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# Historical and Current Forest Landscapes of Eastern Oregon and Washington.
## Part I: Vegetation Pattern and Insect and Disease Hazards

John F. Lehmkuhl, Paul F. Hessburg, Richard L. Everett, Mark H. Huff, and Roger D. Ottmar



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# Historical and Current Forest Landscapes of Eastern Oregon and Washington. Part I: Vegetation Pattern and Insect and Disease Hazards

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From Volume III: Assessment

Paul F. Hessburg, Science Team Leader and Technical Editor

## Eastside Forest Ecosystem Health Assessment

Richard L. Everett, Assessment Team Leader

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# ABSTRACT

**Lehmkuhl, J.F.; Hessburg, P.F.; Everett, R.L.; Huff, M.H.; Ottmar, R.D. 1994.** Historical and current forest landscapes of eastern Oregon and Washington. Part I: vegetation pattern and insect and disease hazard. PNW-GTR-328. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 88 p. (Everett, Richard L.; team leader; Eastside forest ecosystem health assessment; Hessburg, Paul F., science team leader and tech. ed., Volume III: assessment.)

We analyzed historical and current vegetation composition and structure in 49 sample watersheds, primarily on National Forests, within six river basins in eastern Oregon and Washington. Vegetation patterns were mapped from aerial photographs taken from 1932 to 1959, and from 1985 to 1992. We described vegetation attributes, landscape patterns, the range of historical variability, scales of change, and disturbance hazards. Forest cover increased eight percent in three river basins, but remained relatively unchanged in the other basins. Forests became more dense in vertical and horizontal canopy structure as understory cover increased with regeneration, of mostly shade-tolerant species. The distribution of forest age classes and structure has changed, with smaller area in early-seral and old forest stages and greater area in multiple-canopy young and mature stands. The percentage of visible dead trees increased in all river. basins. Landscape pattern has become more diverse and fragmented over time in five of the six river basins. Insect and disease hazards changed little, usually < 10 percent, at the river basin scale because there was considerable variation at the watershed scale, where large changes in hazards were common.

**Keywords:** Historical vegetation, landscape pattern, insect and disease hazard, range of variation, scale, forest health, disturbance, fire suppression, Oregon, Washington, Cascades, Blue Mountains.

# Contents

# INTRODUCTION

The health of forested ecosystems in eastern Oregon and Washington has been the subject of concern in recent years (Gast and others 1991). Land-use practices over the last 100 years have altered the natural disturbance regime and reduced ecosystem resistance to disturbances. Fire suppression, timber harvest, and livestock grazing are among the management practices that have contributed to changes in ecosystem character that are conducive to insect outbreaks and severe wildfires (Agee 1993, Gast and others 1991, Hessburg and others 1993, Martin and others 1976) (fig. 1). Other potentially negative effects of ecosystem change include local extinction of wildlife and native plants, and deterioration of ecosystem health (Agee 1993). These conditions are not pervasive, however, and some forests remain healthy and productive (Gast and others 1991).

Few scientific data describing current vegetation composition, structure, and landscape pattern can be used to assess the extent of the problem and the associated insect, disease, and fire hazards. Moreover, few data describe the historical scale and range of variation in landscape attributes and disturbance regimes. Scale and range of variation are key reference points for judging the scope and direction of change and for guiding ecosystem management (Risbrudt 1992). Research to acquire this information is guided by hypotheses or questions about the roles of fire, insects, diseases, and other disturbances in ecosystems.

Fire has been critical to maintaining ecological diversity (Agee 1981, 1990; Hall 1976). The ecological characteristics of a broad range of eastern Washington and Oregon terrestrial communities from dry sagebrush to mesic high-elevation subalpine environments are closely interwoven with recurring fires (Hopkins and Kovalchik 1983, Johnson and Clausnitzer 1983, Johnson and Simon 1987, Williams and Lillybridge 1983, Williams and others 1990). Variables influencing fire and its interactions with biotic and abiotic factors are so numerous and complex that no two fires could be duplicated in their characteristics and effects. Moreover, variability is an intrinsic and vital characteristic of ecosystems in eastern Washington and Oregon, and fire is crucial to maintaining that natural complexity.

Fire suppression since the turn of the century has resulted in disruption of natural fire cycles, causing a decreasing frequency but increasing intensity of fires (Agee 1993, Gast and others 1991). Surface fires tend to occur in dry and warm vegetation series, such as ponderosa pine[1] and dry Douglas-fir series, at relatively frequent intervals of 3 to 35 years (see Agee 1993 for review). These low-intensity fires influence vegetation composition and structure primarily at a stand scale. Low-intensity fires generally thin understories and result in the suppression of shade-tolerant and fire-intolerant Douglas-firs and true firs, and dominance of ponderosa pines in a parklike setting. Suppression of surface fires along with selective logging of overstory dominant pines often results in a change in the composition and structure of forest stands. Where ponderosa pine is a seral dominant, composition may shift from ponderosa pine to Douglas-fir and true firs, and stand structure changes from open-canopy, parklike conditions to dense overstocked stands with multiple canopy layers (Caraher and others 1992, Gast and others 1991). Within-stand heterogeneity, or clumpiness, decreases without the variability of fire effects on ground vegetation, and with increasing dominance and filling in of canopy gaps by shade-tolerant species (Agee 1993). Where ponderosa pine is a climax species, a dense understory of young pine develops.

Stand-replacement fires historically occurred with much less frequency than surface fires, primarily in the mesic and cool Douglas-fir, grand fir, and subalpine series with moderate-to-high fire-severity regimes. Hall (1990) found a stand-replacement fire frequency of 50 to 300 years in grand fir communities in the Blue Mountains. Studies reviewed by Agee (1993) show a fire return interval from 15 to 100 years in the grand fir series and 50 to 250 years in the subalpine fir series. The effect of stand-replacement fires is a shift in stand composition and age from multicanopy midseral stands to early-successional species, such as lodgepole pine and western larch.

**[1] Scientific names for all taxa mentioned in text are given in Appendix C.**

Fire behavior varies across the landscape as a result of the interaction of weather, topography, fuel conditions, and vegetation composition and structure (fig. 2). The predicted result of high natural fire frequencies and variability at the landscape scale is a mosaic of vegetation patches, the scale of which depends on the fire-severity regime. A mosaic pattern of fire effects is especially true for areas in moderateseverity fire regimes where variable weather and environmental conditions result in a patchwork of surface and stand-replacement effects (Agee 1993). The expected result of fire suppression is a more homogenous landscape, with relatively fewer vegetation types (less area in early successional stages), larger patches at lower patch densities, and less total edge than with natural fire cycles. Timber harvest may counteract the homogenizing effects of fire suppression by fragmenting forest cover at a landscape scale (fig. 3).

The simplification of forest stands with fire suppression and removal of dominant overstory trees by selective logging also increases the probability of insect and disease outbreaks (Hessburg and others, 1993). Increasing vertical and horizontal abundance of host species in forest understory increases host foliage volume and insect dispersal pathways (Gast and others 1991; Hessburg and others, 1993). High stem densities result in more competition and stress on trees and increasing susceptibility to insect and pathogen attack. Simplification of stand structure and increasing host continuity allow for more rapid spread of pests across landscapes. These conditions in eastern Oregon and Washington have resulted in dramatic insect outbreaks and tree mortality (Gast and others 1991).

Although the problems associated with fire exclusion are well known, little has been done to reintroduce fire to restore and sustain desired ecological characteristics and to circumvent problems compounded by fire exclusion. Many scientists, managers, and lay people accept that fire is an essential component in the dynamics and sustainability of fire-dependent ecosystems of eastern Oregon and Washington. A 3- to 5-fold increase in prescribed burning has been suggested for this area to restore the ecosystems to a more healthy state. Prescribed fire, where fires have been suppressed and fuel loads are high, is risky and produces smoke, which can degrade visibility, violate current air-quality standards, and affect human health. Some of these effects run contrary to current Federal and State laws and are extremely unpopular with the public. If fire is to be reintroduced into ecosystems, fire managers, air-quality regulatory agencies, and the public will need to understand fire behavior and the tradeoffs between prescribed fire, forest health, wildfire occurrence, and air quality. This knowledge will equip society to make informed decisions about managed fire versus future catastrophic wildfire, forest health, and air quality.

Knowledge of fuel complexes within a geographic area is the foundation from which fire behavior, consumption of dead biomass, and smoke emissions can be predicted. Understanding potential fire behavior allows managers to predict change in ecological characteristics if fires were to occur and to plan fire management activities, including control measures, fuel hazard reduction, risk assessments, and restoration of desired ecosystem attributes using fire. Significant changes in vegetation composition and structure that affect potential fire behavior over large geographic areas may indicate that fire processes within ecosystems are shifting. With such shifts, fire may have different ecological effects on biotic communities and abiotic resources. If so, new fire control and fuel reduction strategies should be crafted and implemented to achieve management goals and objectives for desired future vegetative conditions.

The objectives of this assessment were to describe historical (35-50 years ago) vegetation composition, structure, and range of variation of these attributes on a representative sample of National Forest lands in eastern Oregon and Washington; to describe current vegetation composition and pattern in that same sample and determine changes from historical conditions; to assess the effect of the measured changes in vegetation pattern on insect and disease hazard, the fire fuel complex, fire behavior, smoke management, and other resources; and to examine the natural processes and management activities, such as fire suppression and logging, that may be driving observed changes in landscape pattern.

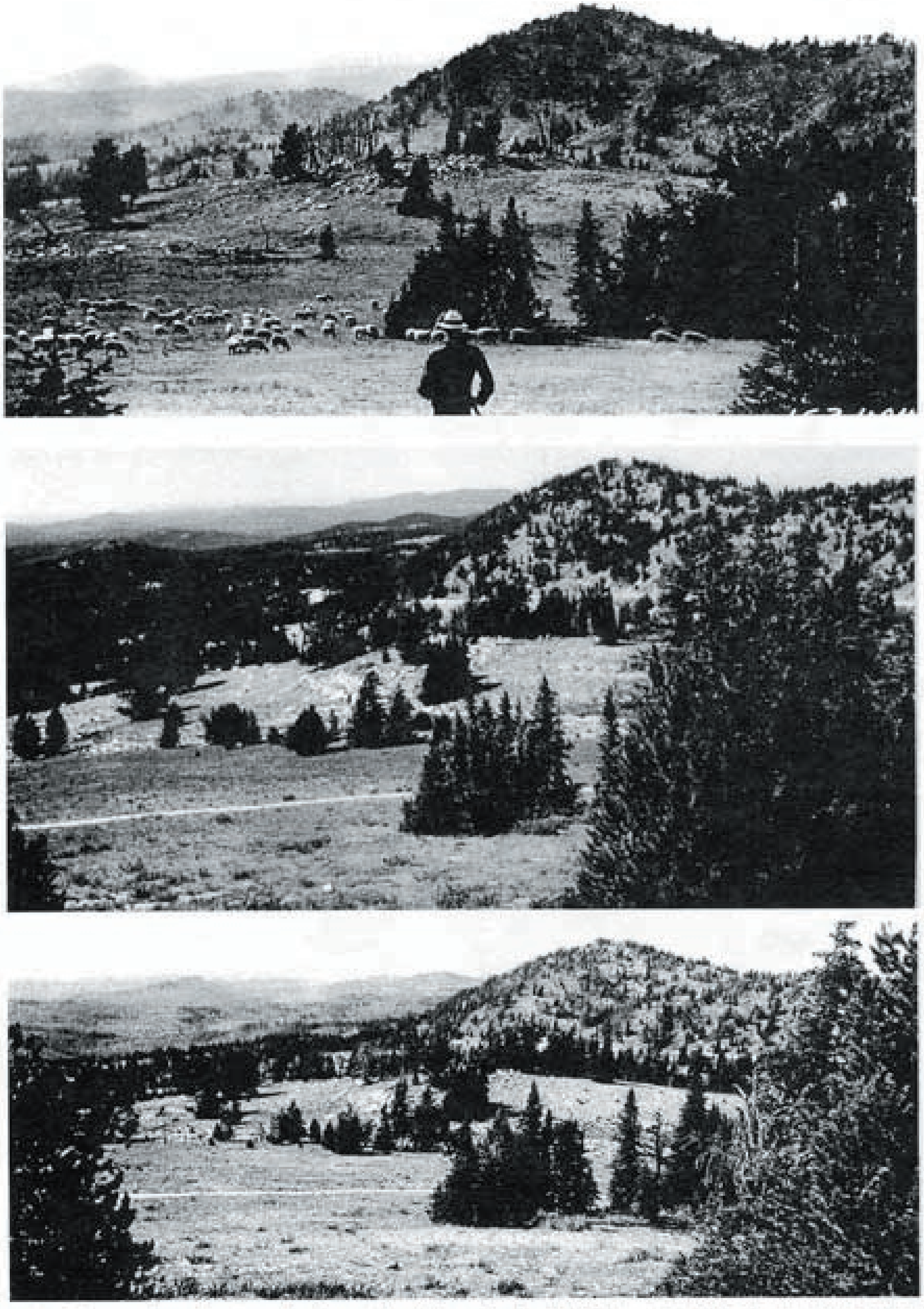

**Figure 1—Time-series photographs from the Lakes Lookout divide west of Anthony Lake, Wallowa-Whitman National Forest, Oregon. Photographs were taken looking west toward Trail Creek.** **Top—1922:** notice the open forest on the hillsides in the left background; **Middle—1974:** noteworthy changes are the greatly increased tree cover on the hills in the left background, the newly established sapling trees in the meadow and the erosion caused by excessive sheep grazing in the rocky area of the meadow in the foreground; **Bottom—1992:** Large fires in the forested hills of the left background left thousands of acres of dead standing trees; the reduction of forest cover on the butte on the right resulted from pine beetle infestations of a decade ago. Photos and information provided by Jon Skovlin, Cove, Oregon.


**Figure 2—Time-series photographs from Looking Glass overlook, Umatilla National Forest, Oregon. Top—1924:** small fires have burned unevenly up the canyons leaving burned and unburned patches, but have completely burned the canyon on the far left side. **Bottom—1992:** note that the basic pattern of vegetation has not changed, but formerly burned areas have regenerated and patches intact in 1924 are larger and more homogeneous. Photos and information provided by Jon Skovlin, Cove, Oregon.

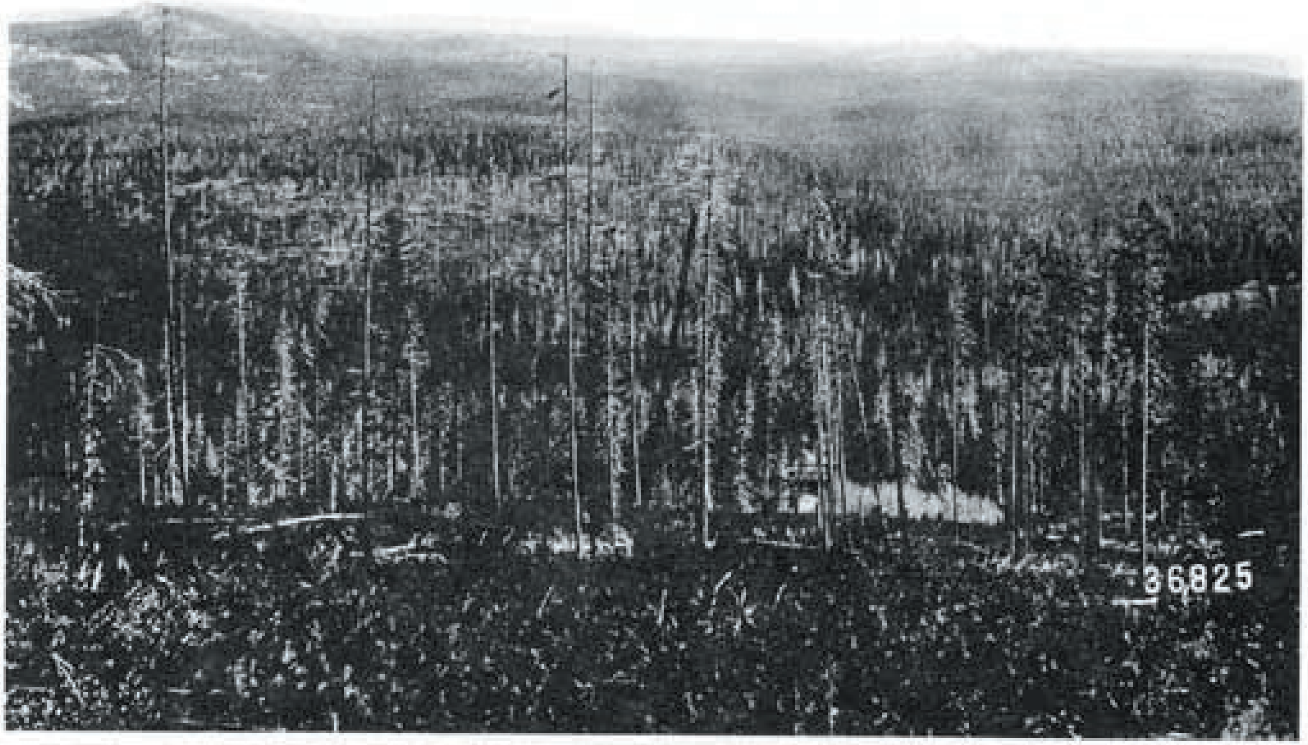


**Figure 3a—Time-series photographs of the North Fork Trail Creek, opposite Chicken Creek, between the Grande Ronde and John Day river basins, Wallowa-Whitman National Forest, Oregon. Top—1902:** areas burned during 1889 are evident in the foreground and mid-ground; ridgetops in the background are quite open; **Bottom—1967:** a new lodgepole pine stands has grown in the burned areas among the western larch that survived the fire; landscape pattern is relatively homogeneous; and ridgetop meadows have diminished.

