with different types of knowledge. He presents a case that experiential knowledge is as valid and useful in providing a basis for action as more formal and systematized forms of knowledge. Likewise, Yankelovich (1991) argues that public judgment is a useful form of knowledge. The role and use of local knowledge in science and management processes, however, is not defined consistently.

Current Public Participation Efforts

Public participation in the ICBEMP is guided by the National Environmental Policy Act, National Forest Management Act, Federal Land Policy and Management Act, their guidelines, and other laws that contain legal requirements for incorporating public input into natural resource decision-making. For example, in situations where an environmental impact statement is required, NEPA requires an early and open process to facilitate free and open communication with the public. At a minimum, this process includes scoping to identify issues that should be addressed and a public comment period after a draft document is issued. Although agencies frequently do more, such as providing opportunities for comment at additional stages of the planning process, they have less commonly involved members of the public in implementation and monitoring.

A recent Forest Service report (USDA Forest Service 1994) stated that the public has "high expectations as to the degree of influence it can have on natural resource management." This expectation was confirmed by the CRB survey in which the public was queried about preferred level of participation in planning (Brunson and others, n.d.). The results were uniform across respondents; the greatest support was for acting as a full and equal partner (chosen by 32% to 39%), followed closely by serving on advisory boards (chosen by 30% to 32%). Providing suggestions and letting the public make decisions was chosen by roughly equal numbers (about 10% to 18%), and no public involvement (letting resource professionals decide) was chosen by just 1 to 3 percent.

People are also concerned about the efficiency of public participation. During EIS scoping and subsequent requests for comments, many members of the public said they valued being asked for their knowledge and opinions in a balanced, representative way, but worried that while time was being spent talking, nothing was happening on-the-ground.

Many collaborative groups have formed in the past few years to jointly address natural resource issues. Wondolleck and Yaffee (1994) conducted an extensive study of what they called "building bridges" that give examples of increased collaboration between the Forest Service and other public land stakeholders. These included many well-known efforts that took place in or adjacent to the Basin: Applegate Partnership, Blue Mountains Natural Resources Institute, Nooksack River Partnership, Tonasket Citizens Council, Yakima Resource Management Cooperative, New Meadows Community Outreach, and Willamette Forest Plan Implementation Monitoring.

The authors surveyed Forest Service employees and nonagency personnel to develop 35 case studies as models for building bridges. The report was designed to identify and analyze success stories that could be emulated and supported within the Forest Service. Each case study was structured to show why the situation was perceived as a success, why success was possible, how barriers were overcome, and what lessons were learned for future bridging. The case studies show how building bridges can:

- Provide powerful examples of the benefits of creating a more permeable membrane between agencies and the public.
- Allow agencies to acquire needed information from the public.
- Generate good resource decisions that will endure.
- Build support for forest management decisions.
- Influence public knowledge and values.
- Broaden the workforce available to accomplish activities on-the-ground.
- Make the agency a better neighbor.

The BLM has created or been involved in similar efforts, such as the Trout Creek Working Group in eastern Oregon.

The report also listed factors contributing to success, such as accepting nonagency participants as full working members; involving dedicated and open-minded individuals; and having required resources, capabilities, and support. Recommendations for future efforts included ways to communicate images of successful bridging, enable employees to build and use bridging arrangements, and encourage employees and nonagency interests to build relationships.

These results demonstrate the public's clear interest in having a greater role in natural resource decision-making. This interest takes many forms, from confrontational arguments that Federal lands should be taken away from the Federal Government entirely, to seeking influence on public land management through grassroots consensus efforts. One example of the latter was the Forest Ecosystem Stewardship Demonstration Act of 1995 proposed by the Flathead Forestry Project, an ad hoc group of conservationists, loggers, small mill owners, and civic leaders in northwestern Montana. This act, introduced into the House of Representatives by Representative Pat Williams of Montana on May 25, 1995 (HR 1682), encouraged the Forest Service to utilize stewardship contracts to accomplish ecosystem restoration in conjunction with logging projects. The proposal included local forest stewardship councils, consisting of public groups that would provide local advice to the Forest Service.

Another recent example of grassroots participation is the "cow cops" program instituted by the Oregon Natural Resources Council. This program reflected how citizens with a special interest can assume responsibility for certain types of planning, implementation, and monitoring tasks. Volunteers carrying copies of allotment plans inspected FS and BLM grazing allotments periodically and reported violations to the respective agency. This effort was spurred by public perceptions that the agencies either would not, or could not, adequately monitor range conditions. The reaction of ranching groups to the volunteer monitoring program was negative, leading to a confrontational atmosphere (Cockle 1995).

A final recent example was a forum on "Dynamics of Northern Idaho Forests" held February 2 and 3, 1996, in Coeur d'Alene, Idaho. Sponsored by various agencies, organizations, industries, and tribes, the symposium was designed to assemble information about the plants, animals, and people of the region and how they interact. This symposium also indicated a scale of analysis viewed as appropriate by diverse interests. Similar local and regional efforts are expected to be scheduled in the future as residents of communities, trade regions, or socio-ecologic regions decide it is time to work together to identify and seek solutions to public land management issues and conflicts.

A related issue for the agencies is how to blend increased opportunities for public participation with the emerging role of science as a pillar of ecosystem management. Public opinion polls have found support for scientific solutions to natural resource problems. Scientists are receiving increasing requests to address and provide information on complex ecological issues and have helped society gain an appreciation of the complexity of human interactions with the environment. However, allocation of resources is inherently a process of judging the relative worth of differing perspectives on natural resources. Science, while assisting in mapping and measuring a variety of values and identifying consequences of alternatives, has a limited role in the allocation process. Although science can provide information about existing social, physical, economic, and biological conditions and processes, their interrelationships, and likely response to change, science cannot dictate how public lands should be managed. That decision is a social and political issue, not a scientific one.

The role of science provides a tripartite combination of expertise to natural resource managers: scientists who measure, analyze, and display data; managers who use such information to make

decisions, and publics who interact with both scientists and managers. Because this forum has been tested in few natural resource situations, however, the roles, processes, and expectations are still forming. The ICBEMP demonstrated one attempt to open up scientific analyses to the public.

Recent Agency Initiatives

The Northwest Forest Plan's creation of Province Advisory Committees was a move toward a new approach to public participation. Each of the 12 provinces created as management units for the plan has an advisory committee comprising federal employees and members of the public. Several of these committees address management of lands that extend to the east side of the Cascades.

Ecosystem assessment at the watershed scale provides an additional avenue for agencies to work with diverse members of the public. The process of inventorying social, physical, biological, and economic conditions in relatively small-scale watersheds calls for both local and scientific knowledge. Because the public's role in these analyses has not been consistently monitored, the effectiveness of this approach to public participation is unknown; additional public incentives may be needed to encourage fuller and broader participation.

The Northwest Forest Plan also established 10 Adaptive Management Areas (AMAs), designed to encourage development and testing of technical and social approaches to achieving desired ecological, economic, and other social goals. The AMAs, which range in size from 84,000 to 400,000 acres, have a clear objective for public participation: "These areas should provide opportunities for land managing and regulatory agencies, other government entities, nongovernmental organizations, local groups, land owners, communities, and citizens to work together to develop innovative management approaches" (FEMAT 1993).

A 1994 mail survey of residents of the Central Cascades AMA found that people highly valued citizen participation in forest planning, even if greater costs were incurred (Shindler and others 1995). Respondents favored an active role for the public, including serving on advisory review boards and, to a lesser extent, acting as full and equal partners with Federal agencies. This survey is consistent with the results of other recent research, as well as the many grass root efforts discussed.

Another recent initiative began in 1995, when the BLM and FS established Resource Advisory Councils (RACs) in the portions of Washington and Oregon not already covered by province committees. The RACs, also formed under the Federal Advisory Committee Act, parallel the intent of Province Advisory Committees. Unlike province committees, RACs do not include federal employees as members, although agency employees attend all meetings. RACs are an outgrowth of the BLM Districts' Multiple Use Advisory Groups, but have greatly expanded scope. Because RACs were one of the few aspects of Rangeland Reform/ Healthy Rangelands initiatives allowed to proceed, they will not be unique to the Basin.

The RACs make recommendations to the FS and BLM on ecosystem management, watershed planning, and other local or regional natural resource issues. The list of objectives for Resource Advisory Councils, taken from the Draft 1784 Handbook on Advisory Committees dated March 20, 1995, includes:

- Collaborating in resource management across jurisdictions.
- Promoting partnerships and working groups to develop regional solutions to management issues.
- Assisting with educational efforts.
- Sharing science and other information.
- Encouraging and supporting local groups to implement ecosystem management.

The Province Advisory Committees and the Resource Advisory Councils were asked by the ICBEMP Executive Steering Committee to provide comments on a preferred alternative for the Eastside and Upper Columbia River Basin EISs. It remains to be seen how successful these groups will be at forming bridges between agencies and the public. Monitoring the effectiveness and efficiency of these and other public participation efforts, using criteria based on those suggested by Wondolleck and Yaffee (1994), can provide the information needed to measure their success.

Implications for Ecosystem Management

One ecosystem management function may be to clarify the role of the public in public land management. It is clear that the public is assuming a more active role in public land management, whether or not the opportunity is provided by the Federal Government. People want various roles in decision-making and assurance that their concerns are heard and treated fairly. Societal debate over the appropriate institutions for public participation will continue.

Natural resource agencies frequently find themselves in situations where goals of resource management disagree with various potential futures described by conflicting groups. In addition, there is often little agreement about cause-effect relationships; forest health is an example of a debate among scientists about the causes and effects of forest decline. Another example is the continuing debate among social scientists about the role of resource commodity flows in issues of community stability and resiliency.

In these situations, collaborative learning processes (Krannich and others 1994) may be more suitable for planning than other techniques. Public participation procedures for ecosystem management could focus on learning, recurrent interaction among participants, and increased opportunities for working through complex problems to identify possible solutions. Krannich and others (1994) said, "No one party, including any agency, organization, or discipline, holds the key to understanding a particular natural resource management situation." They believed that successful design and implementation of ecosystem management policies requires parties to be open to learning from each other and to acknowledge that interactive learning is an ongoing process.

Collaborative learning is based on several assumptions:

- Learning is more likely in active, rather than passive, situations.
- People learn in different ways.
- Learning styles vary.
- Active learning groups can engage conflict and controversy.
- Systems thinking fosters learning.

Collaborative processes based on concepts of dialogue and mutual learning (Friedmann 1973) seem to be appropriate for the kinds of planning situations confronting natural resource managers. Traditional forms of rational-comprehensive planning, where public participation is limited to identifying issues and responding to a draft document meeting the National Environmental Policy Act, may not be viewed by the public as adequate. An institution that provides ongoing opportunities for public-agency interaction, and into which individual projects will flow, may have the greatest chance for success.

As a result of effective public participation and mutual learning, the resulting decision, in theory, should have greater social acceptance. Salwassar (1990) defined the primary goal of "New Perspectives"[9] as developing a "scientifically sound and socially acceptable practice," a statement equally

[9] New Perspectives was a management direction established by the Forest Service in 1990 for the forestry program; its two basic principles were to manage forests to balance values and produce a sustained supply of goods and services; and to maintain biodiversity (Stankey and Clark 1992).

true of ecosystem management. The role of public participation in this context is to provide a forum for developing common social norms and expectations about ecosystem management. Public participation in ecosystem planning therefore helps decision-makers understand the feasibility of potential actions.

In addition to the foundation of collaborative learning, numerous studies have suggested principles for enhancing public participation processes that ecosystem management would be wise to consider. For example, previous researchers suggested a four-phase approach to public participation:

Phase 1: Create an environment for meaningful public involvement.

Phase 2: Initiate a participatory decision process.

Phase 3: Conduct an open decision process.

Phase 4: Complete a successful shared decision process.

McCoy and others (1994) identified the following specific principles to guide public participation in ecosystem assessment and management processes:

- Clearly state goals and objectives.
- Plan for effective dialogue.
- Build cooperation constructively and deliberately.
- Emphasize education and social learning.
- Diversify the public involvement framework.
- Be open, honest, and responsive.
- Understand the multiplicity of publics and techniques.
- Use a third-party intervener when necessary.
- Establish a framework for continuing dialogue.
- Analyze, evaluate, and monitor.

Roles and expectations must be clearly articulated for public participation to be successful. Among the expectations that should be communicated are the role of the public, the use of public input, and methods of using and acknowledging that input. Follow-through is especially important. It is one matter to provide opportunities for public input, and yet another to provide feedback on how that input was used and what the continuing role of the public will be, not just in planning but also in implementation. The process for incorporating traditional environmental knowledge held by the public needs to be made explicit.

The concept of bridging appears to have many social benefits. Wondolleck and Yaffee (1994) identified successful bridging, claiming two important aspects related to success were encouraging public understanding of other groups' interests and needs and promoting interagency cooperation. Some success characteristics could be measured by outcomes, such as generating a better information base to help make resource decisions or creating greater public ownership in a project or decisions. These criteria could serve as an initial set of indicators that could be monitored to determine the success of future public participation efforts. Another benefit could be increased predictability in resource outputs and conditions; public participants could gain a better understanding of the issues, likelihood of implementation, and other information that helps them to be better informed and able to anticipate changes. Predictability of resource flows is a key public issue, and one on which the agencies have a mixed track record.

Another consideration for public participation in ecosystem management is the issue of scale. Krannich and others (1994) suggested setting standards and guidelines at the bioregional level, then developing implementation strategies at the more localized project level. However, public

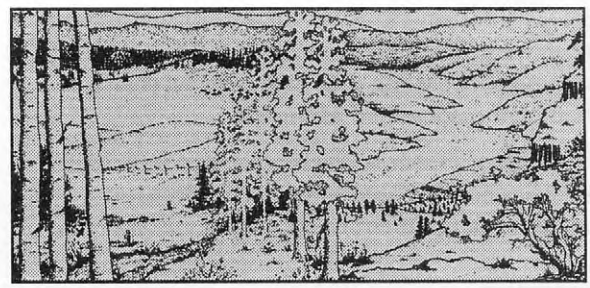
discussion about the transition to ecosystem-based management in the Basin was recommended at the scale that most people connect to the land, which is the local, not the bioregional scale.

Scales of analysis utilized by the ICBEMP included ecological reporting units, economic trade regions, 4th field watersheds, groupings of 4th field watersheds, 6th field subbasins, groupings of counties, groupings of communities, EIS planning areas, the assessment area, and the Nation. The appropriate scales and the role of the public at each level needs to be discussed further. Although methodologies of obtaining local, regional, and national participation should be explored, this issue is sensitive. For example, national conservation organizations have objected to what they perceive as an overemphasis on local input into decisions about public land management.

Finally, monitoring public participation is a key element of measuring success. Moore Information, Inc. (1994) identifies at least five different ways to measure success, including product, politics, interest, responsibility, and relationship orientations. While the obvious intent of planning is to achieve product-oriented success (getting a plan completed and implemented), other forms of success may also be important in a planning exercise. Traditional measures of success typically include number of meetings held, attendance numbers, and the size of mailing lists. However, these are measures of opportunity, not success. True measures include not just the social acceptability and desirability of the outcome, but participants' evaluations of the process, their role and its effectiveness and efficiency, and perceived levels of ownership in the ultimate decisions. According to Krannich and others (1994):

> *It is not merely computers full of social indicator data, GIS maps, or species distributions and habitat effectiveness trends that will determine the success or failure of ecosystem-based management. Rather, it will hinge on whether or not we are able to craft policy mechanisms within which we can mix that scientific information, assign it meaning, sort it out, and then chart a course for ourselves...the participants themselves—both in and out of agencies—are ultimately responsible for the outcome and are the judges of its adequacy.*

WORKING TOGETHER: INSTITUTIONAL COMPONENTS OF ECOSYSTEMS



Institutional analysis allows the story of the Basin to be told from the perspective of organized interests, providing insight into the forces at play in decision-making and the relationships among groups in policy development and implementation. Institutions represent our collective experiences, and it is through institutions that humans solve social problems (Cortner and others 1995). Gary Machlis, lead social scientist for the National Park Service and a University of Idaho professor, described institutions as "collective approaches to solving collective problems."

The importance of institutions to ecosystem management was described by Lee (1994): "Managing ecosystems is an inherently institutional task, because the ecosystems that matter are already exploited by human institutional arrangements, and changing the way that humans interact with ecosystems requires changing institutions." There are multiple ways to consider institutions: as formal organizations; durable social arrangements that guide or control actions; or any social creation that embodies a purpose. The defined bounds of institutions are quite fuzzy (Lee 1994).

In this social assessment, institutions are defined as by Ingram and others (1984): "Legal, political, and administrative structures and processes through which decisions are made with respect to public policy." This definition is a middle ground, accepting a broad but not extensive interpretation of institutions, including organizations such as government agencies as well as formalized patterns of agreement such as property rights. Not included in this description are less formalized patterns such as political beliefs and finer-scale institutions such as human families.

Structure of Government

To link the biophysical, economic, and social interests of citizens into a coherent management strategy, ecosystem management must address implementation methods of such strategy in an institutional environment that is highly fractioned between different organizations and interest groups. The structure of government in the United States has been termed "federalism," a system characterized by the conscious division of powers among governmental units, with coordinate and independent governments legitimized on a constitutional basis (Diamond 1981). The most important of the government units on the national scene are the one federal and 50 state governments; however, local governments (which are technically dependent on the states for authority) exert a surprising amount of autonomy (Sokolow 1987). Local governments include not only county and city governments, but quasi-governmental bodies such as school districts, port authorities, irrigation districts, and a host of others. (The role and status of tribal governments are discussed earlier in this chapter.)

At the Federal and State levels, the executive, legislative, and judicial branches of government provide sometimes discrete but often overlapping functions. The authorities between branches and levels of government are often unclear, due in part to the ambiguity of the Constitution. The division of government results in many opportunities for informal influence over the formal decision-making process, as demonstrated by the existence of thousands of corporate and noncorporate lobbying

groups (McLain 1995). Interest groups operate at whatever point of entry believed to be most effective and concentrate their resources according to their own track record of success.

The Federal executive, legislative, and judicial branches have all been highly active in natural resource management issues during recent years.

Executive

Legal authority to manage and protect natural resources is generally vested with governments, which in turn, assign operational responsibilities to their respective bureaucracies. Bureaucracies are institutions within government that provide a mechanism for consistent policy implementation (Shannon 1994). Several studies have found, however, that the possession of formal authority is distinct from control (Bachrach and Baratz 1970, Kingdon 1984, and Lukes 1974). As McClain (1995) observes:

> *One can have no formal decision-making authority whatsoever yet still exercise considerable control over policy choices provided one controls the processes by which issues become perceived as public problems, the ways in which problems are defined, and the selection (or elimination) of possible solutions.*

Although bureaucracies follow the principles described by Weber (1946) for established rules, written records, and professionalism in the attainment of organizational goals, the bureaucracies are subject to considerable outside influence. The dependency of bureaucracies on political support subjects them to influence from organized interests, as described in earlier text. Members of the bureaucracy may resist efforts for coordination and sharing of authorities (Balmer 1990) if loss of stature is anticipated.

The BLM and FS exist within a system of other federal agencies in various departments that also have management and/or regulatory authority for ecosystem components, and in some cases, a mission with a narrower focus. Regulatory agencies, such as the Environmental Protection Agency, U.S. Fish and Wildlife Service, and National Marine Fisheries Service, have overlapping responsibilities that have potential to conflict with the multiple-use mandates of the BLM and FS; this situation often makes it difficult for the BLM and FS to simultaneously respond to the concerns of these regulatory agencies and the concerns of other agencies, governments, organizations, and individuals. This difficulty is not unique to the BLM and FS; the debate in recent years about the future of salmon in the Pacific Northwest, for example, has been complicated by the numerous agencies, committees, and governments that each have their own authorities, scientists, and perspectives on issue resolutions.

Legislative

The Congress has become highly active in mandating specific BLM and FS actions over the past decade (Jones and others 1995). Although many different pieces of national legislation, including the Endangered Species Act of 1973 and the Wilderness Act of 1964, affect natural resource management in the Basin, basic legislation affecting both the FS and BLM [the Federal Land Policy and Management Act (FLPMA) and the National Forest Management Act (NFMA)] created broad agency mandates that have saddled the agencies with conflicts:

> *The American system of the separation of powers requires Congress to provide fairly specific guidelines lest the courts declare overly broad or vague statues, as unconstitutional delegations of legislative power. Yet, of necessity, statutory requirements mandating multiple uses are susceptible to many interpretations... Administrators were assigned not only the responsibility of developing the technical details but also the task of dealing with conflicts unresolved by Congress, and probably unresolvable to everyone's satisfaction. At times, this has overwhelmed the agencies and their technical capabilities and, perhaps, gone beyond the limits of their constitutional authority (Balmer 1990).*

In this institutional climate, agency actions frequently become controversies that require political solutions. The Congress has responded with additional and sometimes contradictory legislation to address these issues, but informal methods of influence are likely the most important form of congressional oversight (Congressional Quarterly 1991). In other words, Congress can, and does, put direct pressure on land management agencies through "lobbying" agency staff. By communicating the desires of either their constituents or the interest groups that provide political support, congressional representatives are able to direct agency actions outside of the legislative process. Agency personnel, ever aware of anticipated reactions (Culhane 1981), adjust their behaviors accordingly.