(continued next page)

**Figure 3b—Top—1982:** salvage timber harvest of trees killed by western and mountain pine beetle begins to break up the homogeneous landscape. **Bottom—1992:** large fires in the late 1980's burned much of the middle distance and background. Photos and information provided by Jon Skovlin, Cove, Oregon.

In our assessment, we explored questions concerning changes in eastern Oregon and Washington vegetation conditions and associated changes in hazards from insects, diseases, fires, and smoke.

**Vegetation composition and stand structure:**

- Has the proportion of eastside landscapes with early successional species as overstory dominants decreased as the proportion of shade-tolerant species increased?
- How has stand vertical and horizontal structure and understory species composition changed?
- Has vegetation pattern become less diverse at the landscape scale?
- How has timber harvest affected landscape pattern?
- Have landscape-scale changes in vegetation composition and pattern been most evident at the scale of river basins or at the smaller scale of watersheds?
- What is the historical range of variation in vegetation composition and structure?

**Insect and disease hazards:**

- Have shifts in stand and landscape-scale composition and structure resulted in increased hazard from insects and diseases?
- How have changes in landscape pattern affected insect and disease dynamics?
- At what scale are changes in insect and disease hazards most evident?

**Fire and smoke management:**

- How have fuel loadings and potential fire behavior changed between historical and current landscapes?
- Have management activities influenced potential fire behavior characteristics?
- How have smoke emissions changed over time?

We examined these questions through analysis of historical and current vegetation composition and pattern, associated insect and disease hazard, fire behavior, and smoke production in sample watersheds within six river basins. These river basins were meant to represent the five forested ecoregions of eastern Oregon and Washington. Results of the vegetation and insect and disease hazard analyses are presented in this first part of the assessment report. Analyses of change in fire behavior and smoke production are presented in Part II (Huff and others, in press) of the assessment report. We discuss the possible relation between historical land use and our results, considerations for future management, and questions that can be answered by further analysis of these and supporting data.

# METHODS

## Study Areas

Each of the six river basins we sampled represented conditions in a major forested ecoregion (Omernik and Gallant 1987) of eastern Oregon and Washington (fig. 4). The Pend Oreille River basin in northeastern Washington represented the Northern Rocky Mountain ecoregion. The Methow River basin was typical of the Okanogan Highlands described by Franklin and Dyrness (1973), which was not included in the Omernik and Gallant (1987) classification, but which we believe was sufficiently distinct in geology, physiography, and environment to warrant separate analysis. The Cascades ecoregion was represented by the Wenatchee River basin and the northern portion of the Yakima River basin in the Cle Elum Ranger District. The southern part of the Yakima River basin was indicative of the northern end of the Eastern Cascades and Foothills ecoregion. That ecoregion was primarily represented by the Deschutes River basin south of the Metolius River and within the boundaries of the Deschutes National Forest. The Grande Ronde River basin represented the Blue Mountain ecoregion of northeastern Oregon and southeast Washington.

A prime consideration in choosing the Methow, Wenatchee, Yakima, and Grande Ronde basins was our desire to pair the terrestrial analysis, with the aquatic analysis of those basins (McIntosh and others 1993). One selection criterion for all basins was that a large portion of the basin should be managed by the U.S. Department of Agriculture, Forest Service, because the assessment would be confined primarily to lands within the current boundaries of National Forests. Also, similar resource data would be more available from Forest Service lands than from a mosaic of Federal and other ownerships. Finally, we calculated that six basins were the most we could analyze with the available time and resources for the project.

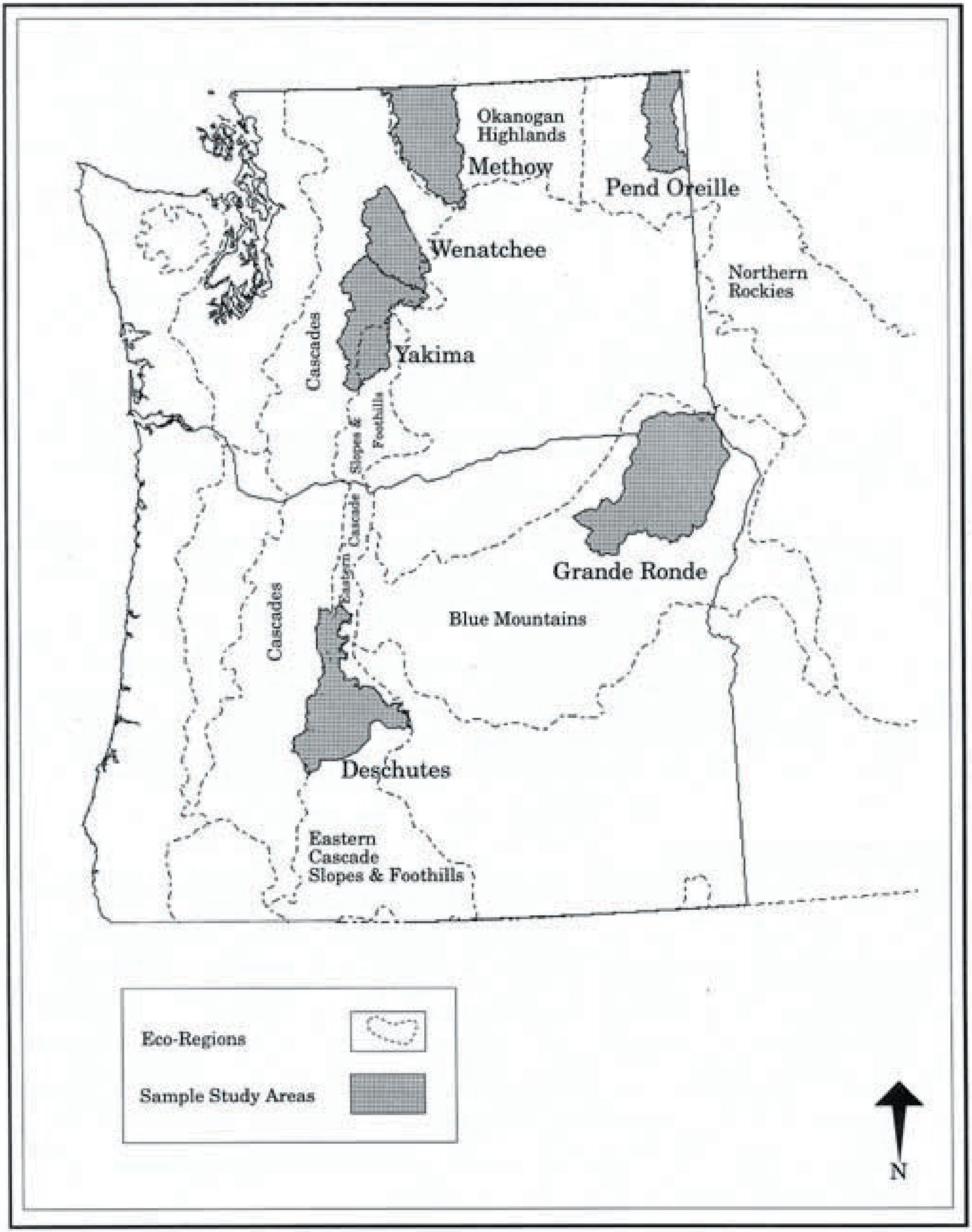


**Figure 4—Forested ecoregions of eastern Oregon and Washington and six river basins sampled for the eastside forest ecosystem health assessment during 1993.**

## Sampling Design

We divided the portion of each river basin within National Forest boundaries into sample watersheds having a mean 8875 ha (range 5100 to 13,500 ha) using existing watershed maps from National Forests, or by drawing them from National Forest maps where watershed maps were currently unavailable. We sampled watersheds instead of the area within regular-shaped sample frames, such as a square or circle, because vegetation pattern created by environmental and disturbance gradients would more closely follow the ridgeline and stream boundaries of watersheds than an arbitrary regular shape. Boundaries of vegetation patches would be less likely to be truncated in watershed samples than in circular or square sample frames placed at random over the study area, thus yielding more realistic measures of landscape pattern.

A potential problem with using sample units of differing sizes, such as watersheds, was the well-known correlation of some landscape pattern attributes and map extent (area) (O'Neill and others 1988, Turner 1989). Studies of forest pattern in western Washington, however, have shown that sample estimates of landscape attributes change asymptotically rather than linearly. Lehmkuhl and Raphael (1993) found most landscape pattern variables differed significantly when map extent increased from 2000 ha to 3250 ha around fixed locations, but few variables differed in value between 3250-ha and 7325-ha landscapes. We believe that sample watersheds of about 8000 ha would result in little or no bias from different-sized sample units.

We used stratified random sampling to select watersheds within river basins for analysis. Each river basin was stratified into two to eight subbasins, depending on basin area, to distribute samples evenly across the basin. Sample watersheds were allocated randomly within subbasins to sample 25 percent of the watersheds and 25 percent of the area in each subbasin, which we estimated would yield a highly representative sample and was feasible with project resources. We initially selected a random 25-percent sample of the watersheds in subbasins, then selected an additional random sample of watersheds if the initial sample area was < 25 percent of the subbasin area. In the event we were unable to process all sample watersheds for this report, we randomly designated first-priority watersheds within each subbasin (figs. 5-10) that yielded about a 15-percent sample. An assessment of landscape change in these first-priority watersheds is presented in this report; the other sample watersheds were mapped and will be analyzed subsequently.

## Vegetation Mapping

Vegetation, mapping required high-quality map data for both current and historical periods. The project assignment dictated using existing data where available, but the data had to be of sufficient quality for a credible scientific assessment. We set mapping standards to evaluate the quality of existing vegetation datasets: vegetation units were mapped at a minimum size of 4 ha; vegetation patches were defined by ecological attributes of patch composition and structure that were critical for assessment of fire, insect, and disease risk (for example, multiple canopy layers); vegetation patches were described by multiple attributes of composition and structure, that is, not one or two descriptive names like "old growth" or "Douglas-fir large sawtimber," so .attributes could be used independently or in combination for analyses of change in landscape pattern, fire hazard, and insect and disease hazard and for later analyses of dynamics; vegetation units were mapped for both current and historical periods by using the same standards and attributes of patch composition and structure; map data verified in the field were preferred, but we would accept expert opinion where necessary to complete the project; current and historical map data were available for all study areas no later than January 31, 1993, and preferably sooner.

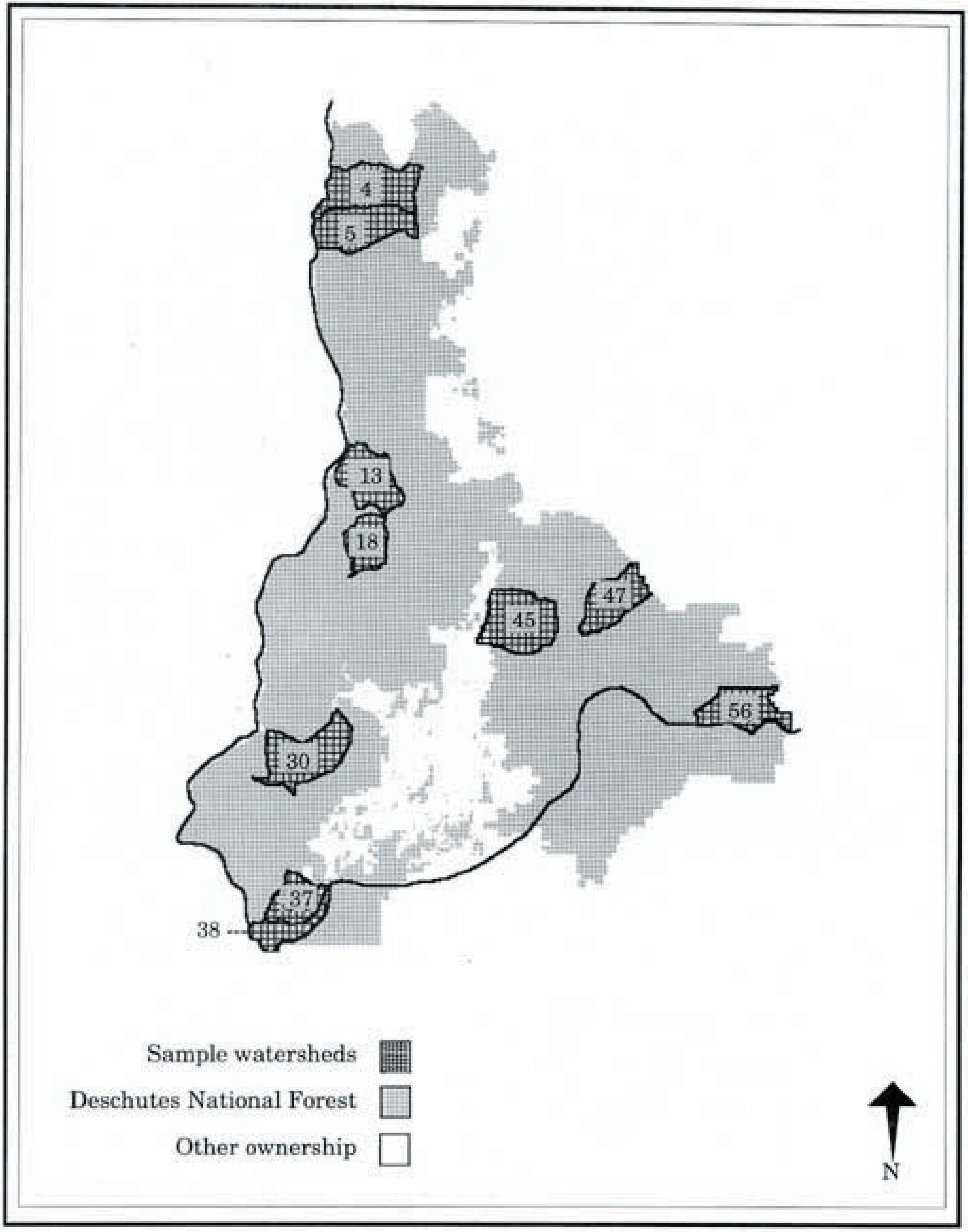


**Figure 5—Watersheds on National Forest and other ownerships sampled for the eastside forest ecosystem health assessment in the Deschutes River basin, Oregon, 1993.**

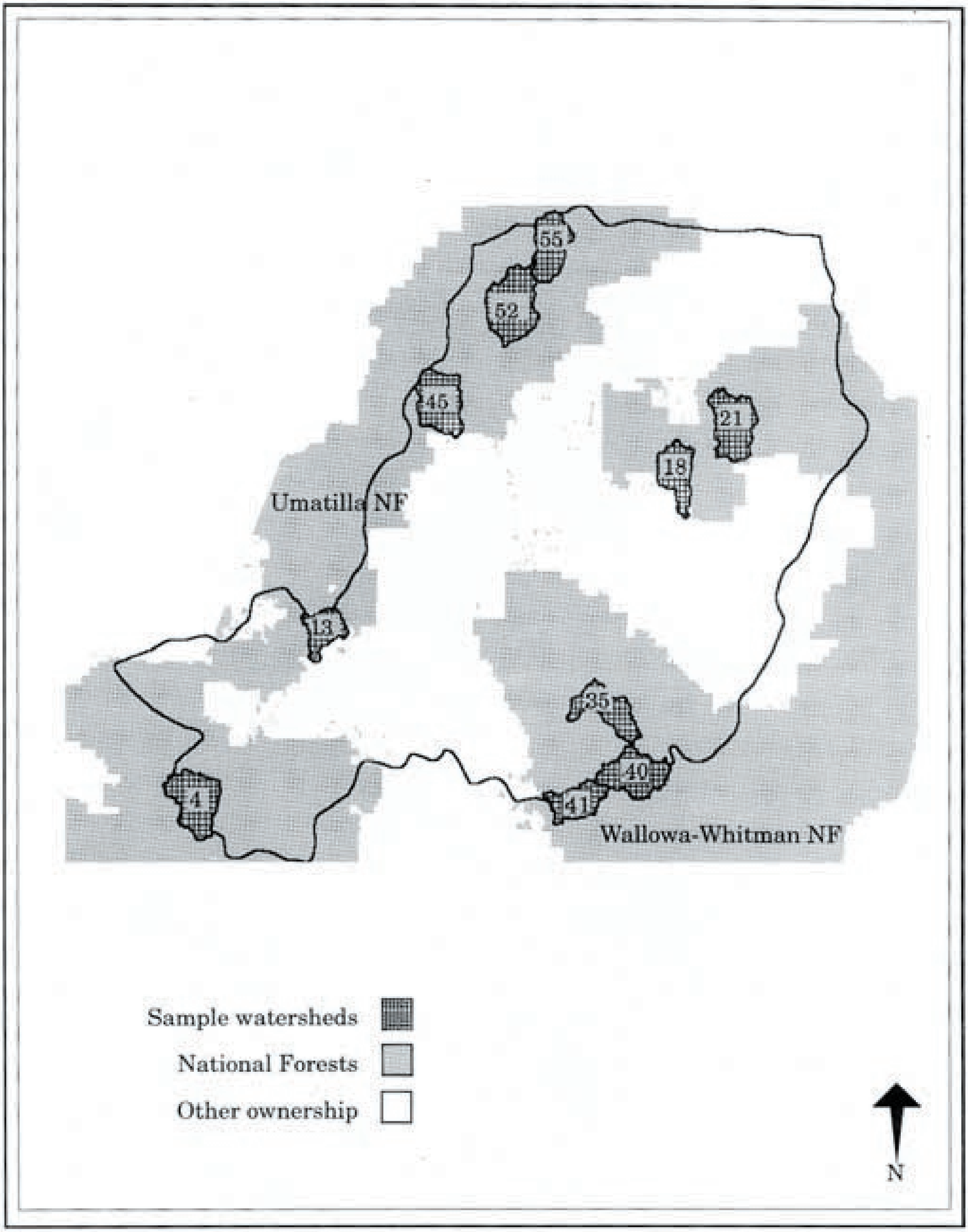


**Figure 6—Watersheds on National Forest and other ownerships sampled for the eastside forest ecosystem health assessment in the Grande Ronde River basin, Oregon, 1993.**

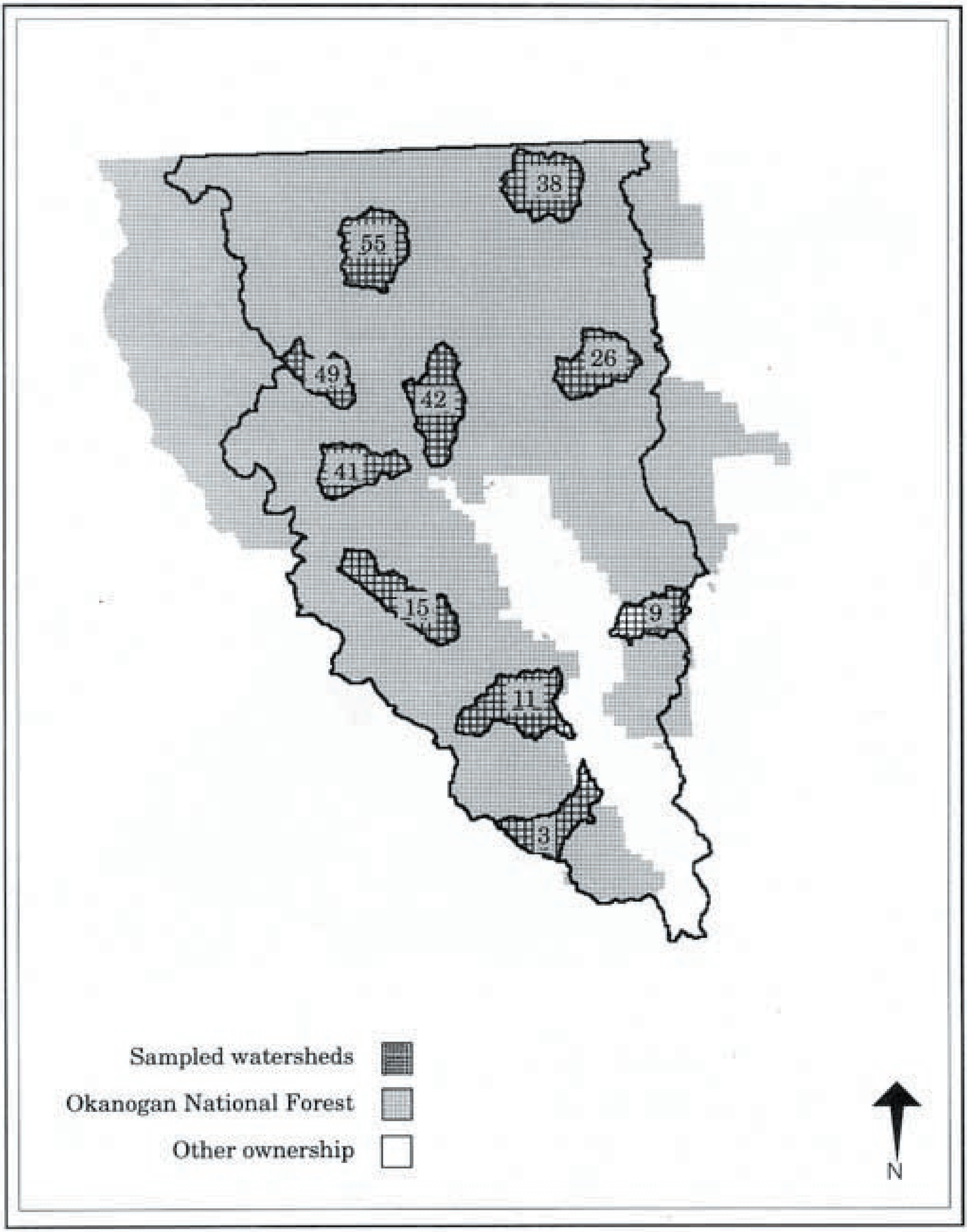


**Figure 7—Watersheds on National Forest and other ownerships sampled for the eastside forest ecosystem health assessment in the Methow River basin, Washington, 1993.**

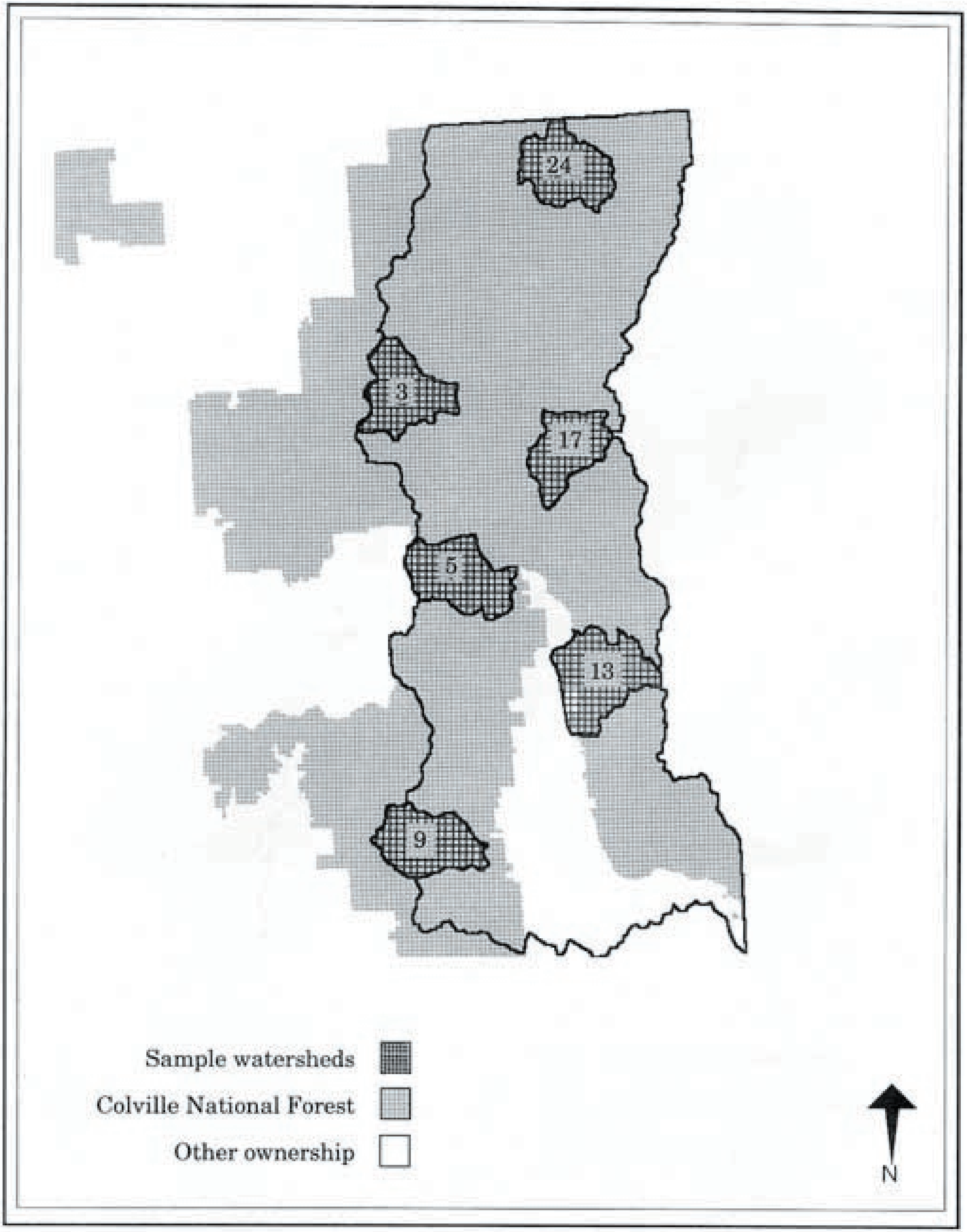


**Figure 8—Watersheds on National Forest and other ownerships sampled for the eastside forest ecosystem health assessment in the Pend Oreille River basin, Washington, 1993.**

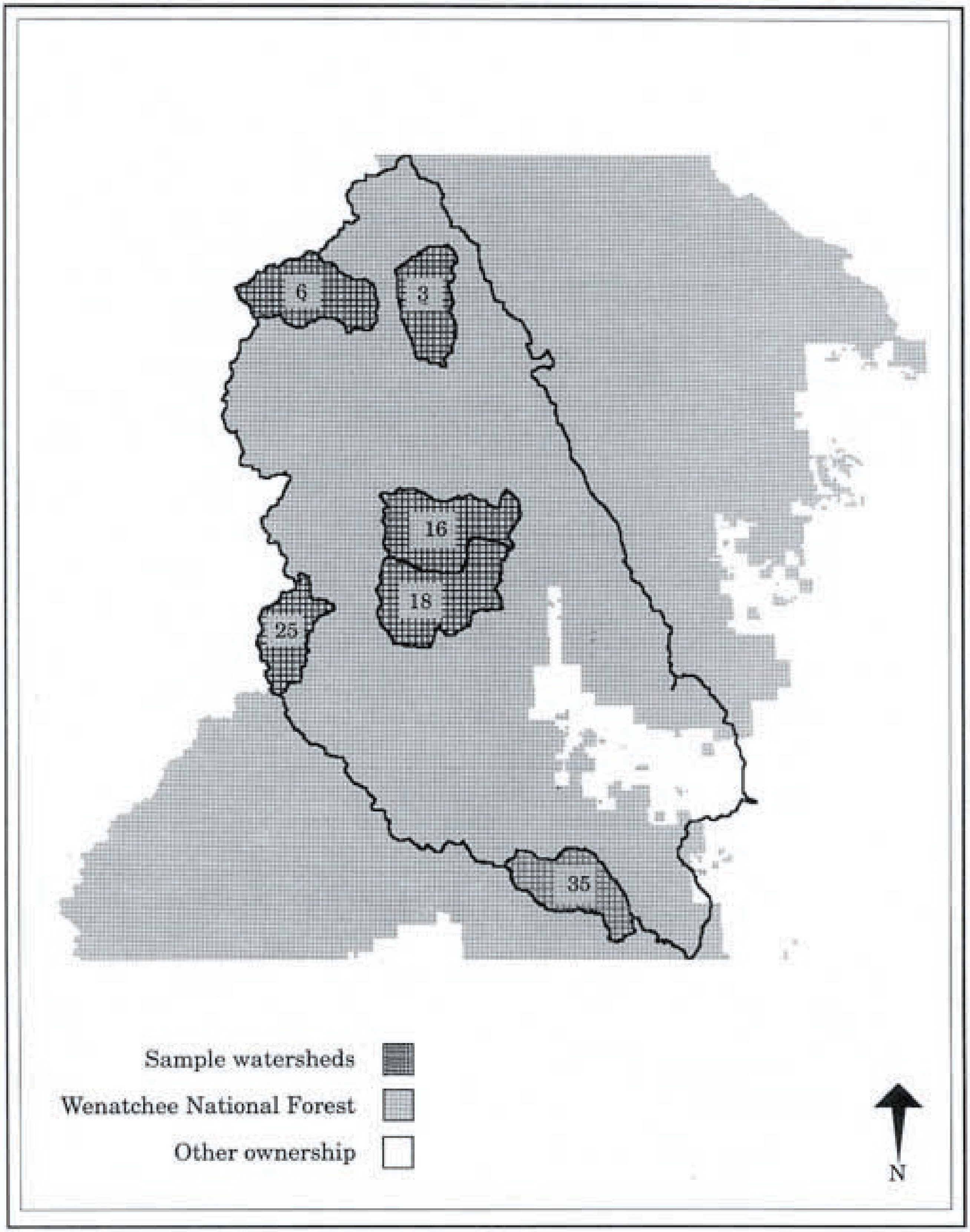


**Figure 9—Watersheds on National Forest and other ownerships sampled for the eastside forest ecosystem health assessment in the Wenatchee River basin, Washington, 1993.**

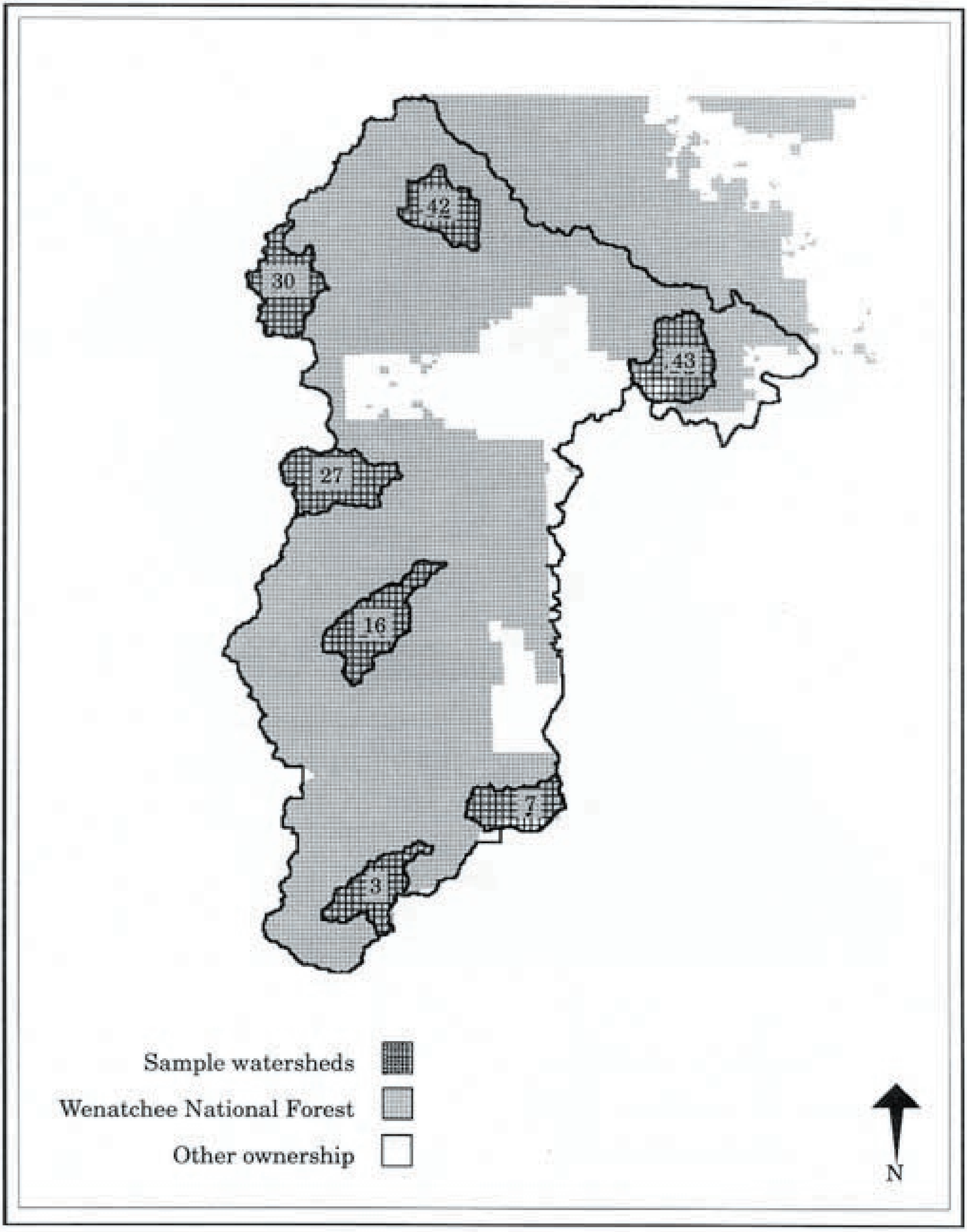


Figure 10—Watersheds on National Forest and other ownerships sampled for the eastside forest ecosystem health assessment in the Yakima River basin, Washington, 1993.