Perhaps the most important legislative responsibilities of the Congress are the drafting and passage of appropriations bills, the "power of the purse" that is the life blood of government operations. The Interior and Related Agencies Appropriations Bill provides funding for both the FS and BLM, frequently carrying direction for agency operations (Bolduan 1990). It has become common practice to attach amendments to this appropriations bill and others to determine public policy. A recent example was passage of the 1995 Recessions Act (P.L. 104-19), which contained the Taylor-Dicks Amendment, a salvage sale rider prescribing how the Forest Service would address the aftermath of the major forest fires of 1994. This rider had sufficiency language overriding major environmental legislation that previously had ensured opportunity for citizen appeals of land management operations. Appropriations language with limitations on judicial review of Forest Service operations had occurred several times in the past decade prior to the Taylor-Dicks Amendment (Jones and others 1995). Although the Ninth Circuit Court ruled that the Taylor-Dicks Amendment was an unconstitutional violation of the separation of powers doctrine, the Supreme Court overruled the decision (*Seattle Audubon Society v. Robertson*, 112 S. Ct. 1407, 1992).

Judicial

The preceding case is one example of increasing judicial involvement in natural resources. The power of Federal judges is considerable, as they possess authority to stop any administrative action by issuing writs of injunction. Although these powers are absolute, the courts have acknowledged that agencies retain responsibilities to carry out actions to implement public policies, giving the agencies greater flexibility and autonomy that appears to be supportive of ecosystem management (Meidinger 1995).

Review of Forest Service-related litigation and administrative appeals between 1971 and 1993 (Jones and Taylor 1995) found markedly increasing use of litigation as a means to address grievances. Environmental groups had more than double the complaints of commodity interests. Although the agency won the majority of these legal challenges, the authors concluded that "the courts and administrative appeals process have likely been significant factors in catalyzing change within the Forest Service." The prospect of legal and administrative challenges force agency personnel to alter or constrain plans in advance of decisions to avoid the high cost of legal conflicts. Decisions about planning, implementation, and monitoring have the potential to shift from what is best for the ecosystem, to what can be successfully appealed.

The strategy to utilize litigation as a tool to influence policy carries a cost, however, because legal and administrative challenges hinder the ability of agencies to carry out their management programs, leading to the characterization of government "gridlock." These challenges also damage cooperative working relationships among those who may be important to the implementation of management actions and frequently exacerbate tensions surrounding difficult public policy issues.

Cross-Jurisdictional Strategies

Although the above summary appears to indicate that many key issues of authority have already been decided, a divided government continues to provide multiple pathways through which advocacy groups may pursue their interests. The courts, the bureaucracy, and the Congress are all likely to remain involved in the evolving policy disputes about natural resources.

The FS and BLM operate within a complex institutional environment challenged by definition and implementation of ecosystem management. Understanding the options available for operating within this environment is a precursor to developing cross-jurisdictional strategies required to manage entire ecosystems. This need was considered in the following review of three common models of decision-making, policy formulation, and previous examples of cross-jurisdictional approaches to natural resources management, which give emphasis on collaboration with states and counties.

Policy Formulation

In an examination of how ecosystem management may operate in the American federalist system, McLain (1995) outlined three approaches to policy formulation:

- The *market politics model*, which promotes maximizing individual satisfaction through assignment of values to individual preferences. Government bodies are engaged only to assure open access to the process and to ensure proper procedures are followed.
- The *adversarial interest group model* which, like the market politics model, continues to view society as a free market, but one in which participants operate in groups to advocate for their interests. Government's role is largely to create the proper settings for the interest groups to interact, and policy makers select the option that satisfies the largest number of groups.
- The *participatory democracy model*, which looks for shared interests among stakeholders. Governments take an active role in facilitating the exchange among individual and group interests to develop a common vision for future actions.

McLain concluded that the participatory democratic model has the best opportunity to advance ecosystem management because, unlike the other models, it allows for identifying shared purposes across governance levels. It provides opportunity for social learning, a critical feature in addressing complex natural resource problems (Lee 1993). McLain also recognized the considerable challenges in creating this common vision in the Basin relative to the diversity of land ownership categories, multiple layers of political authority (which are further fragmented internally), and uneven distribution of resources, including knowledge and capital. However difficult it may be for the participatory model to be implemented, McLain emphasized that the other major models of policy making cannot provide an appropriate framework for addressing cross-jurisdictional issues because their structures lead to social division rather than social cohesion.

Previous Cross-Jurisdictional Efforts

Smith and others (1995) examined 12 case studies of cross-jurisdictional management efforts across the United States. They emphasized that institutions must be capable of learning from past actions and experimental behaviors if the participatory model is to succeed, and that much remains to be done to structure institutions to foster this learning. They concluded that tolerance for change is critical, suggesting an approach that emphasizes incremental changes and places authority for managing change with those most directly affected. They called for open information flow, saying that the success of ongoing management practices depends largely on the learning gained from the trials and errors of past practices:

The different management regimes being practiced today across various ownerships can be viewed as simultaneous experiments, but if the information required for analysis, comparison, and evaluation is not collected, and if one manager does not learn from another's mistakes, the capacity for learning through doing is substantially restricted.

Viewing information as proprietary, collecting and storing information in incompatible formats, and discounting qualitative data as unscientific, along with other institutional attitudes and behaviors, are barriers to open information flow.

The literature suggests that there is no straightforward, patterned approach to managing landscapes across multiple ownerships. Ostrum (1990) warned that attempts to "get institutions right" are not feasible if imposed from upper hierarchies, because there are simply too many cultural and conditional variables on any given landscape. Smith and others (1995) advocate nurturing informal authority across jurisdictions, where institutions that possess formal responsibility to manage resources participate in a supra-organizational forum to coordinate their plans and actions. These organizations may vary in both their degree of formality and their organizational cohesiveness.

At one end of the spectrum is a formalized advisory council with established rules and membership, and at the other end is a loose-knit coordinating body such as an ad hoc organization. Along this continuum of formality, participating organizations can determine appropriate levels of interchange and coordination. The following discussion addresses both the positive and negative aspects of the extremes of this spectrum, from the ad hoc strategy to the council strategies, and from the county context to the international context.

Ad Hoc Strategies—The least formal of the organizational forms to coordinate management across jurisdictions, ad hoc strategies tend to have highly fluid memberships. They begin small and are subject to changing priorities. Major strengths are their capabilities to be accessible to a wide spectrum of interests, to be relevant to local conditions, and to adjust to emerging interests. Their weaknesses are reliance on a few key players, who may become exhausted or disillusioned by slow progress; limited financial resources; and weak authority to ensure compliance of their recommendations among other formal organizations. The Applegate Partnership in southeastern Oregon is an example of an ad hoc organization that has participated in ecosystem management planning.

Council Strategies—Councils, or advisory councils, are generally formed through legislative or administrative initiative, and, unlike ad hoc organizations, often have a highly specific mission or task. Direct regulatory authority is not vested in a council, so their authority remains informal, but by virtue of their official sanction and the stature of their membership, their recommendations carry more weight than less formalized coordinating bodies (Lee 1993). The strength of councils is in their capacity to conduct analyses and the credibility associated with their recommendations. Councils generally operate with prescribed budgets to facilitate their ability to address complex issues common to cross-jurisdictional management. Councils are generally more cohesive and capable of reaching agreement on common goals than are less formalized groups (Agee and Johnson 1988). This latter strength is also the source of councils' greatest weakness; by focusing on membership of a particular type of individual or point of view, councils can exclude representatives who have creative or unsettling alternative solutions. Council agendas may, by omission, ignore key causal factors underlying problems in coordinated management, resulting in council recommendations that may be either too narrow or irrelevant. Additionally, in a more formalized structure, local residents who may be affected by a council's recommendations may feel excluded, possibly resulting in their opposition.

There are many examples of these types of institutions and many others, as discussed in this chapter about the public's role in ecosystem management.

Cross-jurisdictional approaches to ecosystem management require the BLM and FS to work not just with other federal entities, but with state and local governments to identify and accomplish mutual goals. A brief description of the structures and authorities within state and county governments in the Basin provides a vantage point for future research on institutional relationships for natural resource management.

States—Like agencies in the Federal Government, state agencies have divided legal jurisdictions over natural resource issues. Each state within the Basin has its own unique system of agency jurisdiction and policies that relate to natural resource management. Some state agencies oversee activities on public lands or share co-management responsibilities with the federal agencies. For example, the federal Clean Water Act requires the BLM and FS to comply with water quality management requirements of each state, and the agencies must also comply with substantive and procedural requirements of state and local agencies in managing air quality. In addition, co-management responsibilities exist because State fish and game agencies have responsibility for wildlife populations, whereas federal agencies manage much of the habitat.

To accomplish certain goals and mandates, the FS and BLM frequently enter into partnerships with state agencies. These partnerships allow resource management to be shared and combined to accomplish objectives beneficial to all cooperating partners. A state agency may become involved in cooperative arrangements with the FS or BLM when the state agency is interested in supporting a project through funding, labor, or supplies. Many of the relationships previously called cooperative efforts are now recognized as partnerships and documented with some form of agreement. Partnerships between the FS or BLM and state agencies can include memorandums of understanding (MOUs), challenge cost share (CCS) agreements, and collection agreements (Lee 1991).

Differences in priorities between state and federal agencies are expected due to the distinct mandates and constituencies of each. The FS and BLM are required to address the multiple demands placed on Federal lands under their management jurisdiction, whereas the state's fish, wildlife, and recreation agencies must address more specific objectives, often for a more specific population.

A common problem affecting government agencies in recent years is the difficulty in implementing complex mandates under conditions of continuing budget cutbacks. State agencies may possess the desire to assist in developing Federal policy, but have seen their responsibilities expand while their budgets are reduced. Budgetary constraints often restrict States from collaborating with federal agencies, even when requested to do so. Suggestions for greater efficiency to guide State and Federal interactions include improving coordination among federal agencies to facilitate communications and monitoring, using common databases between state and federal agencies (such as compatible GIS technologies), and reducing multiple reporting requirements.

Counties—County governments are a basic political unit of organization in the United States, providing services to residents within their borders and working in conjunction with the governments of states, municipalities, and other special districts to support the public's needs. The states, through legislative and executive mandates, play a large role in determining the services that counties provide, and also commonly use the county infrastructure to deliver the services (Davis and others 1992). County governments are far from homogeneous, reflecting tremendous differences in terms of physical, social, and financial conditions. For example, a 1992 report commissioned by the Oregon Association of Counties, entitled "County Services and Revenues in the State of Oregon", identified eight types of counties based on the location of Federal lands, diversity of economic structure, and population growth (Davis and others 1992).

The different management regimes being practiced today across various ownerships can be viewed as simultaneous experiments, but if the information required for analysis, comparison, and evaluation is not collected, and if one manager does not learn from another's mistakes, the capacity for learning through doing is substantially restricted.

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Machlis and others (1994) termed counties important administrative units for regulations and policy in both the social and biophysical aspects of ecosystem management. County governments are becoming increasingly responsible for environmental management; a national survey of county executives found that environmental issues (including solid waste, land use and zoning, water supply/sewage, and toxic waste) are four of their top five concerns (Waugh and Hy 1988). McGown (1994) identified a large proportion of counties in Oregon, Washington, and Idaho that were involved in activities closely linked to ecosystem management such as planning, water quality monitoring, and wildfire mitigation.

Perhaps the most important aspect of the role of counties in ecosystem management relates to their responsibilities in land-use planning. County governments become de facto land management agencies addressing many ecosystem issues through zoning ordinances, property taxation collections, and comprehensive planning responsibilities (Machlis and others 1994).

Comprehensive plans for counties within the Basin indicate that county governments are taking a very active role in planning for future developments in land use, infrastructure, and economic activity within the Basin (Frewing-Runyon 1995). The counties anticipate having a major role in regulating development and identifying forest and agricultural lands to be protected from nonfarm and nonforest uses. Frewing-Runyon concluded her study by recognizing the important interactions that county-level planning may have with ecosystem management: "The importance of demonstrating knowledge and consideration of local desires for future conditions when making Federal land management decisions cannot be underestimated."

Important elements of cooperation among the FS, BLM, and county governments involve agreements for cooperative fire suppression, managed through regional incident command systems; search and rescue operations; public safety education; and other locally relevant, mutually beneficial services. On some occasions, the FS and BLM sign memoranda of understandings to document the scope and nature of their interactions. Even if rarely referenced, these documents establish a common interpretation of the expectations and responsibilities of each party. Although highly informal and not as yet considered to be official agreements as discussed earlier in this chapter, other kinds of cooperation remain fully relevant to more effective cross-jurisdictional management.

The significance of cooperative relations with county governments has been identified in various BLM and FS policy statements. The importance of agency relations to local and American Indian tribal governments propelled the 104th Congress to provide for a general exemption from the Federal Advisory Committee Act in Section 204 of the Unfunded Mandates Reform Act of 1995. The language within this Act instructed each Federal agency to "develop an effective process to permit elected officers of state, local, and tribal governments (or their designated employees with authority to act on their behalf) to provide meaningful and timely input in the development of regulatory proposals containing significant Federal intergovernmental mandates." This language removed a significant barrier to ongoing dialogue among these critical stakeholders.

Relations between county governments and the FS and BLM took on a new dimension in the Basin during the ICBEMP. The Association of Oregon Counties, the Washington Association of Counties, the Montana Association of Counties, and the Idaho Association of Counties created a new institution, the Eastside Ecosystem Coalition of Counties, to observe activities of the ICBEMP and to communicate the interests of county governments in the development of EISs associated with the project.

In spite of long-standing, generally favorable interactions between FS and BLM field personnel and local government officials, some counties are experiencing increasing polarization regarding the priorities for the use of Federal lands. Several counties in the Basin have adopted some style of

"county rule" ordinances to challenge the authority of Federal land management agencies. Rodriquez (1995) examined 12 Basin counties to observe any differences in economic and social characteristics that may help explain the presence or absence of ordinances and organized groups that oppose the actions of Federal land management agencies. Counties that were more rural and more likely to reflect an association with natural resource extraction were most likely to feel threatened by potential changes in Federal land management practices, and therefore, most likely to actively oppose Federal agency actions.

This trend generated new instructions from the Chief of the Forest Service regarding relationships with county governments (USDA 1995). Each field manager was directed to become personally acquainted with county boards of supervisors, attend their meetings, and brief them about Forest Service activities on at least a biannual basis. The comments of the Chief in the memorandum that provided these instructions offer an appropriate closing to this discussion:

> *We, collectively, need to enhance our relationships with the county governments within which counties our national forests lie. These folks are the elected representatives of a very important segment of our customers. And, more important, they are our neighbors. We belong to the same communities and share many of the same interests and responsibilities... This relationship is and has always been critical to achieving the Forest Service mission.*

International Context—An additional consideration is the international institutional context for ecosystem management. The FS and BLM, as part of a larger Federal Government system, are often connected to government-wide efforts to increase international coordination in the protection and maintenance of environmental quality.

The most widely recognized international event on environmental matters was the 1992 Earth Summit in Rio de Janeiro, Brazil, officially titled the United Nations Conference on Environment and Development (UNCED). Emerging from UNCED were several major international initiatives that involved years of negotiations: the Rio Declaration on Environment and Development containing 27 principles to integrate environmental protection and development; Agenda 21, a 40-chapter document to guide development into the 21st century; and the Forest Principles, a consensus on political will concerning management and conservation of forests.

Other types of nonbinding, bilateral (two-nation) and multilateral (more than two nations) agreements have been signed by representatives of the FS and BLM (or their superiors in the Departments of Agriculture and Interior) to promote coordination among nations on specific issues. These agreements include protocols on pest inspections in international shipments of wood products, cross-boundary fire suppression (with Mexico and Canada), and management objectives for migratory species such as neotropical migrant birds.

Of greater significance to the FS and BLM are public commitments made by the Clinton Administration to manage the forests of the United States in a sustainable manner by the year 2000. The meaning of this commitment was clarified in February 1995, with the signing of the Santiago Declaration by representatives of the U.S. State Department in Santiago, Chile. The Santiago Declaration is a nonbinding agreement among the nations in the temperate and boreal forest zones to identify criteria and indicators for the sustainable management of all types of forests. The declaration offers 7 major criteria and 67 indicators to measure progress toward this goal. The Forest Service has established a task force on sustainability to examine how agency behaviors are addressing these criteria and indicators.

Land and Property Rights

Land and the institution of property rights play a central role in ecosystem management. Along with labor and capital, land is a basic production factor. Being fixed in size and existing in the natural order of things, land is distinguished as a special and separate consideration (Marshal 1964). Land manifests a host of human values, from security, to work, to home. Land also anchors the decisions and actions of the BLM and FS and serves as the reference for agency missions, which allocate lands to various combinations of uses and benefits. As humankind developed agriculture and organized tribal groups, "land became a resource whose value was determined by the sacrifices in blood made in order to take or protect it. It is this development that changed expanse to land, formed society, and thus initiated the historical era of mankind" (Jacoby 1971).

Land possesses physical properties, including observable qualities such as location, size, and slope, as well as abstract properties such as the invisible bundle of obligations and relationships frequently described as property rights. Its physical properties provide one measure of land's capacities; if water is also considered part of the physical component of land, additional values are associated; and yet, the abstract properties of land attract our attention because they offer a much different picture of a land unit's potential.

The central issue in understanding property rights is the recognition that ownership is not the same as control. Others besides fee title holders possess interests and rights, and as society becomes increasingly complex and populated, constraints on land ownership increase. Many landowners maintain that property rights are absolute, even as more variable forms of ownership emerge (Lewis 1995) such as leases, development rights, community land trusts, or rights-of-way (Geisler 1993). Because property is an expression of multiple interests, new forms of property ownership will likely evolve as interests shift and new problems appear, suggesting that property is a social construct undergoing continual modification (Geisler 1993).

The idea of property shapes public expectations about the role of government, and the rapidly evolving private property movement presents important challenges for ecosystem management. The centerpiece of the current private property debate is the idea of "takings," based on the Fifth Amendment statement that "private property [shall not] be taken for public use without just compensation." Advocates for private property insist that government regulations, especially those initiated for environmental protection, constitute "taking" because they reduce the opportunity for property to be freely used at the discretion of the individual. Increasingly, policy decisions about "taking" are being made in the courts.

An additional land issue relating to ecosystem management is the effect of ownership distribution, which in turn determines public access to land and water resources. Due to an expanding population and a fixed land base, the value of private property has increased, constraining opportunities for land ownership by individual citizens. Public lands become the sole mechanism for many people to experience diverse types of natural resource opportunities. Even though one of the assumed pillars of a Jeffersonian-style democracy is a broadly distributed land-ownership pattern, land concentration nationwide among private owners has dramatically increased in the last century (Geisler 1993). In the West, the Federal Government manages much of the land, including a majority of the land in the Basin, and yet, ownership concentration among private landowners is also higher in the western states than anywhere else in the county. Trends are continuing toward further aggregation, as economic pressures in the 1980s forced consolidations in the farming and ranching sector.

Implications for Ecosystem Management

For ecosystem management to evolve as a strategy characterized by the principles outlined by Moote and others (1994), with adaptable institutions, holistic science, social identification of goals,

collaborative decision building, and operations on multiple scales, it must address a series of significant institutional challenges. Structural obstacles, such as the splintering of administrative jurisdictions among different governmental units, are but one type of barrier; legal challenges such as the Federal Advisory Committee Act (FACA) are another. An exploratory survey about challenges to implementation of ecosystem management was conducted by Schlager and Freimund (1994) with a sample of managers, practitioners, and natural resource scholars. Their study revealed a complex web of challenges (termed "barriers" in their report) that will require considerable attention before ecosystem management, as outlined in theory, may be realized.

The challenge most frequently cited by respondents to Schlager and Freimund's study was confusion surrounding the meaning of ecosystem management. Multiple definitions and interpretations have been circulated among administrative and academic circles, creating potential for the term to be so broad as to become meaningless. The term's ambiguity makes many members of the public think that the FS and BLM have ulterior motives. The term's ambiguity also creates unclear expectations, both by the public and many agency employees, who wonder if the status quo will continue, but with new names. A basis for these concerns is the language similarity used in defining broad goals under both multiple-use management and ecosystem management. The agencies hope that the documents being prepared as part of the ICBEMP will answer these questions.

A related challenge is that the direction for ecosystem management is a policy shift, rather than one based on new legislative direction. The management direction is not anchored in legislation that redirects multiple-use management into ecosystem management, and therefore does not reflect "a degree of political consensus" present in social objectives that have been codified in congressional legislation (Sedjo 1995). As a result, ecosystem management is being implemented under existing laws that do not necessarily contain consistent direction and cannot be viewed as reflecting a social agenda to proceed.

The Federal Advisory Committee Act, which imposes regulations on advisory committees to the executive branch of the Federal Government, was cited as another significant challenge to ecosystem management. Its regulations pertain to equal and open access, because FACA was enacted to protect against undue influence of industry groups to government decision-making structures. In other words, FACA was established to prevent abuses, not to encourage and facilitate balanced, representative public participation and the open exchange of ideas. Although FACA does not prohibit advisory committees, it imposes a set of regulations generally viewed as too restrictive for managers to meet independently for what is typically intended to be a less-formal (but still balanced and fair) process for seeking the knowledge and advice of stakeholders and the public. Managers within the agencies are very sensitive to violating FACA and being vulnerable to court challenges.

As mentioned earlier in this chapter, the Congress was aware of this barrier and exempted meetings between agency personnel and elected officials of state, local, and tribal governments (P.L. 104-4, Section 204). However, this provision does not address the issue of agencies collaborating directly with the public; FACA is especially nonsupportive of Federal participation in small-group, grassroots efforts to establish partnerships, working groups, task forces, or other forums for stakeholders to work together over time to reach a consensus and provide recommendations on public land management issues.

Another challenge identified was based on land and property rights. As discussed earlier in this chapter, ecosystems do not stop at boundaries based on land ownership. The ability of the FS and BLM to restore and manage ecosystems therefore will be limited, especially when private lands or the lands and projects managed by other agencies directly affect conditions on public lands. Ecosystem management conjures fears of increased direct or indirect Federal regulations on private landowners' management practices (Gray 1992, Lewis 1995, Sample 1992).

Ecosystem management has also been assumed to imply more strict application of environmental values (Cornter and Moote 1992), which private landowners suspect would create overbearing, costly planning bureaucracies.

Keiter (1994) proposes that the success of ecosystem management depends on the capability of agencies to demonstrate how such management would contribute to more stable economic opportunities for communities having traditional associations with resource extractions. With many of the small rural communities in the Basin undergoing transformations to new types of economic activity, many people are understandably anxious about the future. An expanded dialogue between public agencies and individual landowners about mutually desirable uses of natural resources appears warranted, particularly for the interests of society-at-large to find common ground among the interests of private landowners. Incentives for natural resource conservation or use may be incorporated into future expressions of ownership through models that have yet to be adequately explored.

Schlager and Freimund also identified numerous agency policies and procedures that may need to be re-examined for their compatibility with the goals and principles of ecosystem management. The challenges to effective cross-jurisdictional coordination include the physical isolation of many FS and BLM field units, emphasis on decentralized decision-making, insular attitudes among staff about complex problems, and limited career payoffs for the considerable energy expended to achieve multi-agency coordination (Schlager and Freimund 1994). Other challenges are conflicting missions, values, and expectations among agencies (Agee and Johnson 1988), which may be further exacerbated by clashes between personal management styles and turf battles.

The disciplinary focus of natural resource professions tends to be restrictive, and only on rare occasions do specialists from diverse disciplines interact outside their own agency boundaries. Traditional training and reward systems encourage excelling at one's discipline, rather than collaborating and integrating with other disciplines. Compounding the situation is the inherent complexity and uncertainty associated with understanding ecosystems' functions: "The usual experience with ecosystem data is that there is not enough to define the biology with any confidence, but far too much for a single human mind to assimilate" (Lee 1993). This conflict also is apparent between social and natural sciences; there is the perception that ecosystem management is based solely on biological objectives (Sedjo 1995). Another identified challenge is the relative lack of agency employees trained in social sciences, communication and facilitation, and community planning.

One of the structural problems identified by Schlager and Freimund was the focus of agency activity around functional elements relative to budget appropriations. Hirt (1994), Yaffee (1994), and many other analysts have recognized this same functional emphasis, which translates operationally to the attainment of outputs; historically, the emphasis was simplified to "get the cut out." Attainment of these functional goals is a key factor in evaluating the performance of personnel, and rewards (promotions, recognition, prized assignments) have traditionally been based on meeting established targets (Boyle and others 1994).

An adaptive, ecosystem management approach would seem to be less captive to this type of functioned, output-oriented system, and as Shannon (1987) found, managers will be less responsive to innovation when rewards and a tolerance for experimentation are absent. The "holistic science" attribute of ecosystem management also encounters a structural challenge within the agencies by virtue of the organizational separation of research from management. Grumbine (1994) concluded that, "Implementing ecosystem management requires changes in the structure of land management agencies and the way they operate."

Revenues generated by timber harvests have historically funded a great share of management; more important, however, the commercial value of timber harvests supplied the purchaser credits to build roads on National Forest lands that provide recreation and wildfire suppression access. Timber

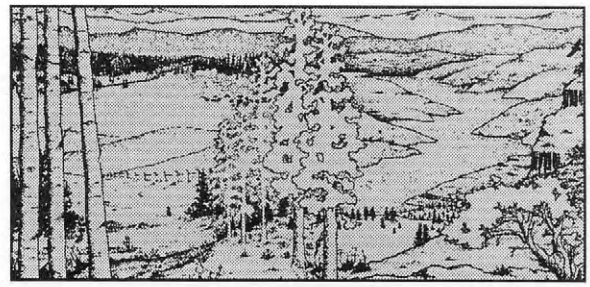
harvest revenues have been the source of deposits to the Forest Service's Knutson-Vandenburg and slash disposal trust funds, which provide monies for reforestation, sale area improvement, and fire hazard reduction. Broad interpretations on the use of these funds have provided countless improvements in wildlife habitat, riparian zone structure, and recreation developments. Timber, through providing revenue such as payments in lieu of taxes, is also the main source of funding that local governments have for roads and schools. Ecosystem management, however, emphasizes achieving desired ecosystem processes and functioning, not outputs such as timber volume.

The financial needs of ecosystem management, both in terms of planning and operations, may face a significant challenge without supplemental financing from other sources. A related concern is that adaptive management requires the ability to be responsive to monitoring results, which may be hampered by current legal requirements for plan modification and amendment. Research also plays a key role in ecosystem management, yet agency research budgets are being reduced substantially. Although monitoring assumes a particularly central role in adaptive management, there is typically inadequate funding for monitoring and also inadequate authority to make changes based on social or economic monitoring.

Administrative rules pertaining to contracting and bidding procedures affect delivery of benefits. Commonly, ecosystem management is linked to support of rural communities; however, the benefits associated with sales of commodities from FS- and BLM-administered lands do not necessarily accrue to individuals or enterprises sited in rural communities, because the commodities are auctioned under strict bidding and contracting rules. Aside from specific programs that provide small business set-asides, contracting rules let anyone participate in the purchase of Federal commodities. Although the logic of maintaining a fair and open process for purchasers is evident, the current contracting and bidding process may not be appropriate for ecosystem management specific to its intent to fulfill other objectives in support of rural communities.

Ecosystem management could encourage experiments with variations of the sustained yield unit concept, along with monitoring of their socioeconomic and biophysical effects. For example, many entities have proposed stewardship contracts under which companies harvest timber and also undertake ecosystem restoration activities as an institution that appears compatible with ecosystem management goals.

In conclusion, a multitude of mechanisms are available to institutions to coordinate their land management operations. There is extensive potential to engage people in land management actions through planning, project implementation, monitoring, and evaluation. The issue facing natural resource management agencies in cross-jurisdictional management is more appropriately one of institutional will, rather than finding the "right" form for coordination. A flexible application of Federal programs offers greater potential for cross-jurisdictional management with state and other agencies, whereas relationships based strictly on rule applications inhibit cooperation and trust among the Federal and other levels of government. Based upon this social assessment, it is reasonable to expect that different types of institutions will be required for the philosophy of ecosystem management to be implemented effectively and efficiently.



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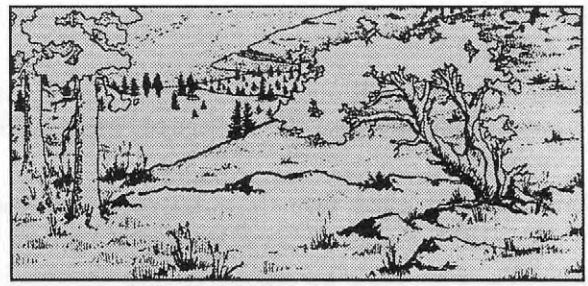
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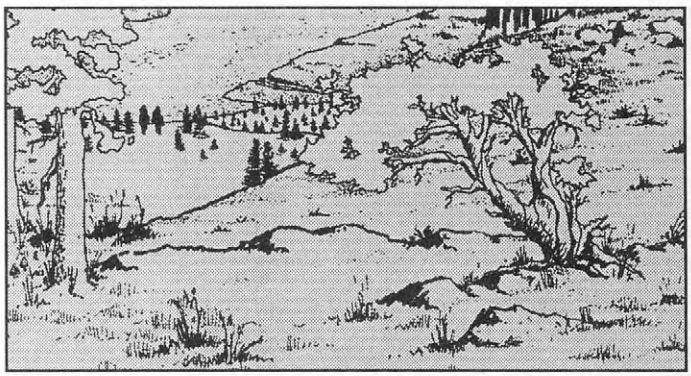
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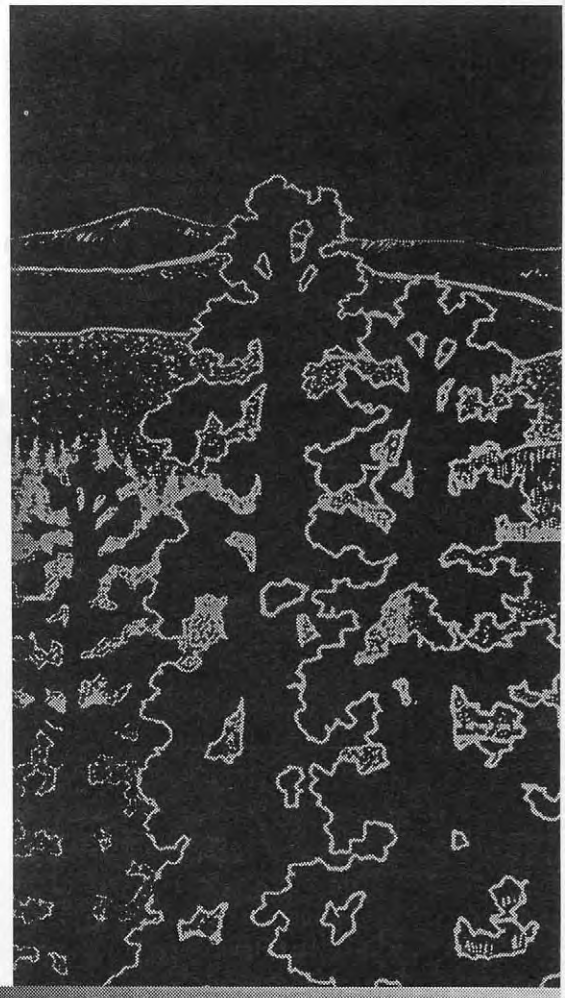
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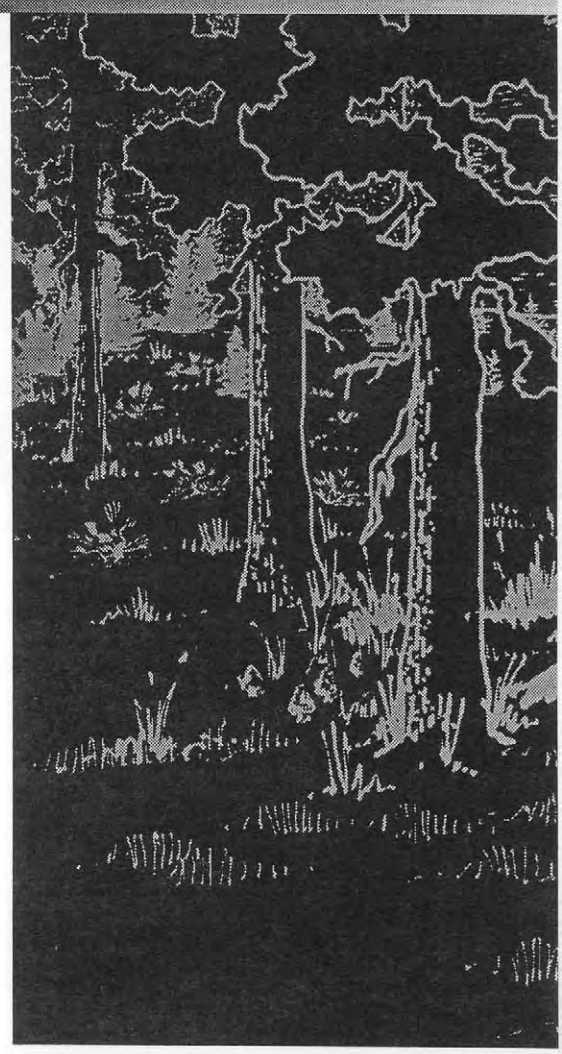




CHAPTER 8

Information System Development and Documentation

Rebecca A. Gravenmier,
Andrew E. Wilson, and John R. Steffenson

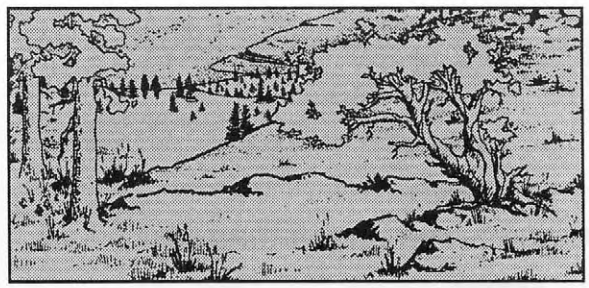


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TABLE OF CONTENTS



BACKGROUND 2017

SPATIAL ANALYSIS TEAM ORGANIZATION AND RESPONSIBILITIES 2018

Walla Walla Organization 2018

Portland Organization 2021

Missoula Organization 2021

Wenatchee Organization 2021

Boise Organization 2021

Coeur d'Alene Organization 2021

U.S. Geological Survey 2021

U.S. Bureau of Mines 2022

TECHNOLOGY 2022

Hardware and software 2022

Telecommunications 2022

GIS Data 2023

Aquatic 2031

Atmospheric 2031

Attributes 2031

CRBSUM 2031

Cultural 2031

Demographic 2031

Disturbance 2032

Fish 2032

Hydrology 2032

Minerals/Geology 2032

Physiographic 2032
Political 2032
Species 2033
Terrestrial 2033
Vegetation 2033
METHODS FOR INTEGRATING DATA 2033
Analysis 2035
GIS 2035
Quality Assurance 2036
Databases 2037
Models 2039
Documentation of Data 2047
Metadata 2047
Automated Tracking Manager (ATM) 2047
Graphics Tracking System (GTS) 2050
Data Release 2050
Data Release Policy and Process 2050
Memorandum of Understanding 2051
Documentation of Data Limitations 2051
RESEARCH, DEVELOPMENT, AND APPLICATION NEEDS FOR INFORMATION MANAGEMENT 2056
Inventory and Monitoring Needs 2056
Maintenance of ICBEMP Data and Models 2057
Standardization of Existing Data 2057
Maintenance of Priority ICBEMP Data 2057
Data Needed for Implementation of Ecosystem Management 2057
Enhancement of Existing Models and Databases 2058
Technology Transfer 2058
MAJOR INFORMATION ISSUES AND RECOMMENDATIONS 2058
Data Development, Documentation, and Analysis 2058
Distributed Work Sites and Systems 2059
CONCLUSION 2060
ACKNOWLEDGMENTS 2061
REFERENCES 2063
GLOSSARY 2065

LIST OF TABLES

Table 8.1 Interior Columbia River Basin Ecosystem Management Project (ICBEMP) Geographic Information System (GIS) Data 2024

Table 8.2 Major Contributors of Geographic Information System (GIS) Data 2034

Table 8.3 Subwatershed Summary Files Used in the Columbia River Basin Landscape Assessment Database (CRBLAD). 2038

Table 8.4 Indicator Variables Summarized By or Predicted Using the Columbia River Basin Landscape Assessment Database (CRBLAD) 2039

Table 8.5 Databases and models obtained or created for ICBEMP 2043

Table 8.6 Spatial Unified Data Dictionary (SPUDD) Metadata Definitions 2048

Table 8.7 Management Area Categories (MACs) 2052

Table 8.8 Management Region and Classes used for the Scientific Assessment 2054

Table 8.9 Summary of the Comparison of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) Predicted Subwatershed Road Density Classes to Actual Forest Road Density Data 2056

LIST OF FIGURES

Figure 8.1 Spatial analysis task-team responsibilities. 2020

Figure 8.2 Data Flow Diagram for Columbia River Basin Landscape Assessment Database (CRBLAD). 2040

Figure 8.3 CRBSUM-6th Field HUC Input Object Attribute Inheritance Diagram. 2041

LIST OF MAPS

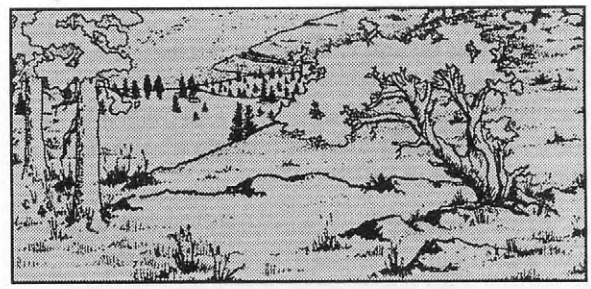
Map 8.1 Spatial team organization. 2019

Map 8.2 Major data extents for the InterioInformation System Information System Columbia Basin Ecosystem Management Project. 2030

Continue

Previous

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BACKGROUND

Land use planning that is regional in scope and proportion requires tools more advanced than those typically used for landscape and resource analysis. Traditionally, maps, graphs, charts, and diagrams have been used to analyze and visualize the natural environment. These traditional methods of manually comparing hard-copy maps have limited accurate analyses to relatively small areas. Today, Geographic Information Systems (GISs) provide the tools and techniques that allow regional projects to be accomplished in a highly efficient, integrated, and accurate manner.

A GIS does much more than just make maps. It is "a computer-based system that provides the following four sets of capabilities to handle geo-referenced data: (1) input (data entry); (2) data management (storage and retrieval); (3) manipulation and analysis; and (4) and output (visual representation in the form of maps and charts)" (Aronoff 1993). These four items were important in the development and use of the large and robust database that supported the Interior Columbia Basin Ecosystem Management Project (ICBEMP). Without this advanced computer technology, software, and trained and experienced individuals, this volume of data would have been a great burden to the project. However, GIS allowed the Science Integration Team (SIT) to dynamically model and analyze living systems throughout the Basin in ways that were impractical only a decade ago.

A GIS is especially well suited for dealing with spatial and temporal problems (problems of dimension, space, and time). The number of kilometers of shoreline for a given lake is an example of a spatial problem that can be quite difficult to solve by traditional methods but is somewhat trivial for a GIS. More complex queries make a GIS a necessity. For instance, one might imagine the difficulty in a problem such as the following: locate, summarize, and display the number of hectares of major vegetation types, for all successional stages, on Federal, State, and private lands throughout the Basin. This example is typical of the GIS summaries performed for this project.

Any project that is both large in scope and under short timelines requires careful information and technology management planning. The ICBEMP is the largest interagency database development effort undertaken by the agencies involved, covering more than 58 million hectares (more than 144 million acres).

The ICBEMP information and technology plan was based, in part, on the plan developed for the Forest Ecosystem Management Assessment Team (FEMAT). Both projects involved many people but the team that developed the Northwest Forest Plan (USDA and USDI 1994a, 1994b) and the FEMAT assessment (FEMAT 1993) was centralized in one location and the timeframe was greatly compressed. The ICBEMP team had more time and considerably more data. Work for the ICBEMP

was accomplished in a number of locations in several states including Oregon, Washington, Idaho, and Montana. A dispersed approach to data collection and analysis was necessary due to the cost and inefficiency of moving all equipment and personnel to one location.

A Spatial Analysis Team was established to manage data and support the analytical needs of the ICBEMP. This interagency group was charged with the collection of available GIS data, capture of new data from prepared manuscripts, management of data, and data analysis in support of the SIT and Environmental Impact Statement (EIS) Teams. The Spatial Analysis Team was also responsible for the documentation and distribution of data to project personnel, federal agencies, tribal governments, the general public, and other interested parties.

This chapter is intended to provide a broad overview of the data, databases, and models employed by the ICBEMP and includes general recommendations for information management. Brief discussions of team organization, technology, GIS data and documentation, methods for integrating data, analysis methods, data release procedures, and data limitations are incorporated. A full discussion of the individual data layers and resulting analyses is not included. Much of this information can be found in either the documentation[1] for each GIS data layer or the various staff area chapters within this document. It is hoped that the documentation of the information resource methods employed by the ICBEMP and the recommendations resulting from them will aid future efforts and highlight the need for a long-term information resource management strategy as part of ecosystem management.

[1]The data layer documentation, or metadata, is available through the Interior Columbia Basin Ecosystem Management Project, 112 E. Poplar Street, Walla Walla, WA 99362, and on the internet (www.icbemp.gov).

Spatial Analysis Team Organization and Responsibilities

The Spatial Analysis Team consisted of BLM, FS, and contract personnel. Map 8.1 illustrates the overall distribution of the Spatial Analysis Team offices. Walla Walla and Portland were the core teams primarily responsible for overall data management and analysis. The other four teams provided data capture or specific analyses for the SIT.

The Spatial Analysis Team had seven task teams. They were: coordination and administration, information and product requirements, documentation and tracking, GIS operations, database design and analysis, quality control, and systems management. Most Spatial Analysis Team members served on more than one task team. Figure 8.1 outlines these task team group responsibilities. This organization allowed team members to understand their role and responsibilities better, and promoted external review of analytical products. The following sections briefly describe the major roles of the Spatial Analysis Team members in each location.

Walla Walla Organization

Spatial Analysis Team members residing in Walla Walla, Washington, provided local support to the SIT and EIS team. The Walla Walla office interacted with the SIT and EIS team to determine data and analysis needs; managed work priorities for the Walla Walla and Portland Spatial Analysis Team members; determined analysis requirements and procedures; interacted with the public and agency personnel; and coordinated all of the activities of the satellite offices using GIS. The Columbia River Basin SUccession Model (CRBSUM) and 6th-field-hydrologic-unit (subwatershed) data were stored and managed in Walla Walla. Most work requests for maps and analyses were also initiated in Walla Walla. The

Map 8.1— Spatial team organization.

Figure 8.1— Spatial analysis task-team responsibilities.

analysis of indicator variables for the ICBEMP science team and the EIS teams was completed by a database design and analysis group based in Walla Walla. This group created reports, spreadsheets, and graphics by producing numerous queries of the Columbia River Basin Landscape Assessment Database (CRBLAD).