Project personnel contacted National Forests, the Pacific Northwest Forest Service Regional Office, and other agencies to determine what data were available that met our criteria. We had hoped to use the National Forests' Pacific Meridian (PMR) vegetation data base to assess current vegetation conditions; however, PMR data were available for only one Forest and their accuracy were not yet verified. However, current vegetation maps based on aerial photo interpretation that met our criteria were available for the Colville, Wallowa-Whitman, and Umatilla National Forests. We used these data for assessing current vegetation on a portion of the Pend Oreille River basin and all of the Grande Ronde basin.

Maps showing current vegetation for the other four river basins on the Okanogan, Wenatchee, and Deschutes National Forests either did not exist for the entire Forest, were not current, were not consistent with our mapping standards, or varied in vegetation mapping criteria. These sources were not suitable for our assessment, so we assembled mapping teams of National Forest personnel to create current vegetation maps by using recent aerial photography and orthophotographs.

We had intended to map historical vegetation from archived aerial photographs taken during the 1930s and 1940s. We found photographs of that vintage for many of the sample watersheds; but we had to use some 1950-era photographs in a few watersheds where earlier photography was unavailable (table 1). High-quality timber-type maps from that same period were being digitized by the Forest Service Geometronics group in Portland, and we investigated using them to save time and money. We decided not to use the timber-type maps for several reasons: vegetation units were delineated by species and stand structure on the basis of commercial timber types and stand structure important for timber production, not by ecological criteria; stand attributes did not include sufficient information on stand structure important to forest health issues (for example, multiple canopy layers); we would have to map current vegetation under the same inappropriate criteria or map by our preferred attributes and then contend with historical and current vegetation mapped by different criteria; maps were done by counties during different years and possibly different mapping criteria, thus making the assembly and edge matching of county maps to create watershed maps difficult; and digitized maps for all the river basins would not be available until the summer of 1993.

In light of these difficulties, teams that were mapping current vegetation also mapped historical vegetation. Using teams would yield high-quality data that were timely and consistent across the temporal and spatial scales of analysis. We were not able to field-verify maps, so photo interpreters with field experience and expert knowledge of local conditions were assigned to teams. Without field verification, maps were to be used only for research associated with this assessment and not for management activities such as forest or project planning. Recent stand exams were used to validate photo interpretation when exams were available.

Quality control of map data was a high priority. We held a two day workshop with mapping crews to standardize criteria for delineating vegetation patches, clarify mapping procedures, and other data collection and submission procedures: Two skilled photo-interpreters visited each mapping crew weekly during the first month of mapping to ensure consistent, high-quality results from all crews. Crew members on each Forest were assigned to map both current and historical vegetation of a particular watershed to minimize variability associated with using several photo-interpreters.

Vegetation was mapped as distinct patches not less than 4 ha, delineated on the basis of homogeneity of vegetation composition and structure. The standard procedure for mapping vegetation was first to delineate patches on aerial photographs with the aid of a stereoscope, and then to transfer the mapped polygons to mylar overlays on geo-referenced orthophotographs. Manuscripting rules for map preparation were established to ensure consistent high-quality maps. Mylar map quads of sample watersheds were digitally scanned, edited, and edge-matched by using the LT + software, and then entered into the ARC/ INFO geographic information system (GIS) software. Composition and structural attributes of vegetation patches (table 2) were interpreted from stereo-photo interpretations and recorded on forms for entry as separate data files that were later merged with the digitized maps in GIS.

**Table 1-Dates of historical and current aerial photography used to map vegetation pattern in 6 river basins in eastern Oregon and Washington for the eastside forest ecosystem health assessment**

| River basin | Watershed number | Historical photo year | Current photo year |
|---|---|---|---|
| Deschutes | 4 | 1959 | 1991 |
| | 5 | 1959 | 1991 |
| | 13 | 1959 | 1991 |
| | 18 | 1959 | 1991 |
| | 30 | 1959 | 1991 |
| | 37 | 1959 | 1991 |
| | 38 | 1959 | 1991 |
| | 45 | 1943 | 1991 |
| | 47 | 1943 | 1991 |
| | 56 | 1943 | 1991 |
| Grande Ronde | 4 | 1938 | 1987 |
| | 13 | 1938 | 1987 |
| | 18 | 1948 | 1987 |
| | 21 | 1948 | 1987 |
| | 35 | 1955 | 1987 |
| | 40 | 1955 | 1987 |
| | 41 | 1955 | 1987 |
| | 45 | 1938 | 1987 |
| | 52 | 1938 | 1987 |
| | 55 | 1938 | 1987 |
| Methow | 3 | 1956 | 1992 |
| | 9 | 1954 | 1992 |
| | 11 | 1956 | 1992 |
| | 15 | 1955 | 1992 |
| | 26 | 1956 | 1992 |
| | 38 | 1955 | 1981 |
| | 41 | 1956 | 1992 |
| | 42 | 1956 | 1992 |
| | 49 | 1956 | 1981 |
| | 55 | 1956 | 1981 |
| Pend Oreille | 3 | 1935 | 1985 |
| | 5 | 1935 | 1985 |
| | 9 | 1935 | 1985 |
| | 13 | 1932 | 1985 |
| | 17 | 1955 | 1985 |
| | 24 | 1934 | 1986 |
| Wenatchee | All | 1949 | 1992 |
| Yakima | 3 | 1949 | 1992 |
| | 7 | 1949 | 1992 |
| | 16 | 1949 | 1992 |
| | 27 | 1949 | 1992 |
| | 30 | 1949 | 1992 |
| | 42 | 1955 | 1992 |
| | 43 | 1942 | 1992 |

**Table 2—Attributes of forest and nonforest stands interpreted from aerial photographs for the eastside forest ecosystem health assessment of eastern Oregon and Washington, 1993.**

**Nonforest type:** A vegetation patch was considered nonforested when total canopy closure was < 10-percent. Categories were: rock, water, wet meadow or marsh, alpine meadow, dry meadow or grassland, grass/forb after logging, shrub, bare ground (burned or logged), bare ground (slumps erosion), agriculture, and urban.

**Overstory and understory species:** Dominant overstory and understory species were recorded. Species were later grouped to maximize reliability of photo interpretation and to minimize the number of codes by grouping uncommon species or species with similar shade-tolerance.

The primary overstory species or species groups were ponderosa pine, western larch, lodgepole pine, Douglas-fir, grand fir/white fir, Pacific silver fir, subalpine fir/Engelmann spruce, western hemlock/ western redcedar, mountain hemlock, whitebark pine/subalpine larch, western white pine/sugar pine, hardwoods, or juniper.

Primary understory species and groups were ponderosa pine, western larch/ lodgepole pine, Douglas-fir/ grand fir/white fir/Pacific silver fir, western hemlock/western red cedar, mountain hemlock, subalpine fir/Engelmann spruce, whitebark pine/subalpine larch, hardwoods, juniper, grass/forb, shrub, and bare ground.

**Overstory and understory tree size classes:** Trees sizes were estimated as: seedling and saplings (<13 cm [<5 in] d.b.h.); poles (13-23 cm [5-8.9 in] d.b.h.); small sawtimber (24-41 cm [915.9 in] d.b.h.); medium to large sawtimber (41-64 cm [16-25 in] d.b.h.; and mature to overmature sawtimber (>64 cm [25 in] d.b.h.).

**Total canopy closure and overstory canopy closure**: Closure was estimated to the nearest 10-percent

**Canopy layers:** Estimated as 1, 2, or > 2 layers.

**Tree density:** Density was not estimated from aerial photographs, but was recorded from field data (stocking surveys, timber stand exams) where available.

**Clumpiness:** Horizontal patchiness of overstory tree cover. Stands were rated as: (1) Clumpy - yes or no; (2) If clumpy, clump distribution is widely scattered, moderately dense, or dense; and (3) average clump size is <0.4 ha (1 acre), 0.4-2 ha (1-5 acres), or >2 ha (5 acres) but <4 ha (10 acres).

**Crown differentiation:** Degree of differentiation among overstory tree crowns. Estimated as low (< 30-percent difference), medium (30-100-percent difference), or high (> 100-percent difference).

**Riparian or wetland:** Indicated whether the polygon was riparian or wetland; used with overstory vegetation to estimate forested and nonforested wetland area.

**Logging entry:** Visible logging was interpreted as no logging apparent, regeneration harvested (clearcut, shelterwood, seedtree), selection harvested (partial cut, selective harvest), thinned (commercial or pre-commercial), or patch clearcut (clearcut patches were <4 ha (10 acres). If patch clearcut, we estimated the percentage of the stand area in clearcut patches to the nearest 10-percent.

**Dead trees and snags:** Dead tree and snag abundance was estimated as none apparent, < 10% of trees dead, 10 to 39-percent of trees dead, 40 to 70-percent trees dead, and > 70-percent trees dead.

## Vegetation and Landscape Pattern Analysis

Vegetation maps and patch attributes derived by photo-interpretation formed the basic data set from which all subsequent analyses were done. Patches were described by attributes of composition and structure, and grouped by vegetation types developed from overstory species composition and stand structural classes. Structural classes were defined as:

*seedling-sapling-pole* (SSP)—one canopy layer, seedling, sapling, or pole trees (< 23 cm diameter at breast height [d.b.h.]);

*young*—two canopy layers, overstory pole or young trees (13-40 cm d.b.h.), understory seedlings, saplings, or poles (<23 cm d.b.h.);

*mature*—≥ two canopy layers, overstory mature trees (41-64 cm d.b.h.), understory trees young or smaller (< 40 cm d.b.h.);

*mature parklike*—one or two canopy layers, mature to old overstory trees (> 40 cm d.b.h.), understory trees absent or saplings (< 13 cm d.b.h.);

*old forest*—≥ two canopy layers, overstory trees larger than mature (> 64 cm d.b.h.), pole to mature understory (13-64 cm d.b.h.).

We used the percentage area in various classes of categorical attributes (that is, the percentage of the watershed with Douglas-fir overstory, mature structure class, dead tree- category, and so on) and the mean watershed value of continuous variables to describe historical and current conditions in a watershed. The change from historical to current conditions in a watershed was estimated as the difference between historical and current values, not as the percentage change from historical conditions. Means, standard errors of the means, and confidence intervals of variables for river basins were estimated by using methods for stratified random sampling (Cochran 1977) with watershed sample units. Significant ($P \leq 0.10$) change from historical to current conditions was determined by examining the 90-percent confidence interval around the mean difference for the river basin, which was estimated as the stratified random mean from pair-wise comparisons of watersheds. If the confidence interval included zero, no significant change was recorded.

We used the basic data set to examine changes in landscape composition and stand structure. We analyzed changes in landscape diversity and pattern by estimating size, density, and shape attributes of vegetation-type patches and indices of vegetation pattern. Indices were estimated for whole watersheds from raster versions of the vector ARC/INFO maps. Grid size in the raster-based pattern analyses was 1 ha. We used the DISPLAY program (Flather 1993) to calculate indices of diversity (Shannon-Weiner H'), dominance, and contagion (point diversity) on the scale of 1 ha (O'Neill and others 1988). The perimeter-area fractal index of patch shape complexity (O'Neill and others 1988) was estimated by regression techniques (Burrough 1986).

## Insect and Disease Hazard Analysis

Major forest insect arid disease hazards were evaluated for historical and current conditions in each watershed. Insect and disease hazard did not equate to actual occurrence because we did not do inventories. Rather, "hazard" indicated presence of susceptible host vegetation in susceptible arrangements. Insects and diseases were grouped into 12 categories for assessment. The two principal defoliators, the western spruce budworm and the Douglas-fir tussock moth, were combined to estimate a defoliator hazard rating, although the hazard variables used were most appropriate to the western spruce budworm. Hazard associated with bark beetles was assessed separately for the Douglas-fir beetle, western pine beetle, mountain pine beetle, and fir engraver. Western pine beetle hazards were type 1, hazard to mature and overmature ponderosa pine; and type 2, hazard to immature and overstocked ponderosa pine. Mountain pine beetle hazards were type 1, hazard to overstocked lodgepole pine; and type 2, hazard to immature and overstocked ponderosa pine. Dwarf mistletoe hazards were computed for mistletoes of western larch, Douglas-fir, ponderosa pine, and lodgepole pine. Root diseases were combined for a group hazard rating. Diseases included were laminated root rot, Armillaria root disease, and S-group annosum root disease. P-group annosum root disease hazard was not evaluated.

The basic procedure was to rate hazard associated with each insect or pathogen species (or group) for each forest and nonforest polygon as the sum of scores for 4 to 6 hazard variables. Site quality, a hazard variable used in all calculations, was based on the presence of host species in the overstory and understory. Host abundance, another hazard variable, was calculated by computing overstory and understory crown cover in host species. Canopy structure was factored into polygon ratings by considering the number of canopy layers and their composition. Stand density was estimated qualitatively from total canopy cover. For some beetle species, crown differentiation was an additional surrogate variable for stand density. Host age was approximated from overstory and understory size-class data. A detailed description of all procedures is in appendix A.

Continuity of host species in entire watersheds was estimated using the DISPLAY pattern-analysis software to determine host-host transition frequencies at the scale of 1 ha. The host-host transition frequency measured the number of times host cells were next to other host cells. The frequency was divided by the total number of transitions to yield an index of host species continuity ranging from 0 to 1. The index incorporated the total area and the spatial juxtaposition or fragmentation of host species area (Turner 1990). Small index values indicated a combination of low area or high fragmentation of host species patches, and high values indicated large, contiguous patches of host species. A value of 1 indicated 100 percent cover by host species.

We used some or all of these variables to rate hazard associated with each of the 12 species or species groups in each watershed and basin. Polygon scores for each variable were summed by species then weighted by the proportion of watershed area occupied by the polygon. A watershed score for each species was computed by summing the weighted polygon scores then adding the host species continuity score, if applicable.

# RESULTS

## Vegetation Change

**Forest overstory composition**—Several basins exhibited changes in total forest cover (fig. 11). Forest cover increased 8-percent ($P \leq 0.10$) during the past 50 years in the Deschutes and Grande Ronde basins, but decreased 6-percent ($P \leq 0.10$) in the Wenatchee drainage. An apparent 9-percent increase of forest area in the Pend Oreille drainage was not statistically significant; this was largely attributed to an increase from 29-percent forest cover in 1935 to 96-percent cover by 1985 in one watershed (watershed 5). This shift was accompanied by a like reduction in the area of bare ground in that watershed as vegetation recovered from a large fire.

No significant change was found in the area of forested and nonforested wetlands at the basin scale (fig. 11). A consistent trend, however, appeared in four of the basins, with 45 to 150-percent increases in forested wetland area from the past. Changes in watersheds were both positive and negative within a basin, however. About 30-percent of the sample watersheds exhibited a difference of 5 to 12-percent of total area in forested wetlands, with 40-percent of those watersheds showing declines, and 60-percent with increases in forested wetland area. Changes in nonforested wetlands were equally varied, with three basins exhibiting potential increases of 15 to 100-percent from historical area.

We found some dramatic shifts at the river basin scale in the composition of the forest overstory from early-successional species to more shade tolerant species (fig. 12a-c). Ponderosa pine decreased, by 30-percent ($P \leq 0.10$) from historical cover in the Methow basin. Compensating increases in the cover of other species were not significant, but an apparent 26-percent increase in Douglas-fir cover probably accounted for most of the change. The greatest reduction (20-50-percent) in ponderosa pine cover occurred in the dry southwestern portions of the basin, in watersheds 3, 9, and 11. Watershed 3 was unique in also displaying a 450-percent increase in Douglas-fir overstory, an 84-percent decline in lodgepole pine cover, and a 43-percent decline in ponderosa pine cover.