Portland Organization

Two offices in Portland, Oregon supported the ICBEMP spatial analysis. The FS office (Region 6 Pacific Northwest Region) provided for data, system and telecommunication administration and tracking; work request processing; data capture; analysis of the current situation for the Assessment and the EISs; preparation of data for release; and GIS analysis technical oversight. Most of the Spatial Analysis Team members worked in Portland. The BLM (Oregon State Office) processed ICBEMP data released to the public and other agencies, and assisted in plotting map products for work requests.

Missoula Organization

In Missoula, Montana, two offices provided GIS support. The team at the FS Intermountain Fire Sciences Laboratory provided major support for the Landscape Ecology team members of the SIT. It prepared and documented the landscape data sets, processed data using the Vegetation Dynamics Development Tool (VDDT) and CRBSUM models for the assessment scenarios and EIS alternatives, and provided numerous analyses. The resulting scenario and alternative data "crosswalk" tables and maps were provided to the Walla Walla Team for further analysis. The team at the FS Region 1 office (Northern Region) provided hydrologic, riparian, and valley bottom setting data and analyses for the Landscape Ecology and Aquatic teams of the SIT.

Wenatchee Organization

The Wenatchee Team, which is at the FS Wenatchee Forestry Sciences Laboratory in Wenatchee, Washington, provided support for the Landscape Ecology Team's mid-scale analyses. The Wenatchee team organized the capture of subsample vegetation data, performed in-depth analysis of that data, and summarized the subsample data in a series of maps, reports, and graphs for the assessment.

Boise Organization

Two teams in Boise provided support for the Landscape Ecology Team of the SIT and the EIS teams. The team at the Boise National Forest Supervisor's Office (Region 4) provided for data capture of the subsample vegetation data. Once this work was completed, a subset of the team moved to the Upper Columbia River Basin (UCRB) EIS Team office to provide local GIS support including map preparation, database query, and an understanding of the assessment data. The team located at the FS Intermountain Forestry Sciences Laboratory provided the Aquatic Team with a variety of analyses and support.

Coeur d'Alene Organization

The Couer d'Alene Team located at the Idaho Panhandle National Forest Supervisor's Office in Coeur d'Alene, Idaho, provided support in the capture of the subsample vegetation and valley bottom setting data for the Landscape Ecology Team.

U.S. Geological Survey

The U.S. Geological Survey (USGS) Office of Mineral Resources, in Spokane, Washington, was responsible for earth science information. Mineral resource information was primarily focused on classifying land for its potential for undiscovered mineral resources and providing estimates of the size and value of those resources. It included diverse thematic maps that classified land by physical properties and potential for geologic hazards. The USGS developed GIS thematic data for and worked directly with the SIT on an ongoing basis.

U.S. Bureau of Mines

The U.S. Bureau of Mines (USBM) maintained extensive data on discovered mineral resources and past and present minerals development activities in their Minerals Availability System (MAS) Database. From this and other organizational sources USBM geologists, mining engineers, and mineral economists developed minerals themes illustrating mineral activity and its relationship to other resources. USBM scientists provided their expertise on a regular basis by working directly with the SIT on integrated analyses of mineral and biophysical themes.

Technology

An important advantage of a distributed GIS analysis model (GIS operations performed in many locations rather than one) was the ability of teams at separate sites to perform a wide variety of tasks simultaneously. While teams at Portland continued to capture important data, the Missoula team began to perform analyses and generate preliminary assessments and models. Geologists in Spokane could build maps showing mineral potential while scientists at Wenatchee assembled data for the mid-scale analyses. The main disadvantage of a distributed model was the difficulty in coordinating efforts and sharing data. These disadvantages occurred because moving all analysts and scientists to one location was not feasible.

Hardware and software

More than 100 computers, from powerful UNIX-based workstations to desktop personal computers (PAS), played a role in the work of the entire ICBEMP team. The major components for GIS tasks were IBM®, Sun®, and Data General (DG)® workstations (multi-user/multi-tasking computers), X-terminals (computers that provide access to the processing capabilities of the workstation), electrostatic and inkjet plotters, black-and-white and color printers, disk drives, Compact Disk-Read Only Memory (CD-ROM) drives, and tape drives.[2] Operating system software for these machines included various versions of UNIX (IBM, DG, Sun, Linux®, SCO®) and Microsoft (MS)-DOS®/Windows (Microsoft).

Various versions of GIS software contributed to spatial data collection, analysis, and map making. ARC/INFO® (Environmental Systems Research Institute, Inc.) played a dominant role. Both ARC/INFO® versions 6.1 and 7 were used because the length of the project spanned revision cycles of the software. Other spatial software included GRASS™ (Construction Engineering Research Labs, U.S. Army Corps of Engineers), ArcView2® (Environmental Systems Research Institute, Inc.), UTOOLS (Umatilla National Forest, Pendleton, Oregon), and LT4-X™ (Infotec Development, Inc). Major statistical software packages included S-PLUS™, Systat™, and SAS™. Analysts used Oracle™, Microsoft® Access© and Excel™, Borland Paradox®, and Quattro-Pro® to summarize and evaluate both non-spatial and spatial attribute data.

Telecommunications

Telecommunications played a key role in uniting the work and systems of the many project work sites. The Coeur d'Alene and Boise sites primarily conducted data collection. The site in Boise also provided end-user support for the UCRB team. Wenatchee and Missoula sites were involved in data collection and were also involved in analysis. Walla Walla served as the central hub where all data and analysis results were eventually assembled. Portland was the primary support site where the data were integrated, organized, and managed.

This telecommunication plan represented a distributed system of data and activity. A sophisticated telecommunications network was required to support such a system. Transfer of large data sets

[2] The use of trade or firm names in this publication is for reader information only, and is not an endorsement or recommendation by the U.S. Department of Agriculture, the U.S. Department of the Interior, the ICBEMP, or any of the affiliated agencies.

required rapid transfer speed and capacity exceeding typical communications lines and hardware. A typical residential telephone service could handle data communications for basics such as electronic mail and personal computer modems, but could not handle the volume of data transfer for this project. To meet the data transfer needs of this project, fractional T-1 and frame relay services were used. The service acquired was based on the projected data transfer needs of each site. Individual connections varied in capacity from 56 kilobits per second to 768 kilobits per second.

These telecommunication lines provided an infrastructure called a Wide Area Network (WAN), which supports work distributed among many sites. A WAN is a regional network. Sites at the end of a line are referred to as hubs. The node itself may be a single computer or a wide array of computers and communications devices. Any given site might also have many systems tied together by a Local Area Network (LAN). The Portland and Missoula sites had the most elaborate LANs due to the number of existing computer systems and the manner in which they were deployed. This allowed the PAS and UNIX-based workstations to communicate and share data.

Various protocols were used to enable computer communications between sites, including transmission control Internet protocol (TCP/IP), a computer communications protocol, telnet, a file transfer protocol (FTP), and network file system (NFS). All application protocols ran with TCP/IP. Telnet allowed authorized users to log into remote computers and execute applications such as ARC/INFO. For instance, a GIS analyst in Walla Walla performed analyses using a computer in Portland. FTP allowed a user to move files between computers, either locally (LAN) or regionally (WAN). NFS allowed a user to "mount" a device attached to another computer, such as a disk drive, and to operate it as if it were a local file system to the host computer. Although NFS has some convenient advantages, it can also put heavy loads on a network. Most data files were exchanged using FTP, while many programs were commonly accessed through NFS.

In addition, analysts and technical coordinators were all linked through commercial phone service and interoffice E-mail using the existing FS mail network.

GIS Data

A GIS allows for both simple and complex analyses in an attempt to measure and characterize real world systems and entities too complex to measure and understand by traditional hard-copy means. The nature of the problem to be solved or the desired end product helps determine the appropriate GIS model. The way the model is constructed dictates what analytical tools can be applied to it and how the results may be displayed. These spatial models are often referred to as spatial themes or data layers.

Multiple spatial themes of digital data in either vector or raster (cell-based) form comprise a GIS spatial database. A GIS is particularly suited for finding and measuring features within a single layer or among layers where different features occupy the same area on the face of the earth.

More than 170 different GIS data layers or themes were compiled or created in support of the ICBEMP assessment and the development of the Eastside and UCRB EISs. Table 8.1 lists the data themes and the scale at which they were collected for this assessment. Some of these themes have numerous files. The data layers were derived from source maps, photos, or transfer media ranging from 1:12,000 to 1:4,000,000 in scale. Some GIS layers mapped features continuously across the entire Basin, and others were for discrete areas only (for example, subsample areas). Map 8.2 illustrates the extents of the majority of the ICBEMP GIS data. Many landscape data layers were collected for an area larger than the assessment area (shown by the landscape characterization boundary in map 8.2) so that ecological units could be mapped in their entirety.

For naming convention and organization, the GIS data sets were named using a hierarchy of resolution, domain (geographic area extent) and theme group.

Table 8.1— Interior Columbia River Basin Ecosystem Management Project (ICBEMP) Geographic Information System (GIS) data.

Theme Name	Extent	Scale/Resolution
AQUATIC GROUP		
Benthic Invertebrates	Omernick regions 9-12, 15	variable
Stream Reaches with Habitat Survey Data	Assessment area	1:100,000
ATMOSPHERIC GROUP		
Air Pollution–Non-Attainment Areas	Landscape Characterization Area	variable
Air Quality–Lake Monitoring Sites	Landscape Characterization Area	nearest second
Air Quality Monitoring Sites for NADP	Landscape Characterization Area	nearest second
Air Quality Monitoring Sites for NDDN	Landscape Characterization Area	nearest second
Air Quality–Point Source Emissions	Landscape Characterization Area	nearest second
Air Quality–Snowpack Monitoring Sites	Landscape Characterization Area	nearest minute
Air Quality–Source Emissions by County	Landscape Characterization Area	county
Class One Airsheds	Assessment area	1:24,0000 to 1:100,000
Climate–Average Dew Point	Assessment area	2 kilometers
Climate–Average Maximum Temperature	Assessment area	2 kilometers
Climate–Average Minimum Temperature	Assessment area	2 kilometers
Climate–Average Yearly Temperatures	Assessment area	2 kilometers
Climate–Total Solar Radiation	Assessment area	2 kilometers
Climate–Total Yearly Precipitation	Assessment area	2 kilometers
Climate–PRISM Precipitation Data	Landscape Characterization Area	2.5 minutes
Weather-Extreme Winds	Landscape Characterization Area	5 minutes
Weather-Freeze Potential	Landscape Characterization Area	2 kilometer
Weather-Lightning Strikes	Landscape Characterization Area	10 kilometer
Weather-Monthly Winds	Landscape Characterization Area	5 minutes
Weather-Palmer Drought Index	Landscape Characterization Area	broadscale
Weather-Rain Days	Landscape Characterization Area	nearest second
Weather-Rain on Snow	Landscape Characterization Area	2 kilometer
Weather-30 Yr Avg Winds by Month	Landscape Characterization Area	5 minutes
CRBSUM GROUP		
Future Broadscale Disturbances from CRBSUM for Scenarios/Alts	Landscape Characterization Area	1 kilometer
Future Broadscale Vegetation by Scenario/Alt.-Cover type/Structure	Landscape Characterization Area	1 kilometer
Carbon Stress Index (Assess. Cur/Hist)	Landscape Characterization Area	2 kilometers
CRBSUM Current Potential Veg Types (Assessment)	Landscape Characterization Area	1 kilometer
CRBSUM Current Potential Veg Types (DEIS)	Assessment area	1 kilometer
CRBSUM Current Vegetation Cover Types (Assessment)	Landscape Characterization Area	1 kilometer
CRBSUM Current Vegetation Structural Stages (Assessment)	Landscape Characterization Area	1 kilometer

Table 8.1 (continued).

Theme Name	Extent	Scale/Resolution
CRBSUM Historical Potential Veg Types (Assessment)	Landscape Characterization Area	1 kilometer
CRBSUM Historical Veg Cover Types (Assessment)	Landscape Characterization Area	1 kilometer
CRBSUM Historical Veg. Struct. Stages (Assessment)	Landscape Characterization Area	1 kilometer
CRBSUM Simulation (alts.) Model Assignments	Assessment area	1 kilometer
Net Primary Productivity (Ass. Cur/Hist)	Landscape Characterization Area	2 kilometers
Nutrient Avail. Index (Assess. Cur/Hist)	Landscape Characterization Area	2 kilometers
Water Stress Index (Assess. Cur/Hist)	Landscape Characterization Area	2 kilometers
CULTURAL GROUP		
Airports	Assessment area	1:1,000,000
Dams	ID/MT/OR/WA	nearest 10 seconds
Dams-from Army Corps & States	ID/MT/OR/WA	nearest 10 seconds
Diversions	Assessment area	1:100,000
Railroads	Assessment area	1:1,000,000
Road Density (Predicted)	Landscape Characterization Area	1 kilometer
Roads–Broadscale–1:1M	Western North America	1:1,000,000
Roads–Broadscale–1:2M	Assessment area	1:2,000,000
Roads–Subsample	Assessment area	1:24k to 1:100,000
Scenic Integrity (Assessment)	Assessment area	subwatershed
Scenic Integrity (DEIS)	Assessment area	1 kilometer
Sense of Place	Assessment area	1:500,000
Sense of Place	Three selected areas	1000 acres
Streets (TIGER)	CA/ID/MT/NV/UT/WY & E. OR/WA	1:100,000
Utility Corridors	Eleven Western states	unknown
Utility Corridors–Energy Sources	Eleven Western states	unknown
DEMOGRAPHIC GROUP		
Census Blockgroups	Socio-Economic Assessment Area	1:100,000
Census Blockgroups	ID/MT/NV/OR/UT/WA/WY/no. CA	1:100,000
Census Tracts	Socio-Economic Assessment Area	1:100,000
Isolated Timber Dependent Areas	Assessment area	1:2,000,000
Milltowns-from 100k towns	Assessment area	1:100,000
Populated Places–1:100,000 (polygon)	Socio-Economic Assessment Area	1:100,000
Populated Places DCW–1:1M (polygon)	Assessment area	1:1,000,000
Towns–1:100,000 (point)	Socio-Economic Assessment Area	1:100,000
Towns DCW–1:1,000,000 (point)	Western North America	1:1,000,000
DISTURBANCE GROUP		
Disturbance–Current Fire Regime	Landscape Characterization Area	1 kilometer
Disturbance–Fire History Study Sites	Landscape Characterization Area/Canada	nearest minute
Disturbance–Fire Locations	Landscape Characterization Area	point data

Table 8.1 (continued).

Theme Name	Extent	Scale/Resolution
Disturbance–Historic Fire Regime	Landscape Characterization Area	1 kilometer
Human Ecological Interaction	Assessment area	1 kilometer
Rural Population Wildland Interface	Landscape Characterization Area	1 kilometer
Rural Population Wildland Interface Fire Risk	Landscape Characterization Area	1 kilometer
Societal Risk To/From Ecological Integrity	Assessment area	1 kilometer
FISHERIES GROUP		
Fish Hatcheries	Assessment area	point data
HYDROLOGY GROUP		
Aquatic Assessment Boundary	Assessment area	1:250,000
ICBEMP Assessment Boundary	Assessment area	1:250,000
Columbia River Basin (CRB) Boundary	Assessment area	1:250,000
Columbia River Basin–US Portion	Assessment area	1:100,000
Consultation Watersheds (Section 7 ESA)	ID/OR	1:500,000
Critical Watersheds–Amer Fisheries Soc	OR	unknown
High Priority Watersheds (Section 7 ESA)	Assessment area	1:126,720–1:250,000
Inland Native Fish Strategy Bndry (USFS)	Assessment area	1:100,000
Interior Columbia River Basin	Assessment area	1:100,000
Lakes	Assessment area	1:100,000
Lakes 1:100,000–Enhanced	Assessment area	1:200,000–1:2,000,000
Lakes and Reservoirs 1:2M–Broadscale	Assessment area	1:2,000,000
Lakes Classified by Water Quality Clusters	Assessment area	1:100,000 to 1:250,000
NURE Stream Sediment Geochemistry-Part 1	Idaho/Montana	200 meters
NURE Stream Sediment Geochemistry-Part 2	Idaho/Montana/Oregon	200 meters
NURE Stream Sediment Geochemistry-Part 3	Oregon/Washington	200 meters
PACFISH Boundaries (BLM/USFS Lands)	Assessment area	1:100,000
Pollutant Sources–Water (CERCLA Sites)	Assessment area	1:24,000
Pollutant Sources–Water (NPDES)	Assessment area	1:24,000
Pollutant Sources–Water (RCRA)	Assessment area	1:100,000
Pollutant Sources–Water (TRI)	Assessment area	1:24,000
Priority Watersheds–PACFISH/BULL TROUT/EIS	ID/OR/WA	1:500,000
River Reach Banks and Water Bodies	Assessment area	1:100,000
River Reach Files Modified for ICBEMP	Assessment area	1:100,000
Rivers–1:1,000,000	Assessment area	1:1,000,000
Rivers–1:2,000,000	Assessment area & west OR/WA	1:2,000,000
Streams at 250k from NMFS	ID/MT/OR/WA	1:250,000
Subbasins/Watersheds/Subwatersheds (6th Field HUCs)	Landscape Characterization Area	1:100,000
USGS Subbasins (4th Field HUCs)	Assessment area	1:250,000
Water Quality Impairment–Lakes	Assessment area	1:100,000
Water Quality Impairment–Streams	Assessment area	1:100,000

Table 8.1 (continued).

Theme Name	Extent	Scale/Resolution
MINERALS/GEOLOGY GROUP		
Bedrock Background Base Metal Content	Landscape Characterization Area	200 meters
Bedrock Fe/Al/Mg Content	Landscape Characterization Area	200 meters
Bedrock Phosphate Content	Landscape Characterization Area	200 meters
Bedrock Potassium Content	Landscape Characterization Area	200 meters
Cascade Volcano Hazards–1cm/yr Ash Probability	Assessment area except WY/UT	1:2,000,000
Cascade Volcano Hazards–10 cm/yr Ash Probability	Assessment area except WY/UT	1:2,000,000
Cascade Volcano Hazards–1 m/yr Ash Probability	Assessment area except WY/UT	1:2,000,000
Cascade Volcano Hazards–Proximal Hazards	Assessment area	2 kilometers
Horizontal Earthquake Accel. Probability	Landscape Characterization Area	5 kilometers
Low-Temperature Geothermal Sites	Assessment area states except WY	1:24,000
Major Lithology	Landscape Characterization Area	200 meters
Mineral Dep Perm/Fav Areas (MPFA)	Assessment area	1 kilometer
Mineral Deposit Perm/Fav Areas for Phosphate	Landscape Characterization Area	200 meters
Mineral Deposits	Assessment area	1:24k to 1:100,000
Mineral Development Interest Area (MDIA)	Assessment area	1:500,000
Mineral Industry Locator System	Assessment area	1:24k to 1:100,000
Mineral Production Facilities	Assessment area	1:24k to 1:100,000
Mining Claim Density	ID/MT/NV/OR/UT/WA/WY	1:500,000
Mining Related Hazard Potential	Assessment area	1:24k to 1:100,000
Potential Bat Habitat	Landscape Characterization Area	200 meters
Relative Bedrock Calcium Content	Landscape Characterization Area	200 meters
Sand and Gravel Permissive Tracts	Landscape Characterization Area	200 meters
PHYSIOGRAPHIC GROUP		
.5 Km Digital Elevation Model (DEM)	Landscape Characterization Area	500 meters
90 Meter Digital Terrain Model (DTM)	Assessment area	90 meters
Bailey Ecoregions	USA	1:3,500,000
Biophysical Environment–Regional	Landscape Characterization Area	1 kilometer
Ecological Reporting Units (Assessment)	Assessment area	1:100,000
Ecological Reporting Units (DEIS)	Assessment area	1:100,000
Ecological Reporting Units by Subwatershed (Assessment)	Landscape Characterization Area	1:100,000
Ecological Reporting Units by Subwatershed (DEIS)	Landscape Characterization Area	1:100,000
Franklin/Dyrness Physiographic Provinces	OR/WA	1:4,000,000
Landscape Characterization Boundary	Landscape Characterization Area	1:500,000
Omernik Ecoregions	Assessment area	1:2,500,000
Photo Interpretation Subsample Areas	Landscape Characterization Area	1:24,000
Soil Susceptibility to Disturbance Stress	CA/ID/MT/NV/OR/UT/WA/WY	1:250,000
Subsample Boundaries	Assessment area	1:100,000
Subsections	Landscape Characterization Area	1:500,000
Valley Bottom Settings-Subsamples	Subsamples	1:100,000

Table 8.1 (continued).

Theme Name	Extent	Scale/Resolution
POLITICAL GROUP		
BLM Administrative Unit Boundaries	Assessment area	1:500,000
BLM Planning Units	ID/OR/WA	1:1,000,000
County Boundaries–1:100,000	CA/ID/MT/NV/OR/UT/WA/WY	1:100,000
Eastside and Upper Columbia EIS Boundary	Assessment area	1:100,000
Eastside EIS Boundary	Assessment area	1:100,000
Indian Reservations	Landscape Characterization Area	1:2,000,000
Management Area Categories	ID/MT/NV/OR/UT/WA/WY	1:24,000 to 1:1,000,000
Management Regions/Classes (DEIS)	Assessment area	1 kilometer
National Forest Boundaries	Landscape Characterization Area	1:100,000
Natural Areas (ASMNT)	Assessment area	1:24,000 to 1:500,000
Natural Areas (FEIS)	Assessment area	1:24,000 to 1:500,000
Ownership	CA/ID/NV/OR/UT/WA/WY	1:100,000
Ownership	MT	1:126,720
Provincial Level Planning Bdys–FEMAT	CA/OR/WA	1:250,000
Range (Grazing) Allotments	ID/MT/NV/OR/UT/WA/WY	1:24,000 to 1:126,720
RARE II and WSA (USFS/BLM unroaded)	Assessment area	1:500,000
Recreation Opportunity Spectrum (ROS)	ID/MT/NV/OR/UT/WA/WY	1:24,000 to 1:250,000
Current Recreation Opportunity Spectrum (DEIS)	Assessment area	1 kilometer
State Boundaries	Assessment area	1:100,000
State Parks	Assessment area	1:2,000,000
Tribal Areas of Interest	Assessment area	1:1,000,000
Tribal Ceded Land	Assessment area	1:1,000,000
Tribal Court of Claims Boundaries	Assessment area	1:4,000,000
Upper Columbia EIS Boundary	Assessment area	1:100,000
Wild and Scenic Rivers	Landscape Characterization Area	1:2,000,000
Wilderness	Landscape Characterization Area	1:24,000 to 1:2,000,000
Wilderness Study Areas	Assessment area	1:24,000 to 1:126,720
SPECIES GROUP		
Centers of Biodiversity–Animals	Assessment area	1:2,000,000
Centers of Biodiversity–Plants	Assessment area	1:2,000,000
Centers of Endemism/Rarity–Animals	Assessment area	1:2,000,000
Centers of Endemism/Rarity–Plants	Assessment area	1:2,000,000
Hot Spots of Biodiversity	Assessment area	1:2,000,000
Hot Spots of Endemism/Rarity	Assessment area	1:2,000,000
Species Ranges–Amphibian Species (Assessment)	Assessment area	1:2,000,000
Species Ranges–Bird Species (Assessment)	Assessment area	1:2,000,000
Species Ranges–Bird Species (FEIS)	Assessment area	1:2,000,000
Species Ranges–Carnivores (Assessment)	Assessment area	1:2,000,000
Species Ranges–Carnivores (FEIS)	Assessment area	1:2,000,000
Species Ranges–Invertebrate Species (Assessment)	Assessment area	1:2,000,000

Table 8.1 (continued).

Theme Name	Extent	Scale/Resolution
Species Ranges–Mammal Species (Assessment)	Assessment area	1:2,000,000
Species Ranges–Mammal Species (FEIS)	Assessment area	1:2,000,000
Species Ranges–Reptile Species (Assessment)	Assessment area	1:2,000,000
Species Ranges–Reptile Species (FEIS)	Assessment area	1:2,000,000
Natural Heritage Data (Sens)	Landscape Characterization Area	point data
VEGETATION GROUP		
Current Midscale Vegetation Subsamples	Subsamples	1:12,000 to 1:31,680
Historic Midscale Vegetation Subsamples	Subsamples	1:12,000 to 1:31,680
Kuchler's Potential Natural Vegetation	Assessment area	1:3,168,000
Kuchler's Potential Natural Veg–Point	Assessment area	1:3,168,000
Lifeform	Landscape Characterization Area	1 kilometer
Vegetation–Historic OR/WA 1930's	OR/WA	1:500,000
ATTRIBUTE FILES LINKED TO SUBBASINS OR SUBWATERSHEDS		
Alternative 5 Secondary Emphasis Areas	Assessment area	subbasin
Alternative Composite Ecological Trends	Assessment area	subbasin
Alternative Emphasis Areas	Assessment area	subbasin
Bailey's Ecoregion Provinces by Subwatershed	Landscape Characterization Area	1 kilometer
Bailey's Ecoregion Sections by Subwatershed	Landscape Characterization Area	1 kilometer
Biophysical Classification for Subwatersheds	Landscape Characterization Area	1 kilometer
Biophysical Setting–Regional by Subwatershed	Landscape Characterization Area	1 kilometer
Boundary and Elevation Information for Subwatersheds	Landscape Characterization Area	1 kilometer
Counties-Economic Attributes (ASMNT)	Socio-Economic Assessment Area	county
Counties-Economic Attributes (DEIS)	Socio-Economic Assessment Area	county
CRBSUM Current Vegetation by Subwatershed (Assessment)	Landscape Characterization Area	1 kilometer
CRBSUM Historic Potential Vegetation by Subwatershed (Assessment)	Landscape Characterization Area	1 kilometer
CRBSUM Historic Vegetation by Subwatershed (Assessment)	Landscape Characterization Area	1 kilometer
Ecoregion Subsections by Subwatershed	Landscape Characterization Area	1 kilometer
Forest/Range Clusters and Integrity	Assessment area	subbasin
Road Density (Predicted) by Subwatershed	Landscape Characterization Area	subwatershed
Slope by Subwatershed	Landscape Characterization Area	1 kilometer
Watershed Characterization by Subwatershed	Landscape Characterization Area	subwatershed
Weather–1989, by Subwatershed	Landscape Characterization Area	subwatershed

Theme Name Codes

(Sens): Sensitive data. Not releasable.

Extents

Assessment area: 'CRBA'. Assessment area of the Interior Columbia Basin Ecosystem Management Project. The area is comprised of Eastern OR and WA, most of ID, and parts of MT, UT, NV and WY.

Landscape Characterization Area: larger than the CRBA; includes more of ID, MT, UT,NV, WY & some of CA

Socio-Economic Assessment Area: also larger than the CRBA; follows county lines

List current as of 3/1/97.

Map 8.2— Major data extents for the Interior Columbia Basin Ecosystem Management Project.

A theme may consist of one or more data layers. Each layer may depict the same entity but have a different source or geographic extent. For this project, themes were organized into a more generalized category called a theme group. This system guided data storage protocols in the GIS corporate database in Portland. It also provided the foundation for organization of records in the Spatial Unified Data Dictionary (SPUDD) used to track and document each data layer. The following briefly describes the basic theme groups.

Aquatic

This theme group contained data relating to the aquatic environment such as stream inventory information and aquatic invertebrate and mollusk occurrence.

The stream inventory information was compiled from a variety of agencies and reformatted for use in the GIS. The aquatic species occurrence information was compiled from reports. This aquatic information was essential for describing and characterizing the historic and current aquatic communities.

Atmospheric

This theme group contained data sets relating to the physical characteristics of the atmosphere and included data such as air quality, precipitation, yearly temperature, average dew point, solar radiation, air pollution sources, and airsheds. Climatic information allowed analysts to classify and model biophysical environments.

Attributes

Numerous attribute files (tabular summary files that relate to GIS themes) have been developed in support of the ICBEMP. Information resulting from analysis, such as biophysical classifications watershed characterization, vegetation, and road density tabular data, have been summarized and related or linked to the subbasin or subwatershed GIS themes. These attribute files have played a key role in summarizing important biophysical and biological components of the Basin.

CRBSUM

This theme group contains Columbia River Basin Successional Model (CRBSUM) related data such as potential vegetation types, vegetation cover types, and vegetation structural stages. Most data in this group are input to or output from the model. The CRBSUM related themes were useful in characterizing the broad-scale vegetative conditions and disturbance patterns for the historical and current situation and predicted management futures.

Cultural

Data sets that describe features constructed or influenced by humans such as airports, railroads, dams, and roads, were included in the cultural theme group. These themes were derived from a variety of existing sources such as ArcUSA™, Digital Chart of the World (DCW)™, Census Bureau files (streets), and the United Parcel Service data set, or they were generated by the project as a result of analysis (predicted road density) or attribution of physiographic features (sense of place). The cultural themes were valuable to the Social, Economic, and other teams because they defined developed or socially valued areas within the project area.

Demographic

This theme group contained data sets describing the human population of the Basin by geographical units such as counties and towns (named places), or U.S. Census Bureau defined blockgroups, tracts, and places. Data consisted of demographic statistics from the 1990 U.S. census, and other social, economic, and lifestyle data. Census geographies and 1990 U.S. census information were extracted from Wessex Corporation "Profiler" and 1992 Census data sets. The census data provided information regarding population, gender balance, age, racial composition, employment, income, poverty level, and education level. Lifestyle information was contained in a data set purchased from Claritas Corporation. This data set provided

proportions of households within each census tract belonging to each of 62 lifestyle clusters. The clusters were determined by cluster analysis of standard demographic information plus a wealth of consumer behavior data. These demographic data sets were valuable tools that helped the social scientists describe the human population of the Basin.

Disturbance

Disturbance related information such a wildfire locations, historical and current fire regimes, and rural population/wildland interface fire risk areas are included in this theme group. This information was useful in describing historical and current landscape disturbances and areas at possible risk of disturbance.

Fish

Databases relating to fish and fish habitat were included in this theme group. The presence of key fish species for subwatersheds was determined using the fish distribution data systems acquired from each of the coordinating state agencies participating in the Northwest Environmental Database. The database includes the Oregon River Information System, the Washington River Information System, the Idaho River Information System and the Montana River Information System. Hatchery locations, diversions, and dams were also included in this theme group. Information describing the fisheries environment was essential in determining the historical and current status of key salmonids and other fish of interest within the Basin.

Hydrology

The hydrology theme group included delineations of the Columbia River basin, subbasins, watersheds, and subwatersheds across the area. Water bodies including rivers, lakes, and oceans captured at various scales were also in this theme group. Other data closely related to water features and various designated watersheds, such as key watersheds (FEMAT 1993), high priority watersheds and other watersheds, were in this group. Hydrologic information often provided the spatial foundation for our analysis work.

Minerals/Geology

This theme group contained all data sets relating to mining and mineral processing, mineral resources, mineral potential, or geology. All these data were provided by the USGS or the USBM. The mineral information was used to provide the locations of known or probable surface disturbing activities such as mine locations. The information provided a foundation for characterization of the physical properties of the Basin.

Physiographic

The physiographic group contained data sets describing the physical geography of the assessment area by characteristics such as landform, climate, elevation, and soils. There are data sets from previously compiled ecoregion and biophysical classifications including Bailey (1994) and Omernik (1987). Sources for the physiographic data sets included the Forest Service, The Nature Conservancy, and the Environmental Protection Agency (EPA). The physiographic data were crucial for characterizing and describing the biophysical environment within the Basin.

Political

Data containing features that were political designations or were human-created delineations were put in the political theme group. Examples include land management boundaries [such as the Northwest Forest Plan area (USDA and USDI 1994), ownership delineations, and management area classes], state and county boundaries, ICBEMP study areas, and both EIS boundary delineations. This information was used to describe the impact of current management and provided a means for summarizing information for all the SIT analyses.

Species

This theme group depicted the range of occurrence of terrestrial species such as birds, mammals, invertebrates, plants, reptiles, and amphibians within the Basin. This information was derived from expert knowledge, field guides, and other sources. The information was used for describing the known ranges of key species and probable suitable habitats within the Basin.

Terrestrial

Terrestrial themes described the flora or fauna within the assessment area. This group of themes contained information on known sensitive, listed, or candidate plant and animal species locations. This information was important for assisting in the determination of terrestrial species viability and population changes within the Basin.

Vegetation

Vegetative information collected included current vegetation, historical vegetation, potential natural vegetation, and life form. Vegetation information was collected at the broad scale (1 km) and for subsample areas at the mid scale (1:24,000). Current broad-scale vegetation cover and structure types were classified from the Advanced Very High Resolution Radiometer (AVHRR) satellite imagery (1 km) data set. Historic cover type and structure for the broad scale were compiled from numerous records such as early federal land survey descriptions. Potential vegetation types were determined by subdividing the Basin into warm/dry to cool/moist environments and associating the potential vegetation types and groups with these environments.

The subsample current and historical mid-scale vegetation information was derived from aerial photography interpretation completed by FS, BLM, and contract personnel. Cover type, structure, and other information was collected in this way.

The CRBSUM allowed for predictions of future vegetation cover types and structures across the Basin under different management scenarios. The vegetation information was crucial in describing and characterizing the current, historical and future conditions of the landscape within the Basin.

Methods for Integrating Data

For the ICBEMP, data sources (agencies) were selected for their expertise in a given field based on either local knowledge or experience in a discipline. The administering agency for a particular piece of land was considered to have the best knowledge about how the land was managed. An agency that specialized in a discipline was considered the preferred provider of data from that discipline. For example, geological data were acquired from the USGS, and fish distribution information was acquired from the Northwest Power Planning Council. Major data providers included individual administrative units of the FS, BLM, USFWS, EPA, USGS, USBM; the Bonneville Power Administration; universities; state agencies; and non-governmental organizations. A complete list of data providers can be found in table 8.2.

For a given piece of ground, mapping and classification of the environment varied widely between different scientists, organizations, and individuals. Some of this was a function of need and some was a function of differing interpretations, knowledge, and skills. These different mappings made the choice of data sources difficult. Data that were continuous across the project area were easier to deal with than data that had to be pieced together from a variety of sources. Some of the problems encountered when trying to compile a continuous data set from different sources included disagreement about features (spatial edge mapping), classifications, and attributes. The reason for using multiple sources was that the data were simply not available any other way, or the accuracy of the single source data was insufficient for the project's needs.

Table 8.2 —Major contributors of Geographic Information System (GIS) data.

American Fisheries Society-(AFS)	Oregon State University-(OSU)
Bonneville Power Administration-(BPA)	Sierra Biodiversity Institute-(SBI)
Bureau Of Indian Affairs-(BIA)	State Of California
Bureau Of Land Management-(BLM)	United Parcel Service-(UPS)
Central Washington University	United States Bureau of Census
Colville Tribe	United States Bureau of Mines-(USBM)
Environmental Systems Research Institute, Inc. -(ESRI)	United States Department of Defense-(DOD)
GAP Analysis Programs-OR, WA, ID, MT, UT, NV, WY	United States Environmental Protection Agency-(EPA)
Idaho Department of Fish and Game	United States Fish and Wildlife Service-(USFWS)
Idaho Department of Water Resources	United States Forest Service-(USFS)
Montana Fish and Wildlife-(MT-F&W)	United States Geological Service-(USGS)
National Park Service-(NPS)	University of Idaho
National Resource Conservation Service-(NRCS)	University of Montana
Nature Conservancy-OR, ID, MT, WY	University of Washington
Nez Perce Tribe	Washington Department of Natural Resources-(WA-DNR)
Northwest Power Planning Council-(NWPPC)	Washington Department of Wildlife-(WA-DWL)
Oregon Climate Service	Western Utility Group
Oregon Department of Fish and Wildlife-(ODFW)	Yakama Indian Nation
Oregon State Service Center For GIS (OSC)	

Although having accurate data was important, having continuous data across the project area was also necessary. To achieve this continuity while maintaining the best data source for a particular area, the following rule sets were applied when integrating data:

- In areas with conflict where one data set had higher accuracy than the other, the data from the higher accuracy data set were used;
- In areas with conflict where source data had equivalent accuracy, priority was given to the data from the federal agency;
- Otherwise, the analyst would consult the specialists in the subject matter and the determination as to which data had priority would be made.

It must be remembered that the resultant data set, without any more specific information on the origin of each piece of data, was only as accurate as the least accurate data set that went into its creation. Where data standards did not exist or were not followed, employing a lowest-common-denominator approach to ensure consistency was necessary. This meant that the data sets with finer attribute resolution would be reclassified into a coarser resolution.

In any case, data were inspected visually as well as through ancillary information. For example, paper maps, other GIS layers, and models using multiple GIS layers, were used to check for data anomalies and errors. The data with the most resolution were not necessarily the preferred data. The preferred data for the project were the data that met the analytical needs of the SIT, were continuous across the Basin, and were consistent.

Raster data had additional potential problems due to the rasterization process. The value at any particular point was determined by the underlying value that made up the majority of the individual cell. Where multiple attributes in a vector data set were reclassified into fewer attributes without due care, "logic" conflicts could occur. That is, the base data set might produce a different result depending upon whether the data were reclassified before or after rasterization. For example, if a given pixel (or cell) was 30 percent value A, 30 percent value B, and 40 percent value C, and the reclassification combined A and B to another class, the results would differ. The data that were rasterized first would have a value of C and not be reclassified, while the data that were reclassified first would have the reclassified value after rasterizing. As a rule, the data with the greatest resolution were rasterized and reclassification was done with that rasterized data set. See the Analysis section below for further discussions of the rasterization process.

Analysis

Analysis of data occurred in GIS and in the database environment. GIS analysis used two data architectures: vector (lines, polygons, and points) and raster (matrices or grids). Some data were created in vector form (such as information captured from a map, like ownership boundaries), while other data were created in raster form (including elevation models, vegetation models, and data based on satellite imagery). Vector data were sometimes converted to raster data for the analysis process.

GIS

Vector—Where all data required for analysis were in vector format, vector analyses were used unless they were too cumbersome. In that case, grid or raster processing was used to increase efficiency. Data quality information was used to assess the amount of precision that the resulting output would have. For example, an analysis using data from small-scale sources (such as a 1:1,000,000 source) would have less precision than an analysis using large-scale information captured from a 1:24,000 source.

Vector data sets were prepared to be as continuous as possible. When data sets were too complex or cumbersome, they were tiled or split into separate but identically structured pieces, based usually on states. In some cases an alternate tiling scheme, such as subbasins (4th field hydrologic units), was used. In either case, coincidence of lines between tiles was the goal, but due to the various sources and times of acquisition, and the amount of work required to achieve this, not all data were brought into strict coincidence.

Linear features, such as roads or streams, were more suited to analysis in vector format. The difficulty with linear features in a raster data set was that the minimum width of the feature became the width of the pixel (one unit of the raster). Additionally, where the feature was sinuous and nearly coincident with pixel edges, the width of the data feature sometimes assumed the width of two pixels. Also, networking and dynamically segmenting the data using the available software was easier in the vector form.

Raster—Examples of data captured in a raster format included topography, vegetation, climate, and the CRBSUM outputs. For consistency, most integrated analyses from which reports were made were done in raster format to simplify quality checking. Two resolutions were used: 100 square meters and 1,000 square meters (1 km^2 cells). The 100 square meter information was used when at least one of the following criteria was met: (1) the data were captured with sufficient resolution and accuracy to justify this resolution (in most cases this was from 1:24,000 sources), or (2) the data had relatively small polygons that were important to maintain. As the size of a data set's individual polygons decreased, the likelihood of missing a significant portion of the polygons during rasterization increased. Although there was no rule-of-thumb, the size limit was approximately two and one-half to four times larger than the cell size. It should not be assumed just because the

raster format had a resolution of 100 square meters that the data had the same accuracy. The finer resolution was used as a device to ensure that the overall values would be appropriate, without loss of data representation. The same argument can be made with the one-square-kilometer resolution data—a given square kilometer may not be very accurate, but when looked at in aggregate (with adjacent pixels), the accuracy increases.

As an example, the representation of lands administered by the U.S. Army Corps of Engineers (COE) in the State of Washington showed 398 hectares in vector form, 398 hectares when rasterized to a 100-square-meter cell size, but only 100 hectares when rasterized to a one-square-kilometer cell size. This occurred for a number of reasons. First, the variance of the difference increases with both increased cell size and decreased size of feature being represented. Second, COE ownership consisted of narrow scattered parcels of land, making it less likely that it would occupy the majority of a larger pixel.

Quality Assurance

With a GIS, there were a number of possible error types, including spatial, attribute, and logical. To minimize the number of errors a number of quality assurance steps were taken throughout the analysis process. However, limits on time and money prevented the team from ensuring that 100 percent of the errors were avoided. The team tried to keep the spatial and attribute features of the data as reliable as possible, as well as to ensure that no logic errors were introduced in the analysis or summarization routines.

Information gathered specifically for this project (that is, did not exist digitally before and was requested in a digital form to accomplish the objectives of the assessment) was either scanned or digitized once a manuscript of the data was created. These digital data sets were then attributed (features identified) and brought into the GIS. Further attribution, error checking, and analysis took place before the data set was placed into the corporate (master) data structure. These checks included manual inspection against other sources of data and logic checks both within the data set and with other GIS data sets. Errors, inconsistencies, and anomalies identified were resolved with the help of field specialists or other sources.

Data that were entered into the corporate data structure were plotted and inspected, and in cases of error or uncertainty, sent back to the originator for validation. Information about the data (metadata) that was compiled included information on scale and accuracy. This metadata were available to the teams and were included with any data distributed to other parties.

The output derived from the analysis required integration of many factors including differing requirements of the data by the SIT and differing qualities of the information itself (for example, differences in representative scale and data resolution). Comparing data from different scales causes the resultant resolution to be equal to the level of the most coarse data set. The scale of the data was difficult to keep in perspective. With over 58 million hectares of data coverage dealing with broad processes, the resolution of the data was more coarse than that with which most specialists were used to dealing. This difficulty was addressed by comparing pieces of the larger data set to pieces with which the resource specialists were more familiar.

To reduce logic errors, or errors in data use, a three-part system was implemented. First, communications between the requester and the geographic analyst were reiterated with great care. The request was written in a specific format and logged into the tracking database. The analysis was done with continued communication between the requesting team member and analysts. Second, routines used to accomplish these analyses were studied for logic. Third, the results were studied for anomalies. This was done by using a set of standard tables containing summary values for important, commonly used attributes derived at the different spatial scales and geographic extents. The different teams used varying areas

of analysis: the minimum area was the subsample subwatersheds scattered throughout the assessment area; and the maximum area was the landscape characterization area. The attributes of interest were pulled from the data and inspected against these summary tables for differences. Additionally, maps were made of the analysis results and visually examined by analysts and scientists to ensure they made sense, were consistent, and were accurate.

It must be remembered that these data were gathered, for the most part, across a large area, for a specific purpose. Much of the data was of poor quality when compared with data that would be collected for a site-specific project at the individual subwatershed level. The expense of gathering data of better quality (that met project level analysis requirements) for the entire Basin and aggregating it to the broad-scale level was too great to justify both in cost and time with the fixed amount of resources available. Some data were derived from broad general maps, while other data were captured through intensive, large-scale photo interpretation and high-resolution image processing. The importance of using and understanding the metadata to determine the appropriate use of GIS data cannot be overstated.