The Pend Oreille basin exhibited a clear shift away from early-successional ponderosa pine, western larch, and western white pine, with 53-percent increases ($P \leq 0.10$) in Douglas-fir and western hemlock cover (fig. 12a-c). Watersheds on the southern and southwestern part of the basin (watersheds 5, 9, 13) displayed large (40 to 200-percent) increases in Douglas-fir cover. Increasing cover of late-successional western hemlock was evident in three watersheds. Watersheds 3, 9, and 24 exhibited 400 to 4000-percent increases in total western hemlock cover, affecting up to 29-percent of total watershed areas. Watershed 9 had a nearly complete loss (-99-percent) of western white pine cover. Watershed 5 was also unique in exhibiting a 96-percent decline in bare ground after fire recovery that was partially accounted for by 5300-percent and 100-percent increases in early-successional lodgepole pine and western larch cover, respectively.

At the basin scale the Deschutes river basin displayed little significant change in overstory cover except for a 45-percent decrease ($P \leq 0.10$) in bare ground (fig. 12a-c), and the 8-percent increase in forest cover noted earlier. At the watershed scale, the greatest overstory change occurred in the three watersheds (45, 47, 56) east of the Deschutes River on the dry Fort Rock District. Forest cover increased 45 to 80-percent, ponderosa pine overstory area increased 35 to 400-percent, and bare ground decreased about 30-percent from historical values. The two northerly watersheds (4, 5) east of the Mount Jefferson Wilderness exhibited change opposite from the southeastern Fort Rock watersheds. Ponderosa pine area decreased there by 45 to 60-percent, and Douglas-fir area increased 10 to 17-percent, as did grass/forb cover.

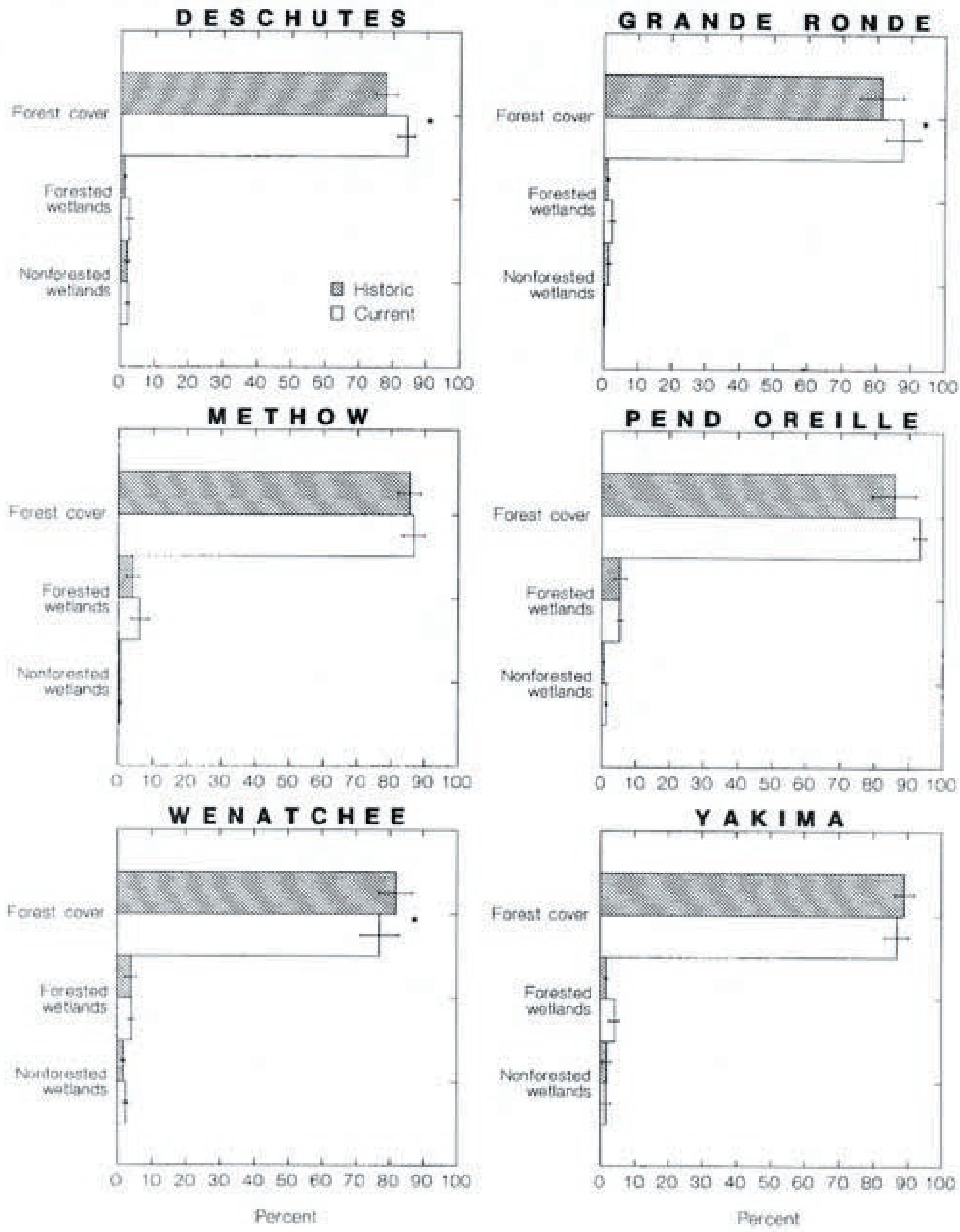


**Figure 11—Historical and current forest cover, forested wetlands, and nonforested wetland area expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences ($P \leq 0.10$) between historical and current basin conditions.

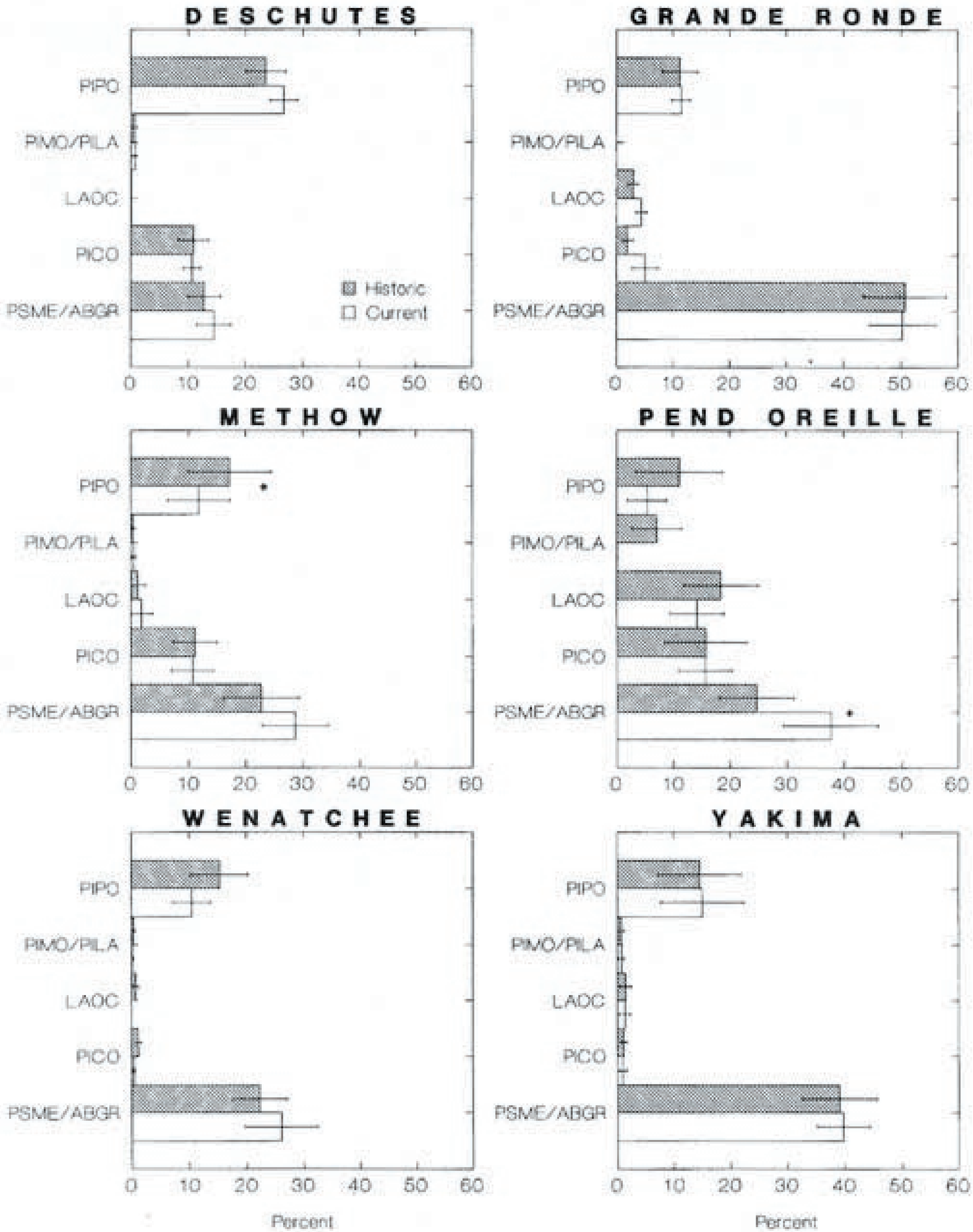


**Figure 12a—Historical and current cover by overstory dominant tree species and nonforested vegetation expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences ($P \leq 0.10$) between historical and current basin conditions. Species codes: PIPO = ponderosa pine; PIMO/PILA = western white pine or sugar pine; LAOC = western larch; PICO = lodgepole pine; PSME/ABGR = Douglas-fir, grand fir, or white fir.

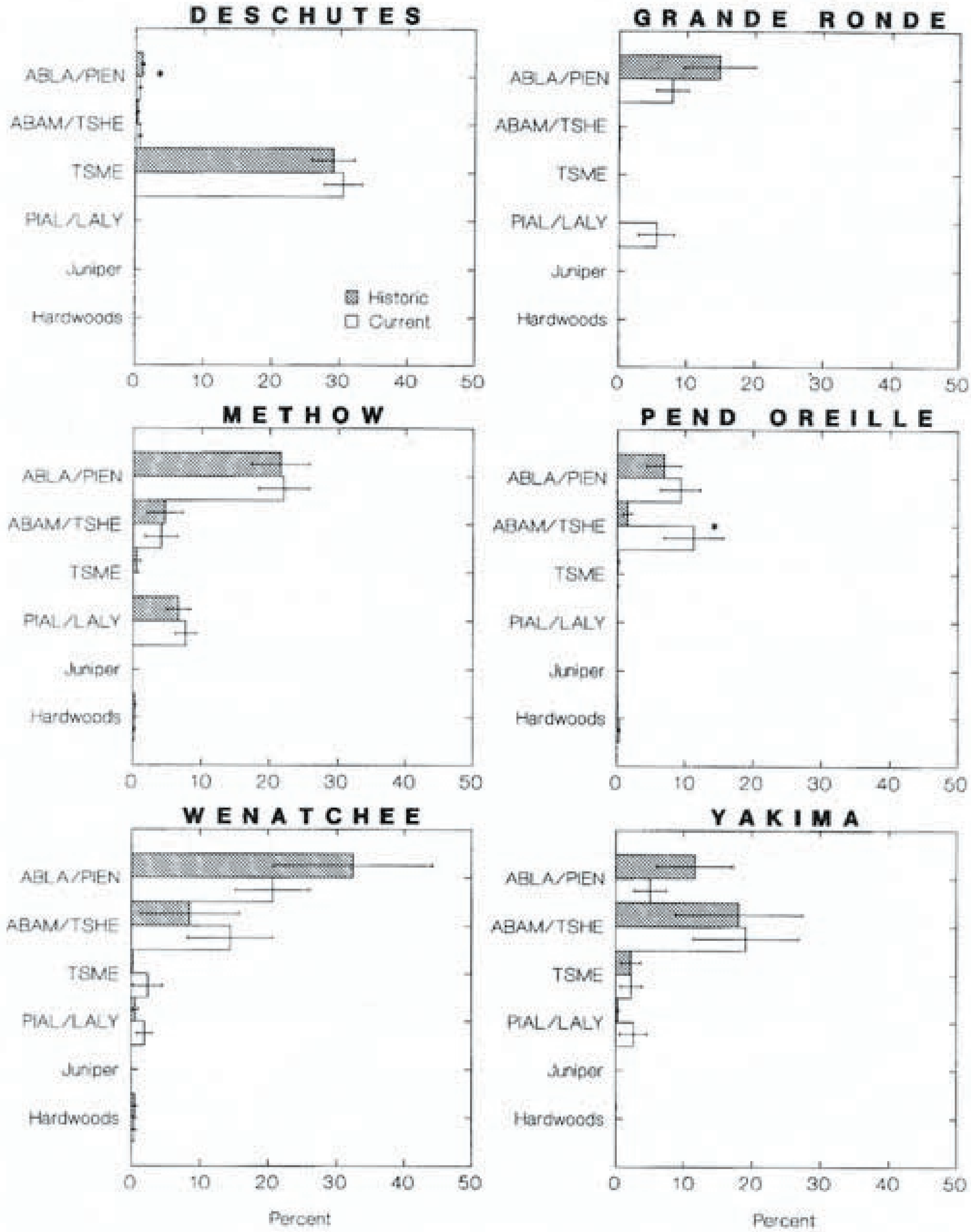


**Figure 12b—Historical and current cover by overstory dominant tree species and nonforested vegetation expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences ($P \leq 0.10$) between historical and current basin conditions. Species codes: ABLA/PIEN = subalpine fir or Engelmann spruce; ABAM/TSHE = Pacific silver fir, western hemlock, noble fir, Shasta red fir, or western redcedar; TSME = mountain hemlock; PIAL/LALY = whitebark pine or subalpine larch.

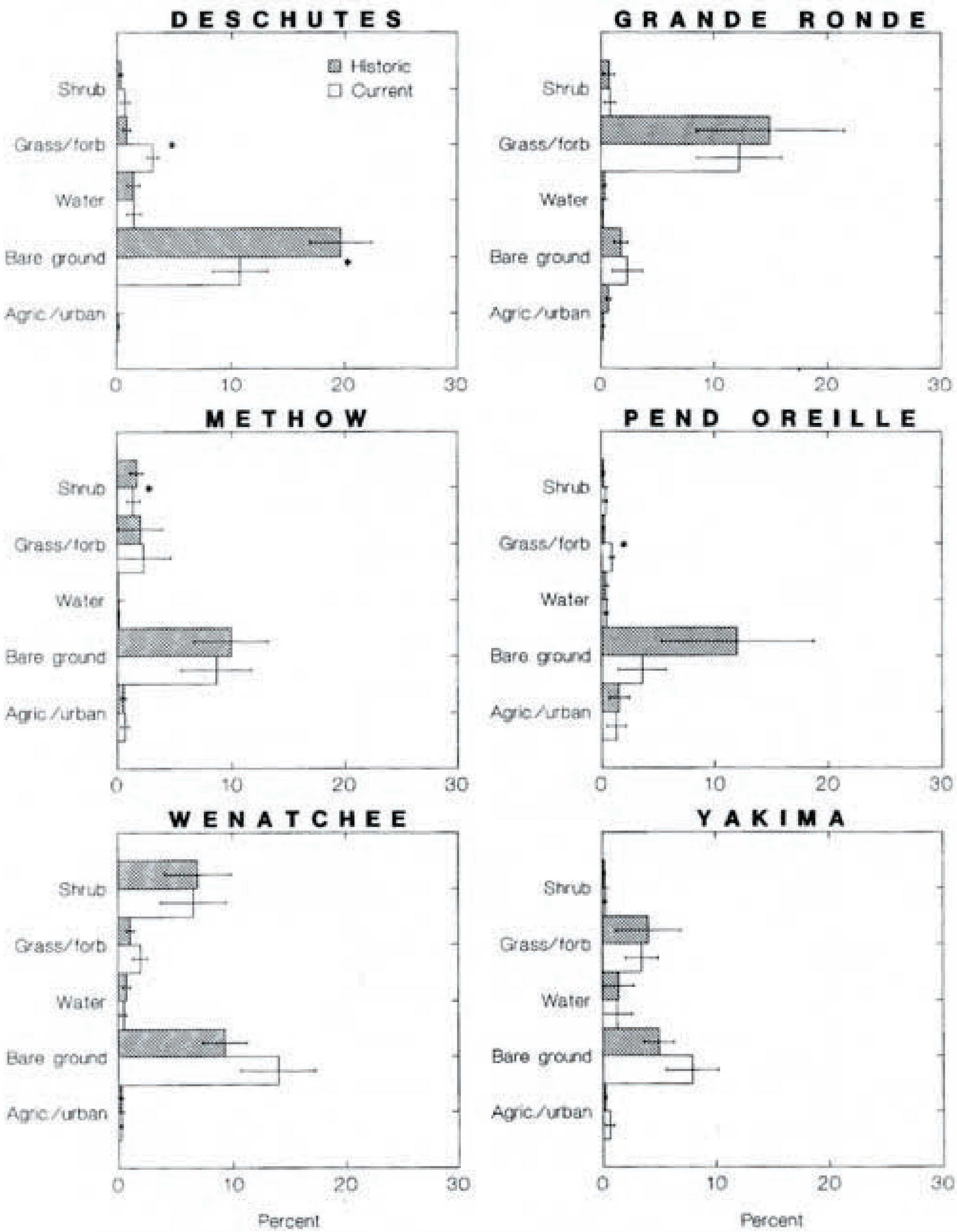


**Figure 12c—Historical and current cover by overstory dominant tree species and nonforested vegetation as a percentage of total area on National Forest lands in river basins of eastern Oregon and Washington.** Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences ($P < 0.10$) between historical and current basin conditions.