Inconsistencies and errors in the data sets are prone to propagation and repeated problems. Some data sets created at the onset of the project had slightly smaller extents than the assessment area. Other data sets may have non-coincident lines that represent the effect of a feature that causes attribute changes in both data sets. Such errors, if not corrected, introduce additional errors in resultant data sets.

In the analysis of the current, historical, and future scenarios, a variety of systems and methods were used to evaluate and analyze the mountains of existing and derived data. GIS played a key role in tying the CRBSUM outputs to the management regions, Ecological Reporting Units (ERUs), and subwatersheds. Conventional databases were essential to synthesizing, summarizing, and reporting information.

Databases

Columbia River Basin Landscape Assessment Database (CRBLAD)—The CRBLAD provided a common framework for relating data from a variety of sources. The database contains data tiled (organized) on 6th-field hydrologic units (subwatersheds) and was developed to summarize the major indicator variables for the assessment.

Using CRBLAD, a set of indicator variables was summarized by the Spatial Analysis Team for the historical (pre-European), current, and future management scenarios. This information was calculated from a combination of broad-scale vegetative and disturbance predictions from the CRBSUM and the ancillary information listed in table 8.3. Table 8.4 lists the indicator variables that were calculated with the database for use in the assessment. Many of these variables resulted from an assignment of a dominant condition to each subwatershed.

A database was used rather than a GIS to provide more efficient processing and generation of document-ready reports. Key spatial relationships were imbedded within the data using GIS software before it was transferred to a database. Input data sets were summarized to the individual subwatersheds using a GIS on a UNIX-based workstation and then transferred to a PC platform for integration into the CRBLAD.

The Access© development environment provided many features such as "querying by example" and broad import/export data formats that enabled the processing to succeed within a short timeframe. Data sets as large as 3.5 million records were encountered when processing; these required partitioning strategies. The total size of the final database was about 1.5 gigabytes.

Table 8.3— Subwatershed summary files used in the Columbia River Basin Landscape Assessment Database (CRBLAD). The following files were summary information from ICBEMP GIS data sets compiled by 6th field hydrologic units (subwatersheds). This information was used to determine the percent of each subwatershed in a variety of hydrologic, biophysical, political and cultural settings.

Subwatershed file	Subwatershed file description
H6Interp	Hydrologic summary file with watershed response characteristics such as: watershed sensitivity rating, erosion potential, sediment delivery potential and a variety of other hydrologic characteristics (see Chapter 2, Biophysical Environments).
Biochar	Series of files summarizing biophysical and related characteristics of subwatersheds such as: dominant landform, elevation, precipitation, climate, slope, ecoregion, subsection, potential vegetation, current vegetation, and historic vegetation.
Bioclass	Biophysical classification file assigning the dominant features to subwatersheds such as: landform, elevation range, slope class, bedrock geology, relief class, and precipitation class.
Curstat	Series of files summarizing current conditions within subwatersheds such as: surface ownership administration, administrative units (BLM/FS), management area classes (MACs), counties, grazing allotments, wilderness, predicted road density, life form, tribal ceded lands, tribal areas of interest, and minerals data.
Huc6lim2	Master 6th-field hydrologic units in project area and hectares of each.

A comprehensive analysis of probable data input and output requirements was done prior to creating the CRBLAD. This was a time-consuming process that led to the creation of both the high level data flow diagram of the database (fig. 8.2), and the object diagram showing the relationships between all data sources for the CRBLAD (fig. 8.3). This preplanning was an essential step in creating a database that would work as soon as it was created. The output of this analysis was also used to communicate data relationship issues to various work groups.

As data were transferred from the workstation to the PC-based CRBLAD they went through various formatting and quality control steps. These steps uncovered many potential and existing problems before any query and report activities were attempted. After the data were imported, relations to other tables were established at the database level to ensure referential integrity.

Once the data were entered into the system and passed the quality control procedures, they were combined to produce various output products. These products were generally hard-copy reports with corresponding spreadsheet and dBaseIV™ files. A summary subwatershed database (referred to as Executive Summary) was also produced for database analysis by other project users or for display using ArcView®.

Quality control of the output products was done by ensuring areas were summed to reference standards and by having a person other than the one producing the products visually compare them with previously generated reference documents. Primary documentation was done by recording design and processing activities as they occurred. After a set of output products was produced, database documentation software was used to print table, query, and report definitions.

Table 8.4—Indicator variables summarized by or predicted using the Columbia River Basin Landscape Assessment Database (CRBLAD).

REPORT NUMBER	VARIABLE NAME
LE-8B	Potential Vegetation Type
LE-9B	Vegetation Cover Type (wildland, urban, agriculture, other)
LE-10B	Vegetation Structural Stage
LE-11B	Vegetation Cover type/Structural Stage Combinations (terrestrial communities, and structure summaries by potential vegetation group)
LE-12B	Road Density Classes
LE-13B	General Disturbance summaries (prescribed fire, wildfire, harvest, insect and disease, and grazing)
AH-18B	Landscape Pattern Departure Index
LE-21B	Vegetation Pattern Classifications
LE-22B	Fire and Successional Regime and Fire Behavior
REC-2B	Estimated Recreation Opportunity Spectrum (ROS)
REC-3B	Scenic Integrity Classification
TERR-2B	Suitable habitats (for 20 vertebrates and 5 plants of interest)
AH-1	General Vegetation Summaries by Vegetation Code and Structure Stage
TERR-13B	Vegetation Summaries by Tribal Areas of Interest

CRBLAD was essential for providing a consistent analysis of the historical and current situation as well as future management scenarios for comparative purposes at the broad scale. CRBLAD and associated GIS data sets provided a context for major vegetative classifications, watershed effects, scenic quality, and disturbance regimes at the subwatershed level. Portions of the GIS data and associated databases may not be appropriate for project level analyses.

Other Databases—There were several databases developed to support the assessment. Table 8.5 outlines and briefly describes each of the major databases used for ICBEMP analysis. Most of these databases will be available to agency personnel and the public through the internal ICBEMP data release policy when they are adequately documented and finalized. Some of the databases can be spatially referenced to an existing ICBEMP GIS data layer. Detailed descriptions of some of these databases can be found in earlier chapters. Several databases were developed specifically for the project (such as the CRBLAD) and will have little utility for other projects.

Models

Several models were developed to simulate landscape changes, successional changes, recreational opportunities, and economic impacts of land management scenarios. The following briefly highlights a few of the major models developed for the ICBEMP. More detailed discussions can be found in the Landscape Dynamics chapter of this report.

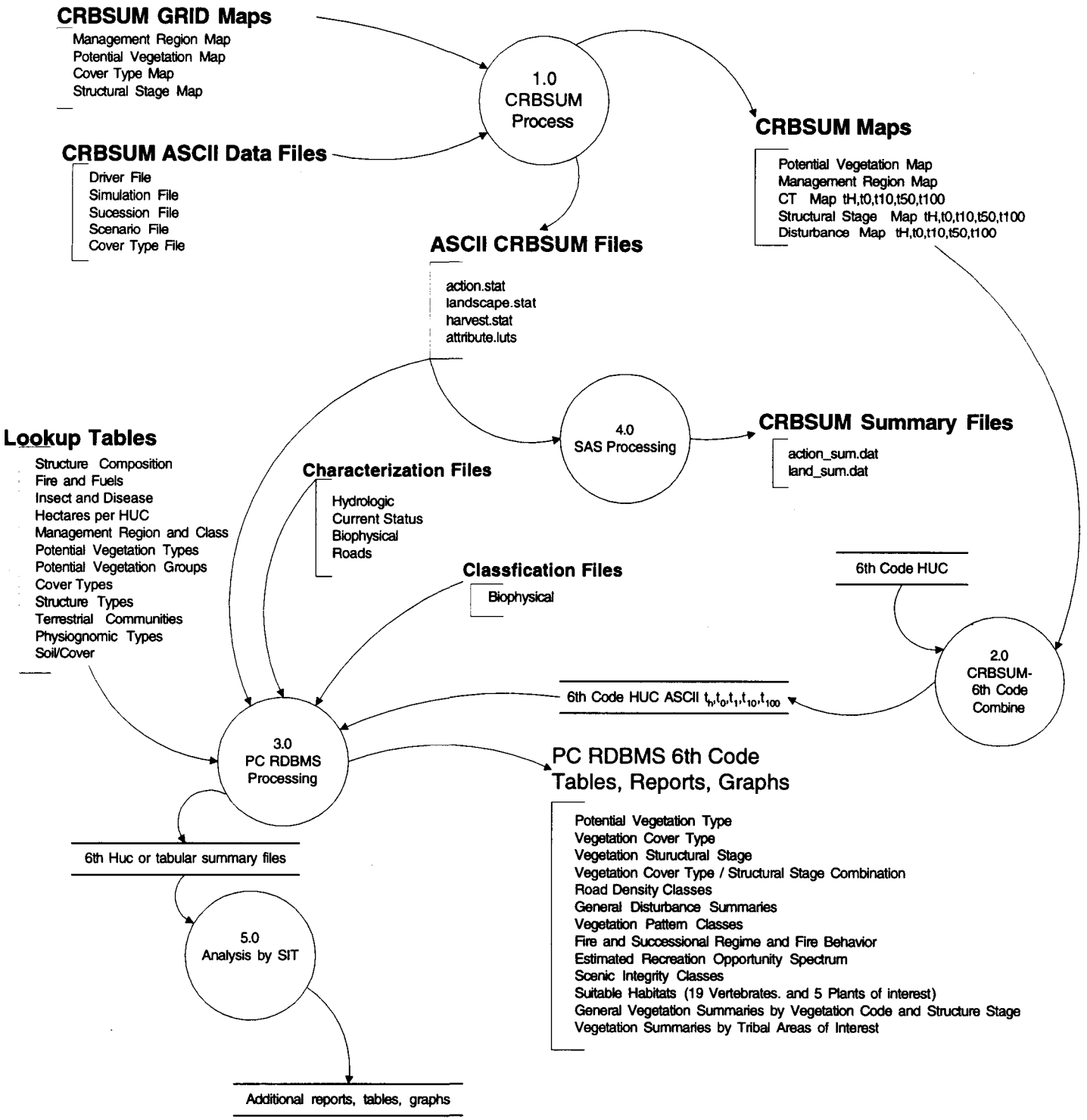


Figure 8.2— Data flow diagram for Columbia River Basin Landscape Assessment Database (CRBLAD). This diagram shows the flow of data for the Columbia River Basin Successional Model (CRBSUM) and Columbia River Basin Landscape Assessment Database (CRBLAD) portions of the Interior Columbia Basin Ecosystem Management Project (ICBEMP). The circles represent the major processes while the lists of text show the data that is passed either to or from a process. The numbers represent Process ID and do not represent process order. They are used for reference by more detailed process diagrams. In some cases the data lists represent groups of tables and/or files rather than a single entity. The input data on this diagram came from a variety of groups working on the ICBEMP.

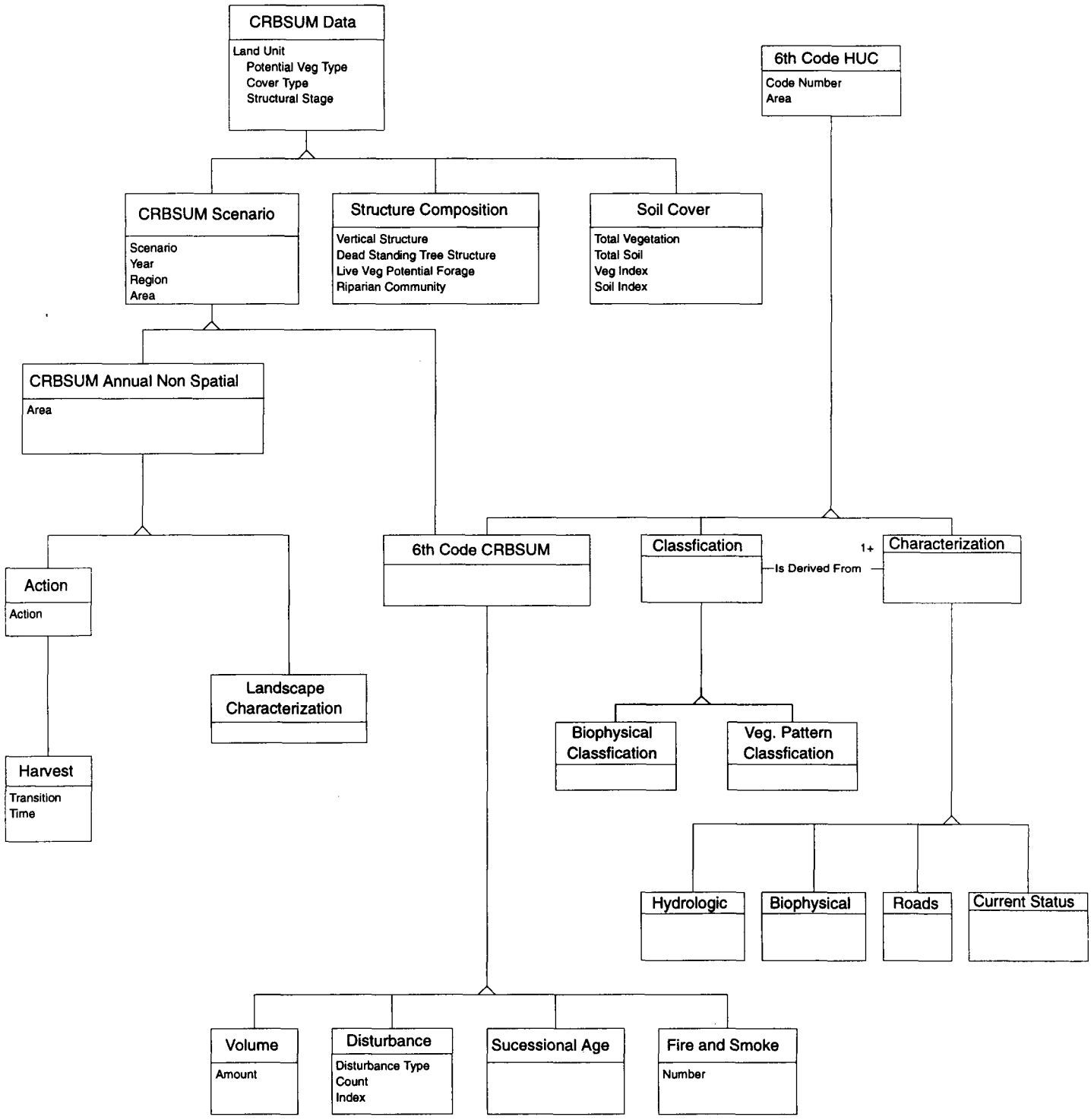


Figure 8.3— CRBSUM-6th Field HUC Input Object Attribute Inheritance Diagram. This diagram shows the attribute relationships between objects used to create the Columbia River Basin Landscape Assessment Database (CRBLAD). These attribute relationships are used to design database structures. The attribute relationships shown are hierarchial. The lower level objects inherit the attributes of the higher level objects.

Vegetation Dynamics Development Tool (VDDT)—The VDDT model was developed for the ICBEMP by ESSA Technologies Ltd. in Vancouver, British Columbia (Beukman and Kurtz 1995). This Microsoft Windows™ application is a user-friendly tool that allows for the non-spatial examination of the role of management activities and landscape disturbances such as fire, insects, and pathogens upon vegetation change. The interaction of these factors is often difficult to predict.

Pathways of disturbance types, their frequency, and the impact upon the vegetation were created for combinations of cover type and structural stages (referred to as "classes"). These pathways were used in the VDDT model to simulate vegetation dynamics over extended periods of time. Changes due to stand dynamics were determined by the amount of time a stand remained in a class and the successional class that it would become in time.

The VDDT model divided the landscape into pixels that were each assigned a successional class and age. The probability of each pixel being affected by a disturbance type was simulated non-spatially by the VDDT model. Pixels changed classes appropriately, independent of the state of neighboring pixels and disturbance history. The VDDT model did not simulate contagion (for example, cell-to-adjacent-cell probability) in space or time. Results were non-spatial and summarized by frequency distributions of cover types at different time intervals (years).

The most valuable aspect of the VDDT model was that it allowed scientists from varying disciplines to define the roles of disturbances and processes upon vegetation dynamics and readily display and review the results for a variety of management scenarios. The VDDT model will be released to agency personnel and the public in the near future.

Columbia River Basin Succession Model (CRBSUM)—The Columbia River Basin Succession Model (CRBSUM), created by the Intermountain Fire Sciences Laboratory in Missoula, Montana, spatially simulates broad-scale landscape level changes resulting from various land management scenarios. This model was used extensively in predicting vegetation cover type and structural stage changes for the management scenarios across the Basin.

Successional dynamics were modeled where community types or "classes" were linked along successional pathways to stable community types referred to as "potential vegetation types." Disturbances were stochastically (randomly) simulated as a change in successional class probabilities developed for each management scenario.

The Landscape Dynamics chapter describes the process of creating and rectifying the input layers for the CRBSUM. The model ran on a UNIX-based workstation. The outputs of the CRBSUM were summarized by a series of tabular files, maps, and GIS grids (raster data) by management region; vegetation cover type; vegetative structure; and disturbance type such as grazing, fire, harvest, and insect and disease (see Keane and others 1995). This information was summarized to the subwatersheds and fed into the CRBLAD for further processing. The CRBSUM results were found to have a 1 to 5 percent variability due to the stochastic nature of the model. These results served as the primary building block for the indicator variable analyses for the assessment.

The coarse-scale CRBSUM provided a useful tool for predicting and comparing vegetative trends resulting from a variety of land management scenarios.

Table 8.5— Databases and models obtained or created for the ICBEMP (as of March 1, 1997) [The following table provides summary information on databases and models created or obtained for support of the ICBEMP Assessment. Some of the databases listed below may actually be spreadsheets.]

Database/ model name	Description	Responsible team	Software	Platform	GIS data layer tied to database
Models					
Vegetation Dynamics Development Tool (VDDT)	PC based disturbance and successional pathway model that displays vegetative outputs (cover type and structural stage) for management options. Alternative and Scenario disturbances and pathways will be packaged and available.	Landscape	Windows	PC	None
CRB SUccessional Model (CRBSUM)	GIS model for predicting broad-scale vegetation management futures based on successional and disturbance pathways from the VDDT model.	Landscape	Unix, Loki and Arc/Info	Unix	Vegetation outputs from model (cover type and structure)
Wildfire and Prescribed Burn Models (CALMET/CALPUFF)	PC model for predicting emissions and visibility impacts of wildfire and prescribed fire.	EIS	dBase	PC	None
Aquatic Databases					
Columbia River Basin Stream Reach Information (CRBRID)	Stream inventory information linked to 17,000 km of river reaches within the CRB	Aquatic	dBase/ Paradox	PC	100K streams
Aquatic Integrity Measures	Measures of aquatic integrity by watershed (5th field HUC).	Aquatic	dBase/ Paradox	PC	None
Vegetation & Management Clusters	Classification of each subwatershed for dominant vegetative composition and management class.	Aquatic	dBase/ Paradox	PC	None

Table 8.5 (continued).

Database/ model name	Description	Responsible team	Software	Platform	GIS data layer tied to database
Fisheries Databases					
Key Salmonid Current Status	Classification of salmonid status within the 6th field hydrologic units	Aquatic	dBase/ Paradox	PC	6th field hydrologic units (subwatersheds)
Fish Species Assemblages	Species assemblages of native and introduced fish taxa	Aquatic	dBase/ Paradox	PC	5th field hydrologic units (watersheds)
Fish Subbasin Presence/Absence	Presumed historic distributions of sensitive, threatened, endangered, or special concern fish taxa	Aquatic	dBase/ Paradox	PC	4th field hydrologic units (subbasins)
Terrestrial Databases					
Endemism & Biodiversity	Documentation of the species comprising the centers of endemism and biodiversity that were delineated by the Scientific Panels	Terrestrial	dBase/ Paradox	PC	centers of endemism and rarity, centers of biodiversity
Species Environment Relations (SER)	Ecological function, environmental correlates and other information from Scientific Panels for candidate, threatened, endangered and sensitive plant, vertebrate, and invertebrate species	Terrestrial	dBase/ Paradox	PC	species ranges (for subset of species)
Landscape Databases					
Ecodata Plot Inventory (1940s-1994)	A synthesis of existing vegetation point data from numerous sources across the Basin.	Landscape	dBase/ Paradox	PC	None

Table 8.5 (continued).

Database/ model name	Description	Responsible team	Software	Platform	GIS data layer tied to database
Burgan & Hardy Fire and Fuels	Fire and fuels attributes derived for CRB vegetation.	Landscape	dBase/ Paradox	PC	CRBSUM historic or current vegetation data
Valley Bottom Settings	Valley bottom and stream type data summaries by each subsampled watershed.	Landscape	dBase/ Paradox	PC	Subsample valley bottom settings
Fine Scale Attribute Plot	Attributes derived from fine scale inventories using 0.10 acre ECODATA plot collection procedures.	Landscape	dBase/ Paradox	PC	None
Disturbance/ Vegetation	Predicted vegetation (terrestrial communities, physiognomic types) and disturbance (prescribed fire, wildfire, harvest, grazing) summaries from CRBSUM for management scenarios and EIS alternatives.	Landscape	dBase/ Paradox	PC	None
Other					
Demographic Databases Wessex Corp. "Profiler" and "Tiger 92"	Demographic information and statistics from the 1990 U.S. census	Social (purchased)	dBase	PC	census tracts and block groups
PRIZM Lifestyle	Data describing the proportions of households within each census tract belonging to 62 lifestyle clusters	Social (purchased)	dBase	PC	census tracts and block group

Table 8.5 (continued).

Database/ model name	Description	Responsible team	Software	Platform	GIS data layer tied to database
Columbia River Basin Landscape Assessment (CRBLAD)	Vegetative information and indicator variable classifications of 6th hydrologic unit codes for the historic, current and Scientific Assessment Scenarios. Created for analytical purposes only.	Spatial	ACCESS	PC	6th field hydrologic units (subwatersheds)
Columbia River Basin Landscape EIS Database (CRBLED)	Vegetative information and indicator variable classifications of 4th field hydrologic unit codes for the historic, current and modeled EIS alternatives. Created for analytical purposes only.	Spatial	ACCESS	PC	4th field hydrologic units (subbasins)
Alternative Summary	Vegetative information and indicator variable classifications of 4th field hydrologic units for various alternatives. Also includes integrity ratings for aquatic, hydrologic, forest and range.	Spatial	ArcView and dBase/ Paradox	PC/Unix	4th field hydrologic unit code (subbasins)
Noxious Weeds	Exotic plant species location by county	Landscape/ Terrestrial	Paradox	PC	vegetation cover type and structures
Community Self Assessment Workshop	Summary of information captured at ICBEMP Community Assessment Workshop.	Social	dBase	PC	none
Research, Development and Application (RDandA)	Research needs, data gaps and assumptions for staff areas	Landscape	Paradox	PC	none
Timber Mill Sites	Information about products and production of timber mills	Economics	dBase/ Paradox	PC	towns
Tracker	Administrative record tracking system	Administration	Paradox	PC	none

Documentation of Data

Metadata

In a project such as the ICBEMP, where many cooperators shared data obtained from many sources, documentation of data is a necessity, not a formality. The documentation of data, often referred to as metadata or data about data, is becoming standardized within the Federal Government. In 1994 Executive Order 12906 gave the Federal Geographic Data Committee (FGDC), currently chaired by the Secretary of Interior, direction to establish the National Spatial Data Infrastructure (NSDI) including the "technology, policies, standards and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data." Part of that order calls for standardized documentation of data. Each agency must use the standard developed by the FGDC (FGDC Content Standard for Digital Geospatial Metadata) to document new data it collects or produces.

At the time initial planning began for the ICBEMP, the FGDC metadata standard was in early draft form and subject to change. The project adopted the metadata standard previously developed by the Northwest Forest Plan effort (USDA and USDI 1994a, 1994b). The resulting metadata are, in general, compatible but less extensive than those described in the 1994 FGDC standard.

For management of metadata, SPUDD (Spatial Unified Data Dictionary), an Oracle database application, was used. SPUDD was developed by FS and BLM personnel for use in the Northwest Forest Plan effort and was enhanced during this project. SPUDD has the capability to store information about proposed data sets, as well as documentation of existing ones. Table 8.6 lists the elements included in the metadata.

Automated Tracking Manager (ATM)

It was recognized at the outset of the ICBEMP that data tracking problems would result due to the large number of people involved at the various offices and to the scope of the analysis that was being planned. There was a desire to make data available to many people as soon as possible and yet to maintain control over the data so that the implications of data changes could be handled. The SPUDD was available to track metadata for themes as they became ready for use in the ICBEMP, but the SPUDD was not able to track the changes to the data after they were entered. For this reason the Automated Tracking Manager (ATM) was designed to track GIS data and associated metadata and recreate GIS processes if needed. Other commercially-available products were reviewed and found to be inadequate for project needs.

The ATM was built using ARC/INFO® and ArcTools© software. It is capable of tracking numerous types of ARC/INFO related data including coverages, grids, information tables, report files, graphic files, and automated macro language (aml) programs. When an existing file was tracked with the ATM it was considered a source file. Any file generated within the ATM was considered a derived file. All derived files in the ATM were created with amls that were also tracked with the ATM. This allowed the ATM to automatically recreate any files dependent on other files in the ATM if the source files were replaced or revised. The ATM contains several tools for evaluating the lineage of data and allows the user to understand the implications of revising data, not just on their own work but on all work done with that data. Because of the possible repercussions of changing data, the ATM was considered a master library for approved data and processes, rather than a development environment.

Table 8.6— Spatial Unified Data Dictionary (SPUDD) metadata definitions.

Identification Information: Describes the data's general content, main characteristics, origins and limitations.	
THEME NAME	Descriptive name indicating the thematic content of the spatial data set.
THEME ID	Unique number identifying this metadata entry.
THEME ABBREVIATION	The established abbreviation for the theme.
EXPORT FILENAME	A unique filename for use when the data are made available outside of the project.
PROJECT NAME	Name of the project or organizational unit for which the data set is being retained.
THEME DESCRIPTION	Description of the thematic content of the data set.
COVERAGE EXTENT	Describes the geographic extent of the thematic coverage for the specific file.
SOURCE	Identifies the organization providing the data.
LAST UPDATE	The date the source was captured or most recently updated.
FEATURE TYPE	The feature type of the data set (line, polygon, grid, etc.).
DISTRIBUTION LIMITATION	Identifies the nature of any limitation restricting sharing of the data.
THEME KEYWORDS	List of common words or abbreviations related to the theme.
DATA RESOLUTION	The dimension of the smallest resolvable object in the data set or description of a unit to which data were generalized.
PROJECTION	The name of the current projection of the data.
FILE PATHNAME	The pathname of the data set. Includes the disk location, directory and file name. If the file is located outside the project location, it can be retrieved from this location.
COMMENTS	Narrative giving information about data origins, characteristics, and limitations which has not been given elsewhere and which may be helpful to someone using the data. This could include when the data were first captures, by whom, for what purpose, and how they may have been subsequently modified. It could tell how complete the data are, give any literature citations, and describe concerns associated with the data.
Source Information: Describes documents used to compile the data.	
SOURCE SYSTEM/SOFTWARE	The GIS system and software name.
SOURCE SCALE	The scale of the source material.
SOURCE PROJECTION	The name of the projection of the source material.
CAPTURE METHOD	The way in which the source material was captured.

Table 8.6 (continued).

Custodian Information: Provides a point of contact for the data. "Steward" is the term used by the Forest Service in the Information Management Framework.	
CONTACT ORGANIZATION	The name of the organization acting as custodian of the data.
CONTACT PREFIX	The prefix of the contact person, if applicable (such as, Dr.).
CONTACT FIRST NAME	The first name of the individual to contact.
CONTACT LAST NAME	The last name of the individual to contact.
EMAIL	The electronic address of the contact.
CONTACT ADDRESS	The address to which correspondence may be sent for the contact. Includes 2 address lines, City, State, and Zip.
CONTACT PHONE	The telephone number of the contact person.
Processing Information: Describes the procedures and parameters used to convert the source materials to the final data and describes any derived layer/cover.	
THEME GENERATION PROCEDURES	Processing steps such as the execution of software commands, user-written programs, or other tasks that may affect the content and/or quality of the data prior to or during automation. If the processing steps include a transformation, then the type and error (root mean square error) should be reported. Also, this area may be used to describe any derived maps.
LINEAGE	A list of themes or files, by abbreviation or name, used to generate a theme.
DATA TRANSFER PROCEDURES	List the type of media being used for data transfer and any special instructions.
PROCEDURE CONTACT	The identity of an individual or organization responsible for the execution of any them generation or manipulation of any existing theme (technical contact).
Attribute Information: Describes the attributes associated with features portrayed in the data.	
LABEL TYPE	The identity of the software where the features are labeled. This may be a GIS or a relational database where attributes are linked to a spatial data set.
TABLE NAME	The name of the table where the attribute, or feature label, is located.
WIDTH (or POSITION)	The width (length) of the attribute, item, or field. This can also be used to give position/location when more than one value is encoded in a string.
ATTRIBUTE NAME	The identity, label, or name associated with an attribute of a feature.
ATTRIBUTE TYPE	Whether the attribute is binary, character, date, floating point, integer, numeric, or real.
ATTRIBUTE VALUE	The valid values of the attribute.
VALUE DESCRIPTION	The description or definition of each value.

The ATM relies on user input to determine location and lineage of data. The ATM requires the user to enter the following information about a data set: SPUDD theme, data location (directory/name), creator, date/time created, data type, lineage of data, amls used to create data and arguments given aml (if derived data). The ATM also generates more information when a derived file is created, such as the aml run time.

Functions in the ATM were organized into four major groups: data entry, data management, system administration, and reporting tools. The data entry tools facilitated the entry of source data, processing of amls, and running of amls to create derived data. The data management tools allowed for editing metadata, replacing data, deleting data, moving or copying data, and rerunning processes when derived files were older than their current source files. The system administration tools allowed user access control, scheduling of rerun batch processing, and easy access to ATM system tables. The reporting tools allowed the viewing and printing of any metadata and information on relationships between data.

The ATM provided a useful tool to determine how the GIS data sets related to each other. While most GIS work was not done within the ATM, it was used as a library of processes performed.

Graphics Tracking System (GTS)

The number of new maps and variations of maps being generated reached a point where the ATM was being overwhelmed with primarily plot generation information. A new, simplified tracking system, the GTS, was created to track just these graphic files. The GTS differs from the ATM in that it does not track any relationships between graphics, only the relationship between a graphic and the aml(s) used to create that graphic. The GTS is not actively tied to the Unix platforms where the graphics and amls reside.

The GTS was built using Microsoft Access software and is distributed using run-time versions of Access which access a central network database. It is organized into several modules including data entry and reporting.

The GTS relies on user input of information through Access forms, and requires the entry of the following information to define a unique record: file name, file location, title, coloration, plot size/scale. The GTS also allows entry of Subtitles, aml template, work directory, associated request number, and file size. It tracks and allows entry of amls independently of the graphics, but maintains user defined links between a graphic and the aml(s) used to create the graphic.

The Spatial Team work request database was eventually merged into the GTS system and is now available through the same interface.

Data Release

Data Release Policy and Process

The ICBEMP began to release spatial data and maps to the public and to government agencies in November 1994. Unlike previous projects, the data and maps were provided to the public and government agencies while the project data were being analyzed. A brief policy paper was prepared to provide interested individuals with the data release objectives, the processes for completing requests for data and maps, and cost information.

The ICBEMP has managed the release of data cooperatively with the BLM Oregon State Office from the time of the first release of spatial data and maps. The project office in Walla Walla received all requests for data, logged them, and sent them to the BLM Oregon State Office for processing. The BLM Oregon State Office contacted the requester with the actual cost (materials and time) to process the information and requested payment. The Public Room at the BLM Oregon State Office collected fees to release the information.

Updated Available Data Lists were prepared with each release of ICBEMP data. Data themes were not listed on the Available Data List until metadata were complete. Metadata and forms for ordering releasable data were available on the project's electronic library. On average, the project prepared a release of data every six weeks.

Sensitive data including threatened, endangered, and sensitive animal or plant species, archeological sites, or other resource data for which the release of locational information would be contrary to the agencies' statutory duties or regulations were not made available for public release. The ICBEMP did not release data layers obtained by the FS or BLM under a license or agreement restricting release.

Spatial information was generally released in ARC/INFO (an ASCII format) export format. Several formats were made available for the expected range of user applications in ARC/INFO and Map Overlay Statistical System (MOSS™). The requester was charged only for materials (tapes, disks, and paper) and time to download the files onto tape or disk. Metadata documentation and other descriptive information were provided to the requester along with the requested materials.

Memorandum of Understanding

Federal records, gathered for purposes of compiling an Administrative Record for the ICBEMP, formed the foundation for the decisions made by the FS and BLM. As such, the responsibility for these records was handled by the FS as outlined in a Memorandum of Understanding (MOU) between the two agencies. The MOU discusses the objectives, authority, procedures, records disposition, and administration for managing records generated by the ICBEMP.

Documentation of Data Limitations

Understanding the limitations of data created for use in the assessment is important. The following provides a brief description of these limitations and the process for creating several of the key coarse-scale data sets for the ICBEMP. Additional information can be found in the "Landscape Dynamics" chapter and the "Aquatic Species and Habitats" chapter in this document.

Management Region and Class—A GIS data theme was developed to represent Management Regions and Classes for use in the CRBSUM and in management scenarios. For the assessment the Management Regions were the Eastside EIS (EEIS) and the Upper Columbia River Basin EIS (UCRB) decision areas and Classes were groupings of ownership types. The BLM- and FS-administered lands were split into two categories: non-wilderness and wilderness-like. The Management Area Category (MAC) classification GIS data layer was used to create these categories. The MAC layer was generated for BLM- and FS-administered lands within the Basin in an effort to provide a basis for consistently displaying management direction on these lands and for use in assessing the overall affects on ecosystems. The criterion for mapping MACs was developed prior to the ICBEMP by Region 1 of the Forest Service and other cooperators. Table 8.7 describes the criteria for the eight MACs. The Management Classes used for each Management Region are shown in table 8.8. Further splitting of classes occurred in the EISs.

The Management Region and Class GIS data layer was rasterized to a 1,000 square meter (1 km^2) grid. A comparison of vector versus raster hectares of each Management Class across the Basin was very close. The rasterization process caused some long linear vector polygons to become generalized and counted in other classes. For instance, in areas within the assessment area where the ownership was scattered, the raster image was slightly more squared due to the pixel size of 1,000 square meters.

Probabilities for disturbance (grazing, fire, insects, harvest, and pathogens) were applied to the 12 management classes within the assessment area. The Management Region and Classes were also used to summarize the outputs of the CRBSUM and CRBLAD.

Table 8.7—Management Area Categories (MACs).

Purpose: Provide a basis for consistently displaying management direction of Federal (and other public) lands to use in assessing the overall affects on ecosystems.

Focus: Describe existing management direction to allow aggregation of similar areas to ecological conditions with an emphasis on human use and occupancy.

1. Natural, Unmodified Environments	Ecological processes such as fire, insects, and disease are essentially allowed to operate relatively free from influence from humans. Diversity resulting from natural succession and disturbance predominates and non-native vegetation is rare. Users must be self reliant and expect low levels of contacts with others. Few, if any structural improvement exists and travel is almost always nonmotorized. Typical types of areas: Designated Wilderness, Wilderness study areas, rivers designated/ suitable/eligible for wild river classification, most Research Natural Areas and back country lands.
2. Special Natural Areas	These areas provide for conservation of representative or particular rare and narrowly distributed ecological settings or components. This helps insure conservation of ecosystems or components that may provide important functions insuring overall sustainability of larger landscapes. The influences of humans on the ecosystem are sometimes evident. Types of human uses varies somewhat but generally is nonintensive. Travel is generally nonmotorized. Some of these areas help provide an important role under an adaptive management philosophy by providing a "natural" reference for areas heavily managed for particular objectives. These areas are often formally designated and include some Research Natural Areas, designated, suitable or eligible scenic rivers outside of wilderness, most (non-ONA) Areas of Critical Environmental Concern (ACECs), old growth reserves, and other special areas are typically included.
3. Essentially Unmodified Forested and Grassland Ecosystems	Although the areas are characterized by predominantly natural appearing landscape, an array of management tools can be used to restore or maintain relatively natural patterns of ecological processes. This will result in some evidence of man's activities. Ecological values are in balance with human occupancy with consideration given for both. Resource management activities may occur but natural ecological processes and resulting patterns will normally predominate. Users may expect to experience some challenge and risk. Restrictions on motorized travel can vary from area to area and season to season. This category would include all unsuitable forests and woodlands with no planned harvest, all special status species habitat areas and all designed and occupied wild horse/burro areas.
4. Natural Appearing, But Modified for Human Use and Occupancy	Ecological values are managed to provide human recreational use, but are maintained well within levels necessary to maintain overall ecological systems. Resource use for other values is not emphasized and has little impact on ecological structure, function, or composition. Human use is recreation oriented. Sights and sounds of humans on site can be expected and even desired. Motorized transportation is common. This category would include all designated/suitable/eligible recreational rivers, all non-linear recreation sites and areas, all other ONA/ACEC and environmental education sites.

Table 8.7 (continued).

5. Modified Forest Ecosystems	The areas are primarily forested ecosystems and are managed to meet variety of ecological and human needs. Ecological conditions will be maintained with an emphasis on selected structures and compositions within the range of natural variability. These lands often display high levels of forest management investment, use and/or activity, density of facilities; and evidence of vegetative manipulation activities. Forest users expect to see other humans and evidence of man's activities. Facilities in support of various resource use are common. Motorized transportation is common.
6. Modified Grassland	The areas are primarily grasslands, and many woodland ecosystems, and are managed to meet a variety of ecological and human needs. Ecological condition objectives are likely to have an emphasis on selected structures and compositions within the range of natural variability. These lands often display high levels of investment, use and/or activity, density of facilities, and evidence of vegetative manipulation activities. A wide variety of structure and composition is present. Users expect to see other humans and evidence of man's activities. Facilities in support of various resource uses are common. Motorized transportation is common.
7. Areas Modified by Human Occupation and Activities	Public lands are intermingled with private lands to the point that without the support and cooperation of the private sector, BLM/Forest Service cannot effectively manage for ecological values. Human activities have altered the natural appearances in most of these areas, both on private and public lands. Sights and sounds of humans are predominant. Private land use is often intensive agriculture, industrial or residential or zoned for residential (40 acres or less/lot). Resource use may not be planned on a sustainable basis but may occur in concert with surrounding private land values. Motorized transportation is common.
8. Modified Non-Sustainable Areas	Ecological conditions (including processes) are likely to be or have been permanently altered by human activities beyond the level needed to maintain natural appearing landscapes and ecological processes. The areas are generally small but could involve the core area of large mining districts. Ecological values are protected where they affect the heath and welfare of human occupancy. Areas such as mines and other concentrated uses are included. Human activities are generally commercial in nature and directly or indirectly, provide jobs and income. Motorized transportation is common.

Table 8.8— Management Region and Classes used for the Assessment.

Management Class	Description
FS/BLM Wilderness-like	MACs 1 and 2. Mostly wilderness, designated/suitable/eligible wild or scenic rivers, wilderness study areas, areas of critical environmental concern (ACEC), and research natural areas (RNAs).
FS/BLM Non-wilderness	MACs 3 through 8. All other BLM and FS lands.
Other Wilderness and National Parks	Wilderness on lands other than BLM or FS, and National Parks.
State and other federal lands	State lands and other federal lands: Department of Defense, Dept. of Agriculture Research Stations, U.S. Army Corps of Engineers, Department of Energy, Bureau of Reclamation, and US Fish and Wildlife lands.
Tribal lands	Tribal lands within reservation boundaries
Private and all other lands	Private land, county, municipal, and other lands

Edits were performed on some portions of the Management Region and Class grid to correct for missing data. During this process, a more generalized grid was inadvertently tracked as the new master grid. This error was not found until after the CRBSUM was processed for the management scenarios used in the assessment.

The overall impact of the incorrect grid was that the total hectares of BLM- and FS-administered lands were approximately 2 percent higher than the vector totals. Therefore, all reports from the CRBLAD for indicator variables had more hectares of land reported as administered by the BLM and FS. The error in the Management Region and Class layer was corrected for use in the EIS alternatives.

Coarse scale vegetation—The coarse (broad-scale) historical and current vegetation data were entered into the GIS at a 1,000 square meter (1 km^2) resolution. The current cover types were derived based on classified AVHRR data. Historical cover types were derived from a variety of historical cover type maps. Current structural stages were predicted using discriminant analysis (multivariable correlation analysis) based on the mid-scale subsample vegetation data [see Hessburg and others (1995) for more information on mid-scale vegetation sampling]. Historical structural stages were predicted randomly based on county records compiled within historical cover type units stratified by subsections.

The current coarse scale vegetation classification was based on the dominant cover type visible from the AVHRR data. Those areas that had the greatest reflectance within a pixel (cell) were the resulting classification.

Both broad-scale vegetation maps were a classification based on the best available data. Direct comparisons of current project level data (fine scale 1:24,000), cover type, and structure information for a particular piece of ground to the classified coarse-scale data should not be made.

Predicted road density classes—A continuous map or GIS data layer for existing roads and trails within the Basin was not available. There were several coarse scale sources obtained for the project including 1:100,000 USGS roads; a United Parcel Service road data set from Geographic Positioning

Systems (GPS); 1:2,000,000 roads from ArcUsa®; 1:1,000,000 roads from the ESRI Digital Chart of the World (DCW); and 1:100,000 roads compiled from a combination of Census Bureau road files. All these existing data sets were continuous across the Basin but were missing most of the unimproved roads and those built by the BLM and FS for logging and other purposes. To analyze the impacts of road disturbances upon terrestrial species migrations and aquatic environments, more detailed information was needed.

The ICBEMP collected more detailed road information in the subsample subwatersheds across the Basin (see "Landscape Dynamics" chapter for a description of the subsample effort). The BLM and FS mapped roads within each subsample and noted a variety of attributes, such as road closures and road surface type, using orthophotos and aerial photography. This information was entered into the GIS. It was a fairly accurate indicator of the road density within the individual subsamples.

From the combination of these data and other information such as ownership, other road data sets, digital elevation models, and MACs, a predicted road density class 1,000 square meter (1 km^2) grid was created using a statistical rule-set (see "Landscape Dynamics" chapter for additional information on this process).