Basin-scale changes in overstory cover were not significant in the Grande Ronde (fig. 12a-c) because large changes in watersheds were both positive and negative. Three watersheds (45, 52, 55) in the northern part of the drainage on the Umatilla National Forest portion of the basin exhibited a 90-percent decrease in early-successional ponderosa pine cover and a corresponding 35 to 230-percent increases in Douglas-fir cover. Western larch cover in these watersheds also declined 80 to 100-percent.

Watersheds west of La Grande followed an opposite path with increasing area of early-successional species. Douglas-fir cover decreased 10 to 45-percent in five watersheds (4, 13, 18, 21, 41). Ponderosa pine cover concurrently increased up to 100-percent to account for 5 to 30-percent of the total watershed area in two watersheds (13, 21), and lodgepole pine increased 300-percent in another watershed (4). The shift in composition from Douglas-fir to ponderosa pine in watershed 21 was accompanied by a 32-percent decrease in grass understories from 59 to 40-percent of total area.

Watersheds in the Eagle Cap Wilderness changed uniquely. Two watersheds (35, 40) exhibited 40 to 60percent declines in historical subalpine fir cover and increases in white-bark pine area from 0 to 22 to 36-percent of total area. This change may have been a result of large fires in the 1980s.

The Wenatchee River basin exhibited no significant basin-wide change in overstory composition, because change in watersheds was highly variable. Two watersheds (16, 35) in managed forest areas had 30 to 40-percent reductions in ponderosa pine cover with concurrent increase of 30 to 50-percent in Douglas-fir. Two of the three wilderness watersheds (6, 18) changed very little in overstory composition from historical conditions.

Changes in the Yakima basin were negligible at the basin scale, but varied at the watershed scale. Four of the seven watersheds exhibited decreases in Douglas-fir and Pacific silver fir cover of 10 to 60-percent.

**Understory composition and stand structure**—We found substantial basin-wide shifts in understory composition and stand structure from open to closed stands in the Grande Ronde and Pend Oreille basins (figs. 13a-b, 14). Open grass/forb and shrub understories decreased from 90 to 100-percent ($P \leq 0.10$) from historical values in the Grande Ronde. Ponderosa pine understory increased by over 1000-percent from historical conditions ($P \leq 0.10$), while shade-tolerant Douglas-fir/grand fir increased 24-percent ($P \leq 0.10$) and subalpme fir increased 100-percent. These changes were accompanied by a marked 325-percent increase ($P \leq 0.10$) in two-layered young stands accompanied by 60 to 90-percent reductions ($P \leq 0.10$) in seedlingsapling-pole (SSP), mature parklike, and old-forest stands. These structural changes occurred with all overstory species (appendix B). Overstory canopy closure declined by 22-percent ($P \leq 0.10$) at the same time that total canopy closure did not change (fig. 15), indicating an increase in understory cover and density. Stand density also increased horizontally as shown by changes in tree distribution within stands, or stand clumpiness. Tree distribution was more dense, less scattered, and occurred in larger clumps ($P \leq 0.10$) (fig. 16).

The composition of forest understory in the Pend Oreille also shifted markedly from early successional to late-successional shade-tolerant species. The area of western hemlock uriderstory increased 250-percent ($P \leq 0.10$) from historical levels (fig. 13a-b). At higher elevations, the area in subalpine fir/Engelmann spruce understory increased nearly threefold ($P \leq 0.10$). Trends in the distribution of structural classes were not significant, but showed a decline in smaller size classes and increases in larger classes. Development of two-layered stands occurred primarily in the ponderosa pine, lodgepole pine, and subalpine fir types (appendix B), but there were slight increases in parklike stands.in all these types. All structure classes of Douglas-fir/grand fir and western hemlock increased in area. Within-stand clumpiness, or horizontal patchiness, decreased, with stands becoming more densely clumped (fig. 16). Other structural changes in the Pend Oreille basin varied among watersheds, making basin-wide assessments difficult; however, the trend among watersheds was for successional advancement with reduction in area of early seedling-saplingpole (SSP) seral stages and an increase in area of young and mature classes.

High variability among watersheds made detecting basin-wide shifts difficult, but increasing density, canopy layering, and tree size with successional advancement were evident. In two northern watersheds (3, 5) in the Deschutes basin, understory ponderosa pine declined by about 65-percent, but Douglas-fir increased 30 to 90-percent. In the eastern dry watersheds where Douglas-fir is largely absent, ponderosa pine in the understory increased dramatically from 100 to 4500-percent, while grass, shrubs, and bare understory conditions decreased. Along with these changes in understory, a shift occurred from SSP to two-layered mature forest ($P \leq 0.10$) (fig. 14). The SSP ponderosa pine stands declined 40-percent and twolayered young and mature stand area increased about 55-percent (appendix B). The area of two-layered mature lodgepole pine stands increased markedly from 0.02-percent of the watersheds to about 1-percent. Mountain hemlock stands advanced successionally from young to mature classes, but also with an increase in parklike conditions. Infilling of canopy gaps and canopy layering was also indicated by the increasing density and differentiation of canopies as shown by greater stand clumpiness ($P \leq 0.10$) (fig. 15) with more dense and larger clumps ($P \leq 0.10$) (figs. 16, 17), and greater crown differentiation (fig. 18).

The primary understory change in the Methow basin was the loss of mature parklike and old-forest structural classes ($P \leq 0.10$) with an increase in young forest (fig. 14). Successional advance was indicated by a 28-percent increase ($P \leq 0.10$) in the area of stands with subalpine fir/Engelmann spruce understories (fig. 13a). Parklike and old stands of ponderosa pine decreased, and two-layered young stands increased (appendix B). Understory ponderosa pine increased by 350-percent in one low-elevation watershed at the south end of the basin (3), similar to trends in the Grande Ronde and Deschutes basins. Lodgepole pine stands also exhibited seral advancement with declines in the SSP stands and more two-layered young stands. Area of young and mature two-layered Douglas-fir/grand fir stands increased by 70-percent, and parklike and old stands declined 35 to 40-percent. The structure of Pacific silver fir/,western hemlock stands exhibited a definite shift to old forest conditions. Increasing understory density was associated with apparent declines in shrub, hardwood, and grass understories (fig. 13b).

Structural change in the Wenatchee basin was shown by an 18-percent decline ($P \leq 0.10$) in young stands, with an apparent 26-percent increase in old forests (fig. 14). Early successional ponderosa pine and western larch understories decreased, Douglas-fir/grand fir/Pacific silver fir and western hemlock understones increased by 80 to 100-percent. In contrast to increasing development of understories, grass/forb understories increased from historical times in the Wenatchee basin ($P \leq 0.10$), most likely in association with increases in parklike ponderosa pine, Douglas-fir, Pacific silver fir, and mountain hemlock types (appendix B). Seral advance to mature and old stages was evident in Pacific silver fir, mountain hemlock, and white-bark pine/subalpine larch types.

Change in stand structure in the Yakima basin was characterized by a 50-percent increase in the SSP stage, an 80-percent reduction in old forest area, and a 79-percent increase in bare ground (fig. 14). Most of the decline in old and mature classes was in the ponderosa pine, Douglas-fir, and Pacific silver fir types (appendix B). These changes were the likely result of a 15-percent increase in logging activity, mainly clearcut logging (fig. 19). Development of forest understories and stand layering was indicated by large increases in the area of two-story young Douglas-fir, Pacific silver fir/western hemlock, and white-bark pine/subalpine larch stands (appendix B), and by an increase in highly differentiated crowns ($P \leq 0.10$) (fig. 18).

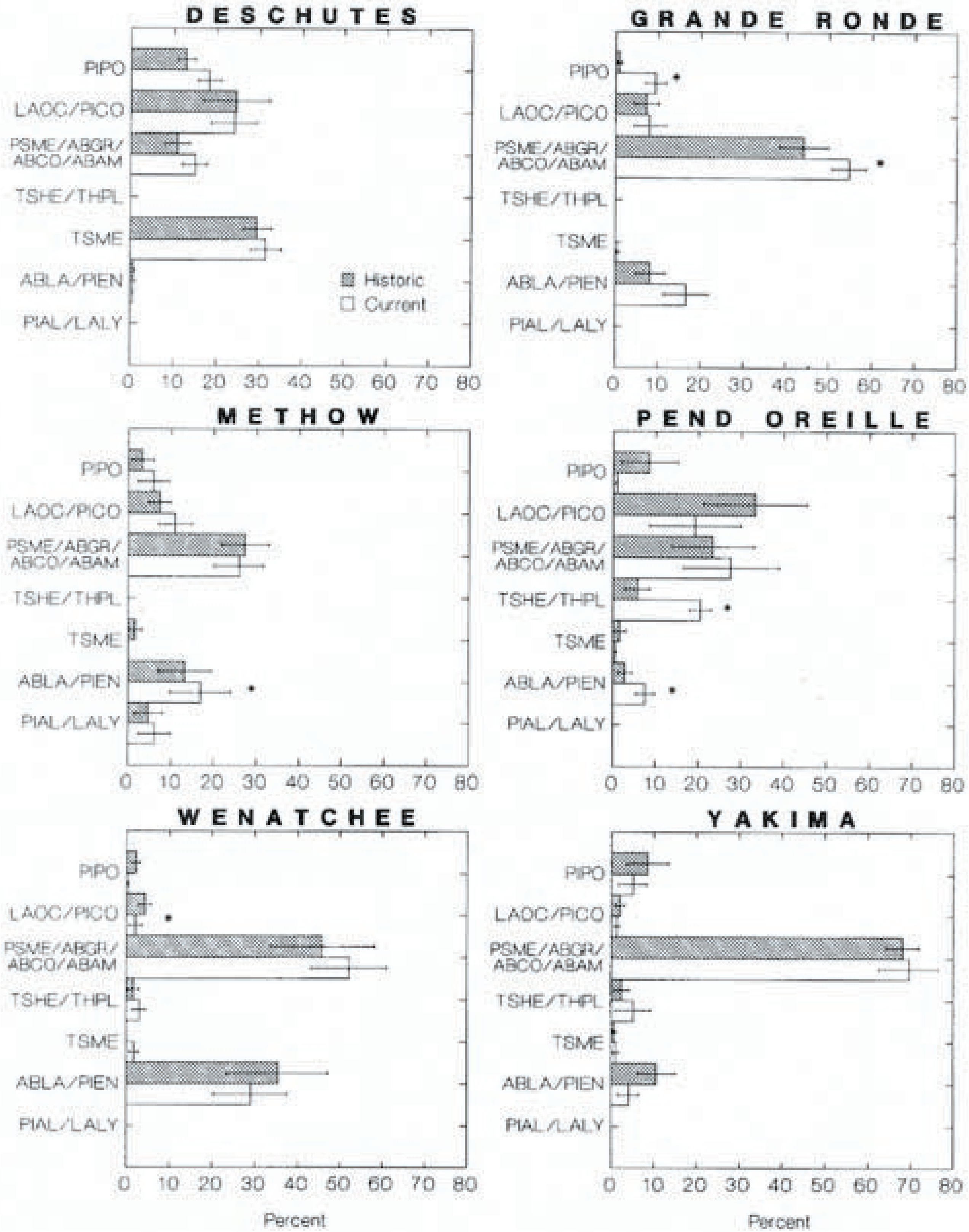


**Figure 13a—Historical and current cover of understory tree species expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.** Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences ($P \leq 0.10$) between historical and current basin conditions. Species codes: PIPO = ponderosa pine, western white pine or sugar pine; LAOC/PICO = western larch or lodgepole pine; PSME/ABGR/ABCO/ABAM = Douglas-fir, grand fir, white fir, Pacific silver fir, noble fir, or Shasta red fir; TSHE/THPL = western hemlock or western redcedar; TSME = mountain hemlock; ABLA/PIEN = subalpine fir or Engelmann spruce; PIAL/LALY = whitebark pine or subalpine larch.

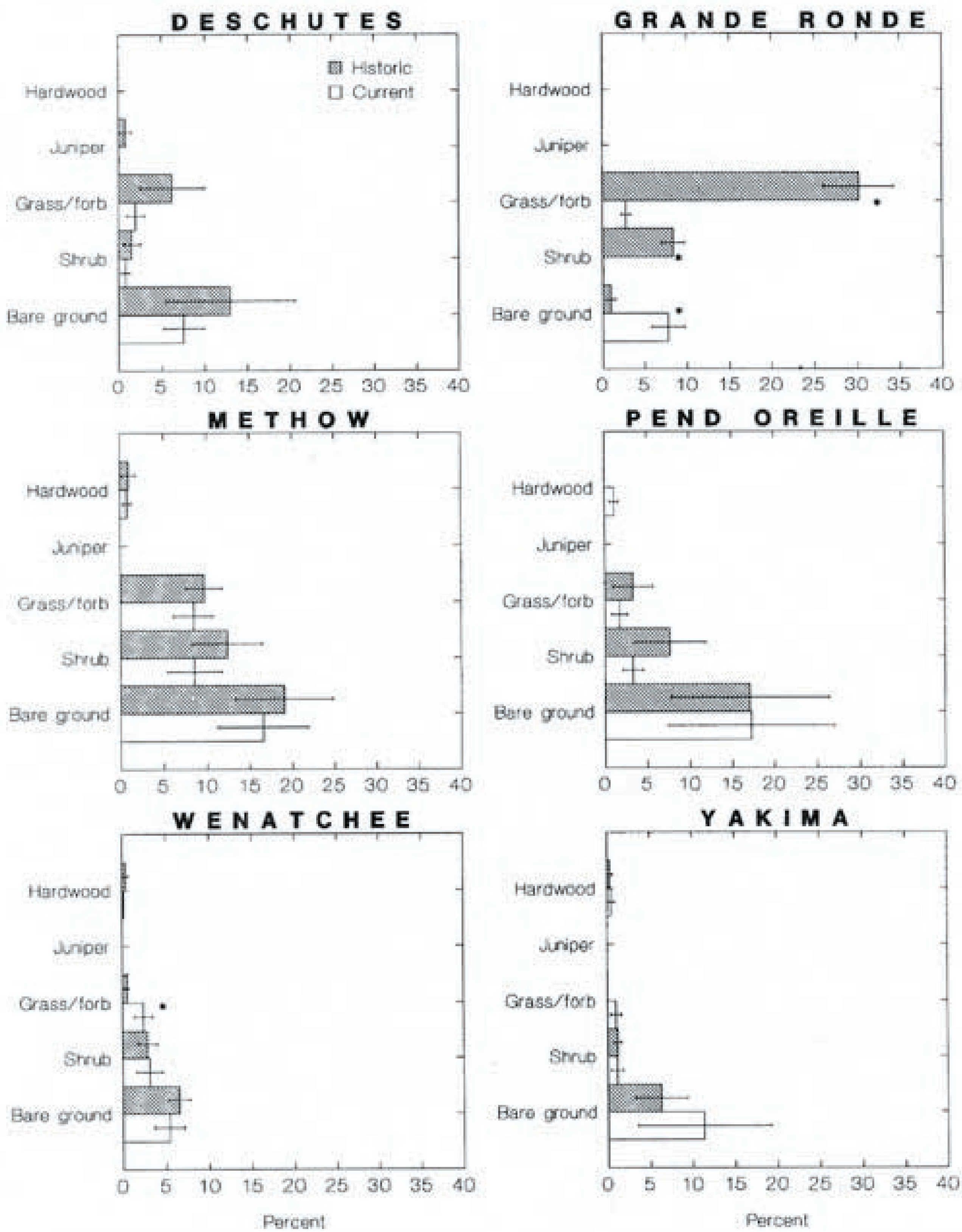


**Figure 13b—Historical and current cover of understory tree species expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences (P≤0.10) between historical and current basin conditions.

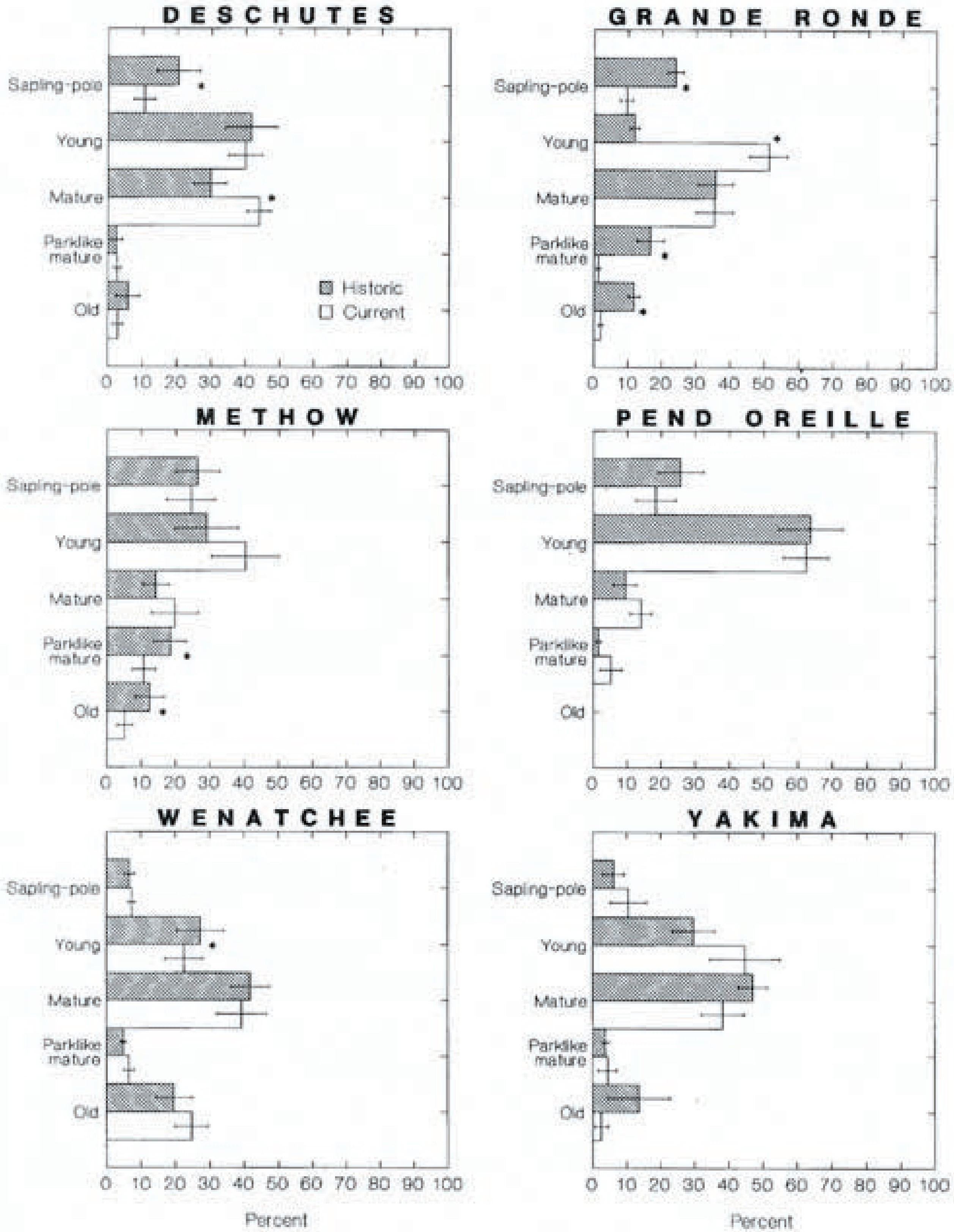


**Figure 14—Historical and current stand structure expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences ($P \leq 0.10$) between Historical and current basin conditions.

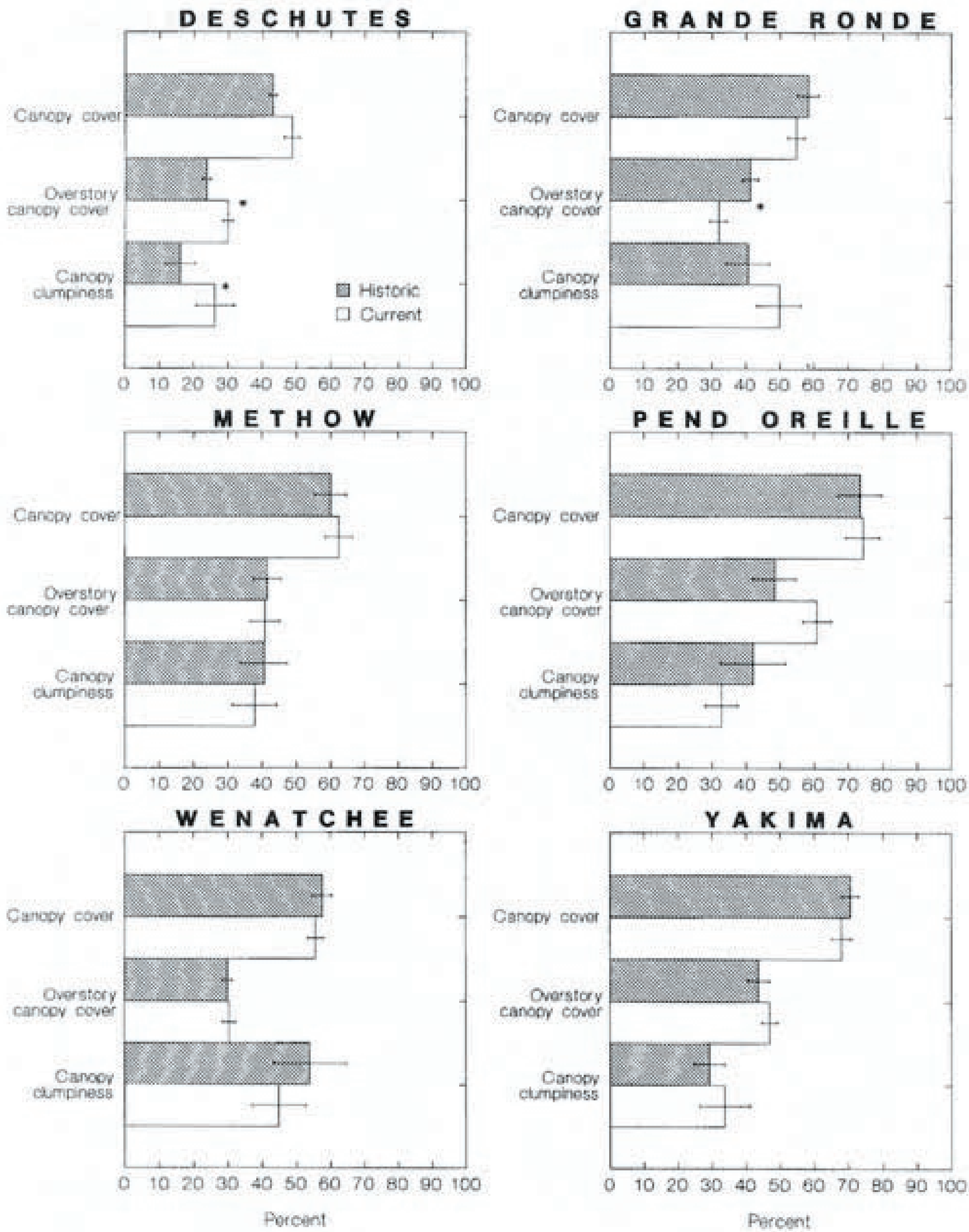


**Figure 15—Historical and current total and overstory canopy closure, and clumpiness of forested stands expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences ($P \leq 0.10$) between historical and current basin conditions.

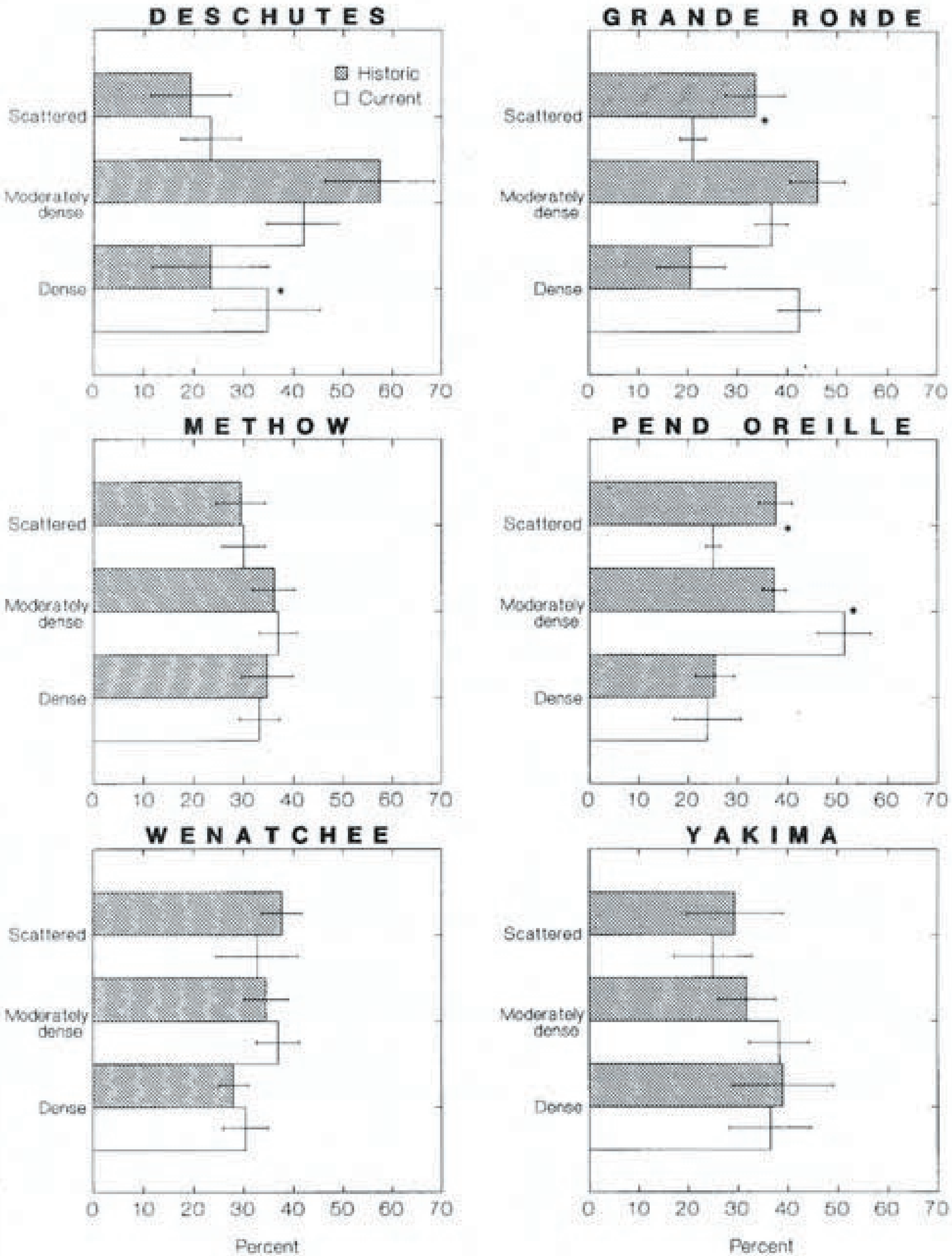


**Figure 16—Historical and current clump distribution within clumpy forest stands expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences ($P \leq 0.10$) between historical and current basin conditions.

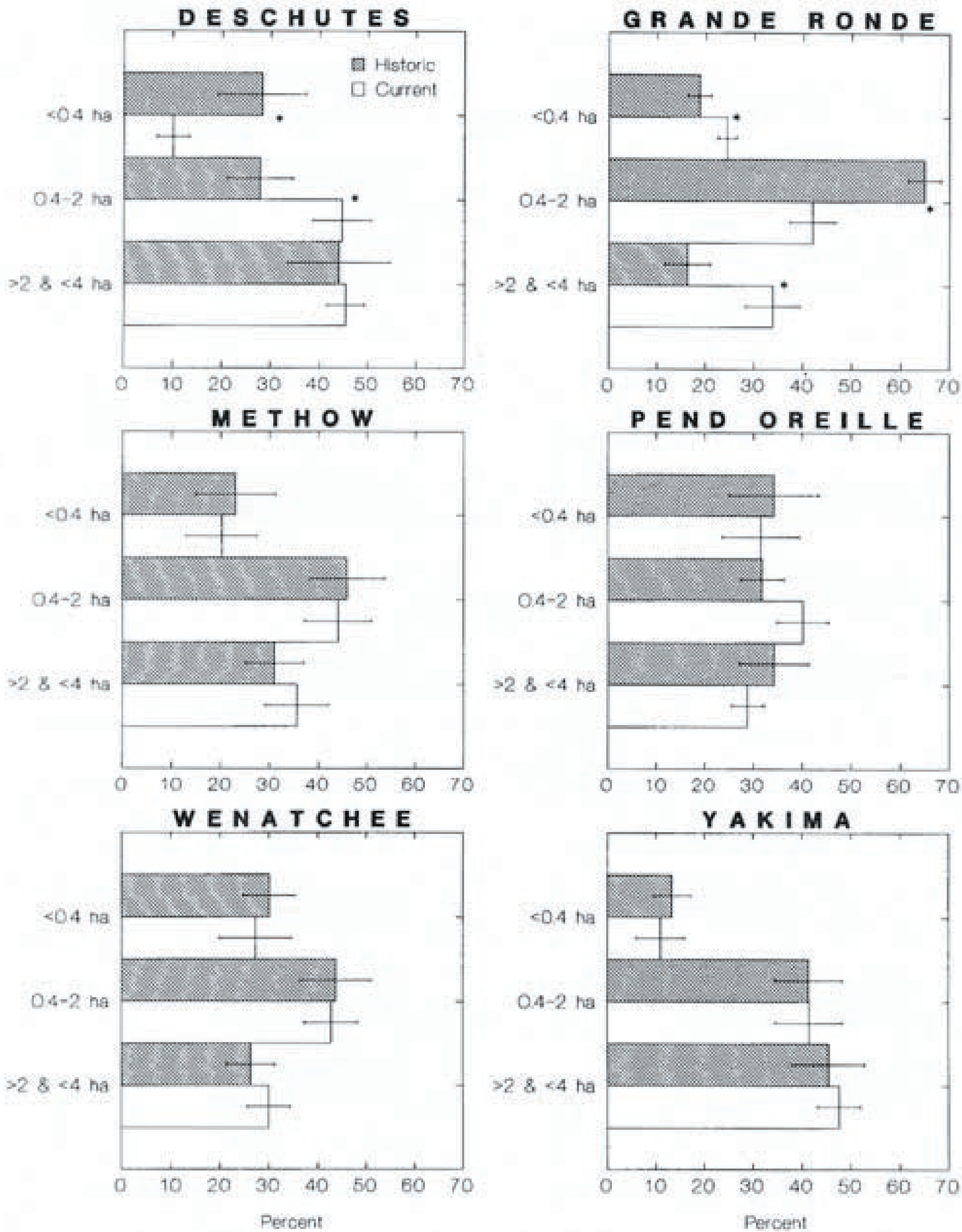


**Figure 17—Historical and current clump size within clumpy forest stands expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.** Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences (P≤0.10) between historical and current basin conditions.

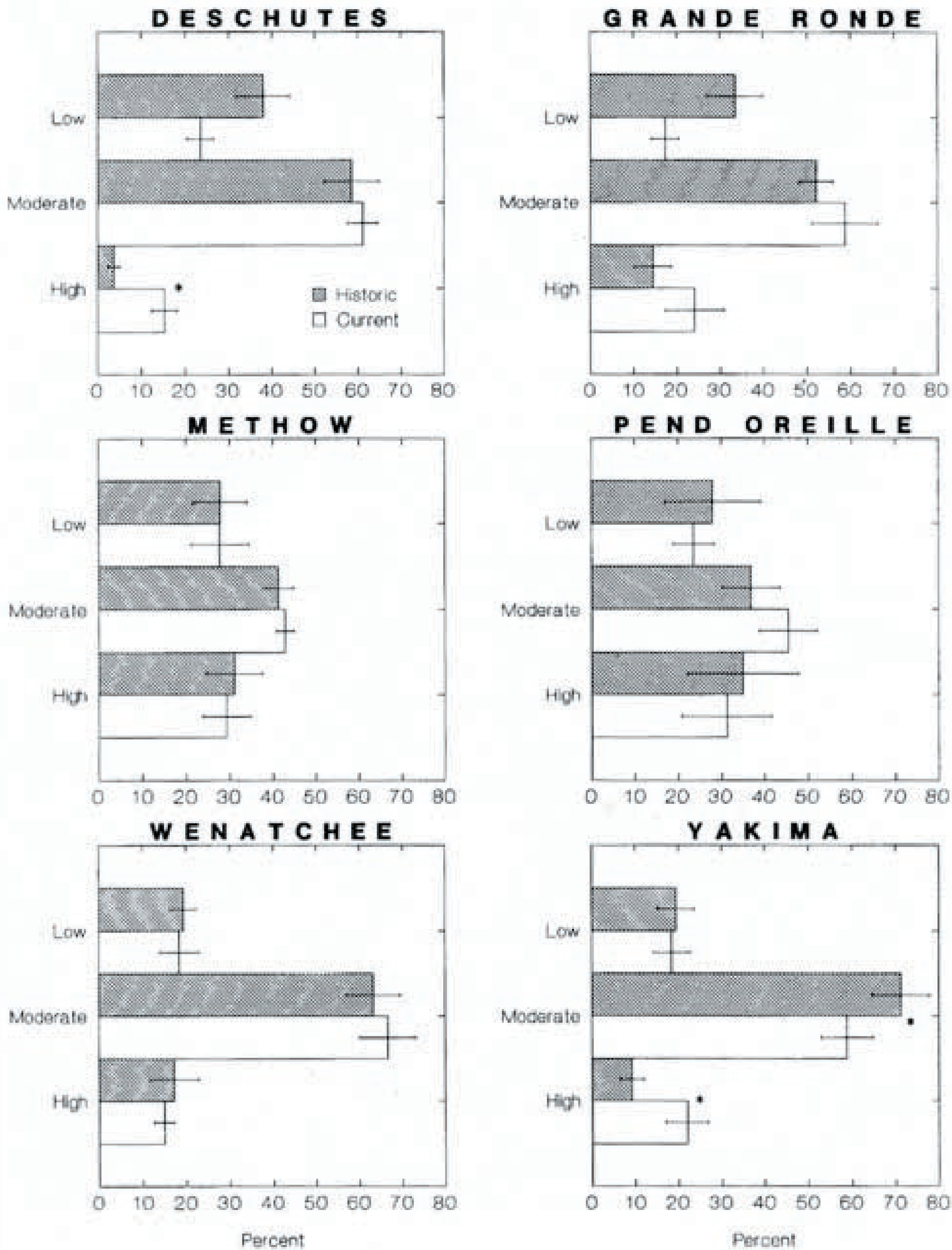


**Figure 18—Historical and current crown differentiation of forest stands expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.** Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences (P≤0.10) between historical and current basin conditions.