Each 1,000 square meter pixel was classified into one of the following road density classes:

None	(0 - 0.02 mile/square mile of roads)
Very Low	(0.02 - 0.1 mile/square mile of roads)
Low	(0.1 - 0.7 miles/square mile of roads)
Moderate	(0.7 - 1.7 miles/square mile of roads)
High	(1.7 - 4.7 miles/square mile of roads)
Extremely High	(4.7 or more miles/square mile of roads)

From this 1,000 square meter grid a 6th-field hydrologic unit (subwatershed) GIS theme was developed using a weighted average based on road density class midpoints. This data set was used for subwatershed characterization and analysis in GIS and other databases. The subwatershed predicted road density GIS layer was used in the CRBLAD as the baseline for current road densities. For each of the management scenarios for the assessment, road densities were predicted for each subwatershed based on a rule set.

In general, the statistical extrapolation rule set for the 1,000-square-meter road density grid was conservative toward higher road densities. Since the road density classes increased in width and size of midpoint, the weighted average for the subwatershed version also tended to be conservative toward higher densities. In many areas of the Basin where there were narrow mountain ranges, areas that should have been roadless (such as the Cabinet Mountain Wilderness Area in Montana) were shown as roaded in the subwatershed road density classification. Subwatersheds at each side of the narrow mountain range had roads in the lower end of the subwatersheds and these roads were averaged into the total subwatershed.

The Aquatic Staff conducted a ground truthing of the subwatershed-predicted road density layer within several 4th-field hydrologic units on the Umatilla National Forest, Wenatchee National Forest, Ochoco National Forest, and the South Fork Salmon River area of the Payette National Forest. The subwatershed predicted road density classes from the project were compared with actual National Forest level data for 155 5th-field hydrologic units. Accuracy of the subwatershed predictions was as follows: Umatilla and Ochoco National Forests were 86 percent, Salmon River was 44 percent, and Wenatchee Forest was 71 percent. The more detailed results of this comparison are in table 8.9. The possible reason for lower accuracy on the South Fork area could be the higher variability of road densities in Management Area Categories 3 through 8 (non-wilderness areas). This appears to be typical of most of the UCRB EIS area.

Table 8.9—Summary of the comparison of the Interior Columbia Basin Ecosystem Management Project (ICBEMP) predicted subwatershed road density classes to actual forest road density data.

Comparison of Actual Forest Road Density Class to ICBEMP Predicted Road Density Classes	Number of 5th Field Hydrologic Units and Percentage		
	Umatilla/ Ochoco Forest	**Salmon Forest**	**Wenatchee Forest**
Same	48 (86%)	25 (44%)	30 (71%)
Higher	6 (10%)	10 (17%)	7 (17%)
Lower	2 (4%)	22 (39%)	5 (12%)
TOTAL	56	57	42

Overall the 1,000-square-meter predicted-road-density layer can be rated as a good estimate of the actual road situation in the Basin, given that it was based on a 3 percent sample of subwatersheds and a fairly conservative rule set. The subwatershed GIS data set can be rated as a fair estimate of the current road situation, given the conservative nature of the rule set and the averaging of mid-points from unequal classes. A road density class rating could be highly skewed in individual subwatersheds; that is, the roads could all be in one part of the subwatershed, and the rest could be roadless. Given that subwatersheds range in size from 200 hectares to 10,000 hectares, this could result in a significant misconception if the limitations are not considered.

The predicted road density GIS layers created for the ICBEMP were a classification that was valuable for estimating broadscale disturbance impacts such as sediment transport and erosion within the assessment area. These classifications were not meant to be a replacement for a mid- or fine-scale continuous road layer. It is important to remember the limitations of these data sets. They should be used for relative comparisons only.

Research, Development, and Application Needs for Information Management

A key element for ecosystem management is the need for consistent, current, and accurate information concerning the ecological and biophysical environments across the landscape. This information is necessary at several levels of resolution. Research is needed to develop better data structures that link scales (both temporal and spatial). To implement ecosystem management, the collection and management of these data, and information between Federal, state, and local agencies need to be effectively coordinated and shared. Federal, state, and local governments working with the public can help ensure success through a shared commitment and vision.

Inventory and Monitoring Needs

An ongoing commitment to ecosystem management and modeling will mean that federal agencies will need to reassess their individual resource inventory programs and strive for a set of interagency standards tied to ecosystem management. Currently, data are collected in many formats both between and within agencies. This makes inte-

grating data very difficult. Data need to be collected for all ownerships across ecosystems in a standardized fashion for ecological and biophysical information. Minimum data standards for vegetation, aquatic, fisheries, and terrestrial components of the landscape need to be established. Additional information in excess of the minimum required could be collected by individual agencies for their own needs. Data collected at the project level, once standardized, could be aggregated for mid-scale and broad-scale analyses.

Maintenance of ICBEMP Data and Models

The GIS data and associated databases collected and created for use in the assessment need to be managed, maintained and shared. A central information clearinghouse could be established to support the update and implementation of FS and BLM plans. This clearinghouse could manage, distribute, and provide user support for both spatial and non-spatial data and models from the ICBEMP. Agencies could profit from the information investment of this assessment by developing processes for long-term resource information management that benefit ecosystem management.

There are several GIS data layers that need to be standardized and collected continuously across the Basin for broad-scale and mid-scale analyses. Many of these themes have been created or collected by the ICBEMP and may be used for project level work where no finer resolution data exist. There are some additional data that will be needed for implementation of ecosystem management principles.

Standardization of Existing Data

Standardization of theme content and attributes for the following data sets would assist in building a more functional interagency data set for future work. Such an interagency data set could be built once the following building blocks were put in place:

- Administrative boundaries
- Surface ownership administration
- Current land use allocations for all agencies
- Natural areas, wilderness, and unroaded areas
- Current Management Area Categories (MACs) for all agencies.

Maintenance of Priority ICBEMP Data

Many of the newly captured data sets from the ICBEMP could be maintained and improved for future analyses including implementation of plans, watershed analyses and project level planning. Major effort and expense went into the continuous and consistent entry (data capture) of many of the GIS data layers and associated databases across the assessment area. These include but are not limited to:

- 6th-field hydrologic units (subwatersheds)
- Broadscale vegetation (1 km^2)
- River reach stream inventory and databases
- "Fish Related Databases".

Data Needed for Implementation of Ecosystem Management

A number of critical data sets needed by ICBEMP were not readily available across the assessment area nor could they be captured into GIS in time for use by the project. For use in project level planning and implementation of Forest and BLM plans, the following GIS data sets are important to standardize and capture continuously across the Basin:

- Land type associations;
- Consistently classified vegetation from satellite imagery (mid-scale vegetation);
- Enhanced 1:100,000 stream network (until continuous 1:24,000 base data is available);

- Base data at 1:24,000 [digital elevation models, cultural features, streams (should be enhanced), and roads (enhanced to contain logging roads and others not on USGS base maps)].

Enhancement of Existing Models and Databases

A few of the existing models, such as the VDDT, have been fully documented and have user guides, while other models, such as CRBSUM, have limited documentation and need additional work before they can be released to FS and BLM offices. The following are examples of some of the types of enhancements needed to make the existing models and databases created for the ICBEMP more useful for the future.

- To the extent possible, make critical models and databases more user-friendly, with pull down menus, user interfaces, and user guides.
- Develop CRBSUM to run at the mid-scale level with the contagion function for use with field office vegetation data.
- Enhance CRBSUM so that novice users could run it efficiently.
- Provide training on use of models and key databases developed for the ICBEMP.

Technology Transfer

A technology transfer program would provide field offices, other agencies, and the general public with access to and comprehension of the data, models, and information that were developed for the ICBEMP. Technology transfer is crucial for providing user support and training to the field offices over the next several years. Maintenance and periodic update of the GIS data, databases, and models collected and developed for this project will benefit subsequent regional analyses. Otherwise, the data will become outdated. Refer to other chapters in this document for additional research, development, and application needs for implementing ecosystem management within the project area.

Major Information Issues and Recommendations

The information and technology plan developed for the ICBEMP was functional and fairly efficient for a project of this scope. The overall project was larger than was actually planned in terms of the number of people involved, the amount of data collected, and the scope of analyses performed. In addition, the project's timeline was overly ambitious for what could actually be accomplished for many of the tasks. Several things could be improved in future projects of this type.

Data Development, Documentation, and Analysis

Many of the GIS data sets took over nine months to compile or create. Time could have been spent more efficiently if key base data, such as subwatersheds and broad-scale vegetation (1 km^2), had been available at the beginning of the project. Many GIS themes that should have been based on subwatersheds were created before the subwatershed layer was finalized. This required data to be modified once the subwatershed layer was available. A stepwise approach should have been followed for completion of many of the base biophysical layers.

Data were received from many organizations, agencies, and individuals. The Spatial Analysis Team collected metadata for each layer from the provider. Although this process worked well, metadata should have been reviewed, edited, and verified against the actual GIS data layers early in the project. Much time was spent correcting inaccurate information or gathering more information from the data source.

A formal quality control process for analysis and data layers was in place in Walla Walla and Portland. Both the GIS analyst and the appropriate SIT member reviewed GIS data layers before they were used for analyses. However, in several instances, data from the individual National Forests or BLM Districts were missing, an oversight that

required re-processing of data and analyses. During projects with tight timelines quality review of information is often difficult because individuals are simultaneously performing a variety of high priority tasks.

Standard map templates were developed and shared between analysis sites for large size plots (1:1,000,000 and 1:2,000,000) early in the project. Page size map templates that ensured that all maps were the same extent and could be overlayed were not developed until later in the project. Such a standarized template would have ensured that all products were similar and could be used together.

The ICBEMP data release process was very successful. By having a specialized group (Oregon State Office of the BLM) handle and process data release, analysts were able to concentrate on GIS analysis. Metadata nad other project information are available on the ICBEMP home page (www.icbemp.gov). The release and distribution of data via the Internet did not materialize until the latter part of the project. This slowed interagency connections at the Federal level, coordination with other agencies and organizations (data collection and distribution), problem solving, and information sharing. Using the World Wide Web/ anonymous FTP to distribute data and share information with agencies and organizations with Internet connections will be an effective information sharing route. This distribution route is currently being developed and ICBEMP data are expected to be made available in the summer of 1997.

Much of the data and analyses for the ICBEMP had not been developed before, and the creation of a formal information needs assessment plan was not possible at the onset of the project. This would have been helpful in managing the project since many of the SIT members could not, initially, determine their analysis needs for a project of this scope, and since more data and analyses were continually added throughout the project. Most SIT staff areas relied heavily on the Landscape Ecology Team to determine the broad-scale analysis procedures since they were most familiar with the biophysical data and broad-scale processes. This caused a bottleneck during the analysis phase. Broadscale analyses of this type and scope had not been performed prior to the ICBEMP and many procedures had to be developed during the analysis process. A limited set of models was tested during prototyping. However, all procedures and analyses could not be tested due to time limitations. If they had been tested, the overall analysis process might have run more smoothly.

Distributed Work Sites and Systems

The telecommunications network between the distributed analysis sites allowed resources (human and machine), which would not have been available otherwise, to be accessed for the ICBEMP. It would have been difficult to physically move some of these resources as they were also dedicated for other activities and duties outside the ICBEMP. Additionally, costs of relocating personnel and equipment were reduced. However, the lack of face-to-face communication hindered understanding of both data and analysis needs. It also took more time to solve problems and answer questions concerning analysis requests between the various offices. All GIS processing and data development would have been more efficient if the analysts and scientists had been in one location. To improve interagency coordination in the future other federal agencies could be added to the WAN that was established for the ICBEMP.

The Portland and Walla Walla offices dedicated certain individuals to perform certain tasks such as preparing plots, documenting metadata and data release, performing quality control, or serving as primary analysts for SIT staff groups. This assignment of tasks allowed those individuals to develop a working relationship and shared understanding of the data with the scientists. However, those analysts assigned to specific task groups would have performed more efficiently had they been in

the same location as the group to which they were assigned. This would have promoted interaction, idea development, and a richer understanding of the data and analysis procedures.

The Spatial Analysis Team was ultimately responsible for all the GIS data and associated databases collected or created for the ICBEMP. The Spatial Analysis Team, however, was not in direct control of the data collection or analysis in Missoula, Wenatchee, or sites other than Walla Walla or Portland. The Landscape Ecology and Aquatic Teams were directing the data collection and analysis at these other locations. This created problems with data standards and documentation, quality control of products, and the setting of work priorities. It may have been more efficient to have all GIS analysts reporting to one Spatial Analysis Team Lead. Less time would have been spent trying to correct data and documentation or to understand analysis that had been completed by other sites.

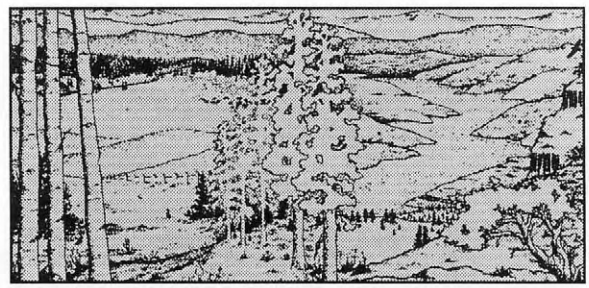
Conclusion

Good progress has been made in building cooperation between agencies in order to implement ecosystem management. "Few, if any, activities have more comprehensive implications for the successful implementation of ecosystem management than information management: the inventory, acquisition, storage, maintenance, use, and dissemination of data and information" (FEMAT 1993). Our experience shows that information management is both possible and critical in an interagency environment. It is hoped that the documentation of information resource management methods employed by the ICBEMP and the resulting recommendations will provide a means for future efforts of a similar scope to be more effective, as well as highlight the importance of a long-term information resource management strategy for the implementation of ecosystem management.

Continue

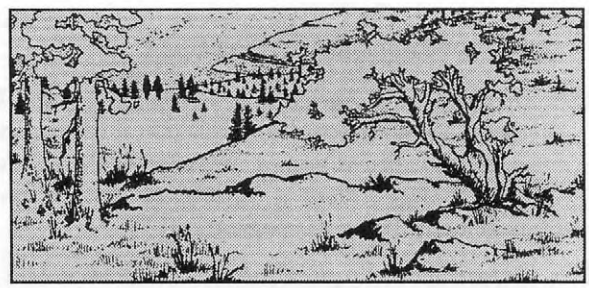
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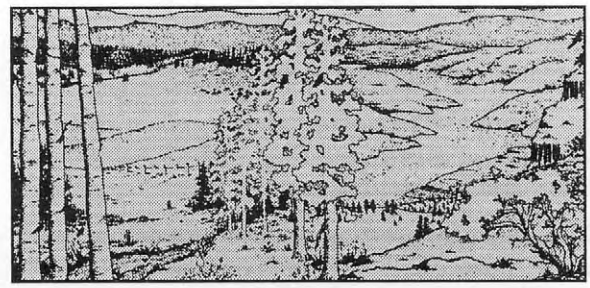
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GLOSSARY

Accuracy, Map Accuracy - The degree to which a mapped location is known to approximate an actual location. Accuracy relates to the quality of a result, and is distinguished from precision which relates to the quality of the operation by which the result is obtained.

Attribute - (n) A qualitative or quantitative non-spatial characteristic which describes a map feature. Attributes for a road might describe surface characteristics, maintenance level, width, length, etc. In the GIS environment, usually analogous to a data element or a column in a database table. (v) The process of assigning an attribute or label to a particular feature.

Cell, Grid Cell - The basic element of spatial information in a raster or grid description of spatial entities. See pixel.

Database - A collection of interrelated data stored together with a minimum of redundancy to serve multiple information needs. Generally thought of as data internally accessible to and manipulated by a computer-based system. A GIS database includes data about the spatial or locational characteristics of geographic features as well as their attributes.

Data Layer, Layer - A physical or digital separation of geographic information according to theme. In digital applications it is often used to refer to a distinct computer map file.

Data Set, Geographic Data Set - Any one of several types of data units such as a data layer (or coverage), database, or data table which can be moved, copied or manipulated as a whole distinct unit.

Derived Data - Data that result from manipulating or combining one or more data sets, as opposed to data that have been directly captured from maps, observations, or other sources.

Digitize - Conversion of any character, symbol or graphic image into computer compatible binary data. In the context of GIS, digitizing is particularly concerned with recording of spatial location of geographic phenomena in real-world coordinates, but also includes the entry of any alphabetic or numeric data which describe these phenomena. Usually accomplished by means of keyboard entry, manual tracing using a digitizing table or by optical scanning.

Domain - Same as extent.

Extent, Geographic Extent - Area of the earth covered by a digital map.

Feature, Map Feature - The map representation of a real-world phenomenon, or entity, such as a well, town, road, boundary, swamp or timber stand. Also: geographic object.

Lineage - A narrative description of the source materials from which data are derived and the methods and processes of derivation.

Manuscript - The original drawing of a map as compiled or constructed from various source data to be used in digitizing for GIS.

Metadata - Information or documentation about data. A data dictionary contains metadata (rather than the physical data itself).

Pixel - A contraction of the words picture element. A data element of a raster matrix or grid map. Equivalent to a cell.

Raster - A digital representation or display of an image or map, consisting of a regular array of rectangular pixels or cells.

Resolution - The smallest size of feature that is measured, recorded or observable, in a graphic image such as a map, or in quantifiable data. The larger the map scale, the higher the possible resolution. As map scale decreases, resolution diminishes and feature boundaries must be generalized or not shown at all. In a grid map or raster file, the cell size defines the resolution.

Scale - The relation between the distance on a photograph or a map and its corresponding distance on the ground. Scale may be expressed as a ratio, 1:24,000; a representative fraction, 1/24,000; or an equivalence, 1 in.= 2000 ft. The term "large" in "large scale" and "small" in "small scale" refers to the fraction representing the ratio of map to ground distance. For example 1:10,000 means one map unit = ten thousand ground units, and a map of that scale would be a larger scale map than one of 1:1,000,000. The larger the scale of a map, the smaller the real-world area that can be shown on a given size map, and the greater the detail that can be displayed.

Spatial Data - Data describing position or geographic location of natural and human constructed features. In this document, refers to both the locational component of geographic data and the attribute or other descriptive component.

SPUDD - Spatial Unified Data Dictionary. An Oracle database application used by the project to store and retrieve metadata information about planned and existing data sets. Developed by the Forest Service and BLM during the Forest Ecosystem Management Assessment Team (FEMAT) project.

Theme - As used by the ICBEMP, a descriptive name referring to one or more data sets indicating the specific subject matter content of the data.

Theme group - The general subject matter category of a group of themes. Used by the ICBEMP to help organize its data.

vector - 1: In statistics, a quantity whose complete description requires two or more numbers. 2: A matrix with only one row or column; its elements are referred to as components. 3: An organism that carries or transmits a pathogenic agent; *cf* carrier. 4: Any agency responsible for the introduction or dispersla of an animal or plant species [LB]

Vector Data - In GIS systems, data comprised of x-y coordinate representations of locations on the earth; taking the form of single points, strings of points (lines), or closed lines (polygons). Data are coded to express magnitude, direction, and connectivity.

List of Acronyms

ASQ	Allowable Sale Quantity
AUM	Animal Unit Month
BEA	Bureau of Economic Analysis
BLM	Bureau of Land Management
BMPs	Best Management Practices
BTUs	British Thermal Units
CFR	Code of Federal Regulations
CRBSUM	Columbia River Basin Succession Model
EIS	Environmental Impact Statement
EEIS	Eastside EIS Planning/Management Area
EPA	Environmental Protection Agency
ERU	Ecological Reporting Units
ESI	Existing Scenic Integrity
FACA	Federal Advisory Committe Act
FEMAT	Forest Ecosystem Management Assessment Team
FIRE	BEA designation, Finance, Insurance and Real Estate industries
FS	Forest Service
FSH	Forest Service Handbook
GIS	Geographic Information System
GPM	General Planning Model
GSP	Gross State Product
HUCs	Hydrologic Unit Codes
LWD	Large Woody Debris
ICBEMP	Interior Columbia Basin Ecosystem Management Project
ICRB	Interior Columbia River Basin
INFISH	Inland Native Fish Strategy
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWFP	Northwest Forest Plan
PACFISH	Pacific Anadromous Fish Strategy
PILT	Payments in Lieu of Taxes
RAC	Resource Advisory Committee
RHCA	Riparian Habitat Conservation Area
RMA	Riparian Management Area
ROS	Recreation Opportunity Spectrum
PVG	Potential Vegetation Group
PVT	Potential Vegetation Type
RVD	Recreation Visitor Day
SER	Species-Environment Relations (database)
SIC	Standard Industrial Code
SIT	Science Integration Team
TES	Threatened and Endangered Species
UCRB	Upper Columbia River Basin EIS Planning/Management Area
USDA	United States Department of Agriculture
USDI	United States Department of Interior
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

Metric Conversion

Mile (mi)=1.61 Kilometers (km)

Kilometer (km)=.62 Miles (mi)

Square Kilometers (km^2)=.39 Square Miles (mi^2)

Centimeter (cm)=.3937 Inches (in)

Meter (m)=3.28 Feet (ft)

Hectare (ha)=10,000 Square Meters (m^2)

Hectare (ha)=2.47 Acres (ac)

Acre (ac)=43,560 Square Feet (ft^2)

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Quigley, Thomas M.; Arbelbide, Sylvia J., tech. eds. 1997. An assessment of ecosystem components in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 4 vol. (Quigley, Thomas M., tech. ed.; The Interior Columbia Basin Ecosystem Management Project: Scientific Assessment).

This paper provides detailed information about current conditions and trends for the biophysical and social systems within the basin. Social and economic conditions within the assessment area differ considerably depending to a great extent on population, diversity of employment opportunities, and changing demographics. This information can be used by land managers to develop broad management goals and priorities and provides the context for decisions specific to smaller geographic areas.

Keywords: Columbia basin, biophysical systems, social systems, ecosystem.

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