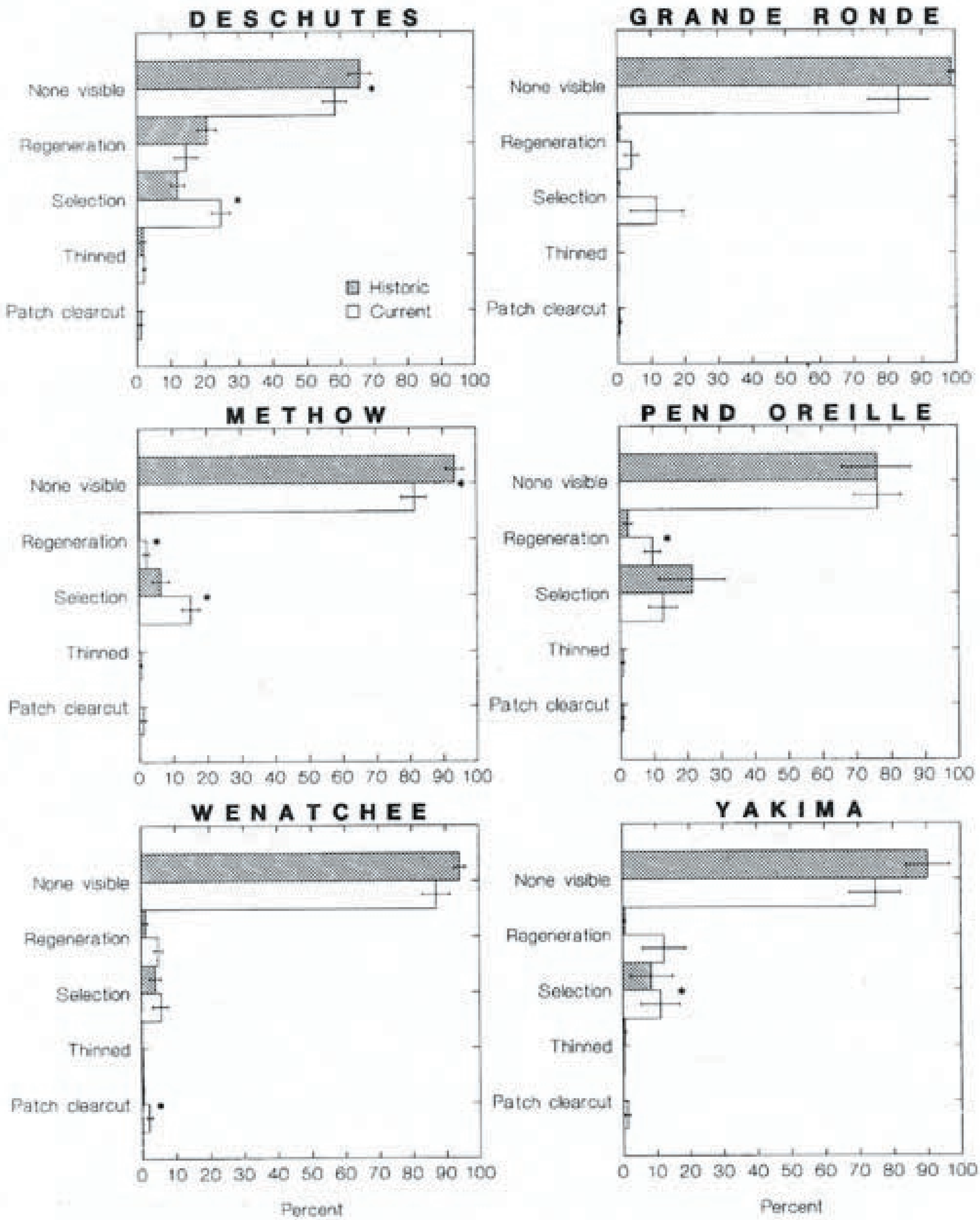


**Figure 19—Historical and current logging activity expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Categories are: no historical visible logging, regeneration harvest, selection harvest, thinning, and patch clearcutting. Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences (P≤0.10) between historical and current basin conditions.

**Dead trees**—The percentage of dead trees increased in nearly all river basins (fig. 20). Two patterns were noted. High concentrations of dead trees (> 10-percent dead) were mostly found in the Deschutes and Grande Ronde basins, but affected areas were less than 20-percent of the basin areas. In the Wenatchee and Yakima basins, dead trees were less concentrated within patches (< 10-percent dead); but this condition was more widespread, however, and occurred in 40 to 50-percent of the basin areas. In the Deschutes basin, the area with some dead trees increased 19-percent, which was largely accounted for by a 1000percent increase in severely affected stands (10-39-percent dead trees) ($P \leq 0.10$). In the Grande Ronde, the trend was for less area in the low mortality class (≤10-percent dead), and a 1400-percent increase ($P \leq 0.10$) in stands that had 40 to 70-percent dead trees. Two exceptions were watersheds in the Eagle Cap Wilderness where large fires occurred in the 1980s. Those watersheds exhibited decreases in area with dead trees and a 28 to 58-percent increase in the area of stands with no dead trees. In the Wenatchee and Yakima basins, the area with 10-percent or fewer dead trees increased 40 to 55-percent.

Little basin-wide change in the occurrence and severity of dead trees was noted in the Methow basin (fig. 20) because watershed data were highly variable. Individual watersheds revealed several patterns of change. Two watersheds, one in wilderness (55) and one in managed forest (3), indicated 80 to 100-percent declines in dead tree classes and increases in unaffected area by 14 to 27-percent. One watershed (15) displayed a 35-percent increase in unaffected area, but a 1150-percent increase in area with 10 to 39-percent dead trees. In other Methow watersheds, the area of stands with up to 10-percent dead trees increased to occupy 2 to 40-percent of the watershed.

The change in dead tree abundances was also variable in the Pend Oreille basin, and no significant basin-wide changes were found. A basin-wide increase in unaffected and lightly affected stands was indicated, however (fig. 20). The area with no apparent mortality increased in four of the six watersheds from 10 to 7200-percent of historical mortality because the area with high mortality decreased. Three watersheds also exhibited increased low mortality, however. Watershed 5 displayed the largest increase in unaffected area and decrease in severely affected stands because the area had recovered from a large stand-replacement fire before 1938. Stands with up to 10-percent dead trees increased, however, indicating that recent insect and disease damage or other disturbance had recently occurred. An unusual pattern of recovery and mortality occurred in watershed 9 where unaffected area increased 23-percent at the same time the area of concentrated mortality increased 100-percent (10-39-percent dead trees) to 200-percent (40-70-percent dead trees).

**Logging activity**—The area with apparent logging increased in the Deschutes basin by 11-percent and in the Methow basin by 12-percent from historical rates ($P \leq 0.10$) (fig. 19). (Note that changes in area obviously logged, or showing logging activity, were determined as the inverse of changes in the "none-visible" category in fig. 20; an increase in the none-visible category indicated increased logging activity.) Other basins also exhibited increases in logging activity, but high variability among watersheds because of wilderness status or unsuitability for timber harvest, precluded tests of statistical significance. All basins except the Deschutes displayed 2 to 20 times greater area affected by regeneration harvest than in historical times. All watersheds in the Pend Oreille basin indicated up to 20-percent increases in logging, except for watershed 5, which revealed a decline in logging activity over 77-percent of the area since 1935. Selective harvesting increased from 30-percent to over 100-percent in all basins except the Pend Oreille which exhibited a decline in area logged by selection techniques. A 3 to 13-percent increase in selective harvesting occurred in three Pend Oreille watersheds, but the 88-percent decline in selectively harvested area in watershed 5 (which had burned before 1938) had a large negative influence on the mean.

All watersheds in the Yakima basin likewise exhibited increased (up to 50-percent more) logging activity since 1949. Much of the logging in the Yakima basin was split between regeneration and selective harvesting, except in two watersheds (27, 30) with checkerboard ownership, where clearcut area increased from 0 to 2-percent of the area during 1949, to 20-percent of watershed 27 and 50-percent of the area of watershed 30. Logging in the Wenatchee basin occurred primarily in only two sample watersheds, where the visibly logged area increased by 30-percent, with more than 35 to 45-percent of the area of those watersheds modified. Thinning and patch clearcutting increased, but affected less than 2-percent of the sampled area in all basins.

**Landscape pattern**—Current landscape pattern in five of the six basins was more diverse and fragmented than in the past (fig. 21a-b) as measured by several attributes. Mean patch size decreased 30 to 130-percent ($P \leq 0.10$) and edge density increased 15 to 40-percent ($P \leq 0.10$) in the Deschutes, Methow, and Pend Oreille basins. Patch shape, measured by the fractal index, became more complex ($P \leq 0.10$) in the Deschutes basin. As patch size decreased, patch density increased 17 to 48-percent ($P \leq 0.10$) in the Deschutes and Methow basins. Vegetation composition and landscape diversity increased ($P \leq 0.10$) in the Pend Oreille basin as dominance decreased ($P \leq 0.10$). A decline ($P \leq 0.10$) in patch contagion in the Methow basin also indicated greater vegetation complexity at the 1-ha scale of measurement. These changes in landscape pattern followed the pattern of change expected when timber harvesting is a primary influence (fig. 22). Pattern in the Wenatchee and Yakima basins also followed these trends, although changes over time were not statistically significant.

Change in landscape pattern in the Grande Ronde was entirely different and more closely followed the pattern of change expected when fire suppression activities had effectively excluded fires. Diversity decreased ($P \leq 0.10$) and dominance increased ($P \leq 0.10$), primarily because of the 325-percent increase in the percentage of landscape with midseral stands (figs. 14, 23). Other pattern attributes did not indicate significant change in the Grande Ronde at the basin scale because changes among watersheds were highly variable.

A comparison between wilderness and managed watersheds in the Grande Ronde revealed clear differences in patterns of change and in the role that timber harvest and active fire suppression with a well-developed road system may have played in pattern development. Wilderness watersheds (35, 40, 52, 55) became less diverse and less fragmented than managed watersheds as shown by 24 to 69-percent declines in patch density, whereas, patch density in managed watersheds increased 40 to 100-percent. Patch size increased 30 to 225-percent in wilderness but declined 30 to 50-percent in managed areas. Edge density decreased 30 to 60-percent in wilderness but increased 6 to 35-percent in five of six managed watersheds. Landscape diversity decreased and dominance increased, contagion increased, and edge density decreased in wilderness, whereas managed areas followed opposite trends.

Wilderness watersheds in the other five basins were less conspicuously different than managed watersheds but did show the effects of timber harvest. A close look at the change in landscape pattern attributes in all watersheds in the six basins exhibited considerable variability in the amount of change over time and in the influence of logging activity, and it indicated some thresholds of landscape change. A line fitted to the scatterplot of the change over time in landscape attributes against the current visible percentage of area logged should be level if logging has no influence. Scatter around the line shows the residual variation, or variation in change that is explained by other factors such as fire suppression and natural succession. Patch density increased with logging up to a threshold of 30-percent affected area. Beyond that, patch density did not increase (fig. 24). Residual scatter was high even when very little logging occurred, especially above the fitted line, which indicated other disturbances made important contributions to the higher patch densities now observed. Edge density and fractal patch shape complexity had similar relations with the area logged (fig. 24), but residual variation was more evenly distributed, indicating that negative and positive changes were equally frequent and often associated with other factors. Logging had a negative influence on patch size (fig. 24), although decreases in patch size were evident in the absence of logging, probably as a result of insect and disease disturbance. This effect of fragmenting the landscape was also shown by the relation between logging and landscape contagion (fig. 25). Diversity of vegetation composition and structure did not appear to be influenced by logging (fig. 25); diversity was slightly higher now than in the past, regardless of logging activity. Dominance also changed little during the study period, and logging had little effect on it (fig. 25).

## Insect and Disease Hazard

Insect and disease hazards changed little at the river basin scale (fig. 26a-b) because variation at the watershed scale was considerable. Basin-scale changes were usually less than 10-percent difference from the historical conditions, even when shown to be statistically significant ($P \leq 0.10$). Moreover, changes in hazard among basins were often inconsistent in the direction of change, except perhaps for western dwarf mistletoe hazard, which increased substantially in the Grande Ronde (29-percent) and Pend Oreille (11-percent) basins. Large changes in insect and disease hazards were common in individual watersheds, however, which indicated watersheds were the appropriate scale for hazard analyses of many insects and diseases.

Analysis of the distribution of hazard scores for all watersheds revealed a preponderance of change within ±10-percent above or below historical ratings, with some watersheds exhibiting larger changes in both positive and negative directions. Increases and decreases in hazard for all species evaluated were fairly well distributed across all basins. Within sampled watersheds, hazard from defoliators declined in slightly more watersheds than it increased (fig. 27). The large increases in defoliator hazard occurred in watersheds of the Grande Ronde, Methow, Deschutes, and Pend Oreille basins. In general, defoliator hazards decreased or stayed the same in sample watersheds of the Wenatchee and Yakima basins.

Douglas-fir beetle hazards increased more often than they decreased, with seven watersheds in the Grande Ronde, Methow, and Yakima basins showing 30 to 60-percent increases (fig. 28). Western pine beetle Type 1 hazard to overmature ponderosa pine decreased in about 20-percent of sample watersheds, and increased in 10-percent of the watersheds. In some Deschutes watersheds, increases of 50 to 60-percent were evident (fig. 28). Western pine beetle Type 2 hazard to immature ponderosa pine followed a trend similar to Type 1 hazard (fig. 28), with most of the large increases occurring in Deschutes and Grande Ronde watersheds.

Mountain pine beetle Type 1 hazard to overstocked lodgepole pine increased by 1 to 10-percent or remained unchanged in about 50-percent of the watersheds (fig. 28). Some individual watersheds displayed a 5 to 10-percent increase in Type 2 mountain pine beetle hazard (fig. 28), and a few increases in hazard as great as 30 to 70-percent have occurred in some Deschutes, Grande Ronde, and Methow watersheds. Change in fir engraver hazards were evenly split, with 45-percent of the watersheds exhibiting as much as a 10-percent increase in hazard (fig. 28). The greatest decreases (20 to 38-percent) in fir engraver hazard occurred in sample watersheds of the Grande Ronde basin.

Mistletoe hazards increased in at least half of all watersheds. Most watersheds that experienced an increase changed by 5 to 10-percent (fig. 27). Douglas-fir dwarf mistletoe hazard increased the greatest in Grande Ronde and Pend Oreille watersheds. Douglas-fir dwarf mistletoe hazard increased in nearly every Grande Ronde watershed, with some increases as great as 50 to 90-percent. Mistletoe hazard in Douglas-fir decreased in all but one sample watershed in the Yakima basin. The largest increases in hazard associated with western dwarf mistletoe occurred in Deschutes and Grande Ronde watersheds. Western larch dwarf mistletoe hazards decreased or remained the same in most sample watersheds.

Root disease hazards increased in 50-percent of the sampled watersheds (fig. 27). The greatest increase in root disease hazard occurred in the Pend Oreille basin, where hazard increased in all watersheds. Large increases were also noted in some Grande Ronde and Deschutes watersheds.

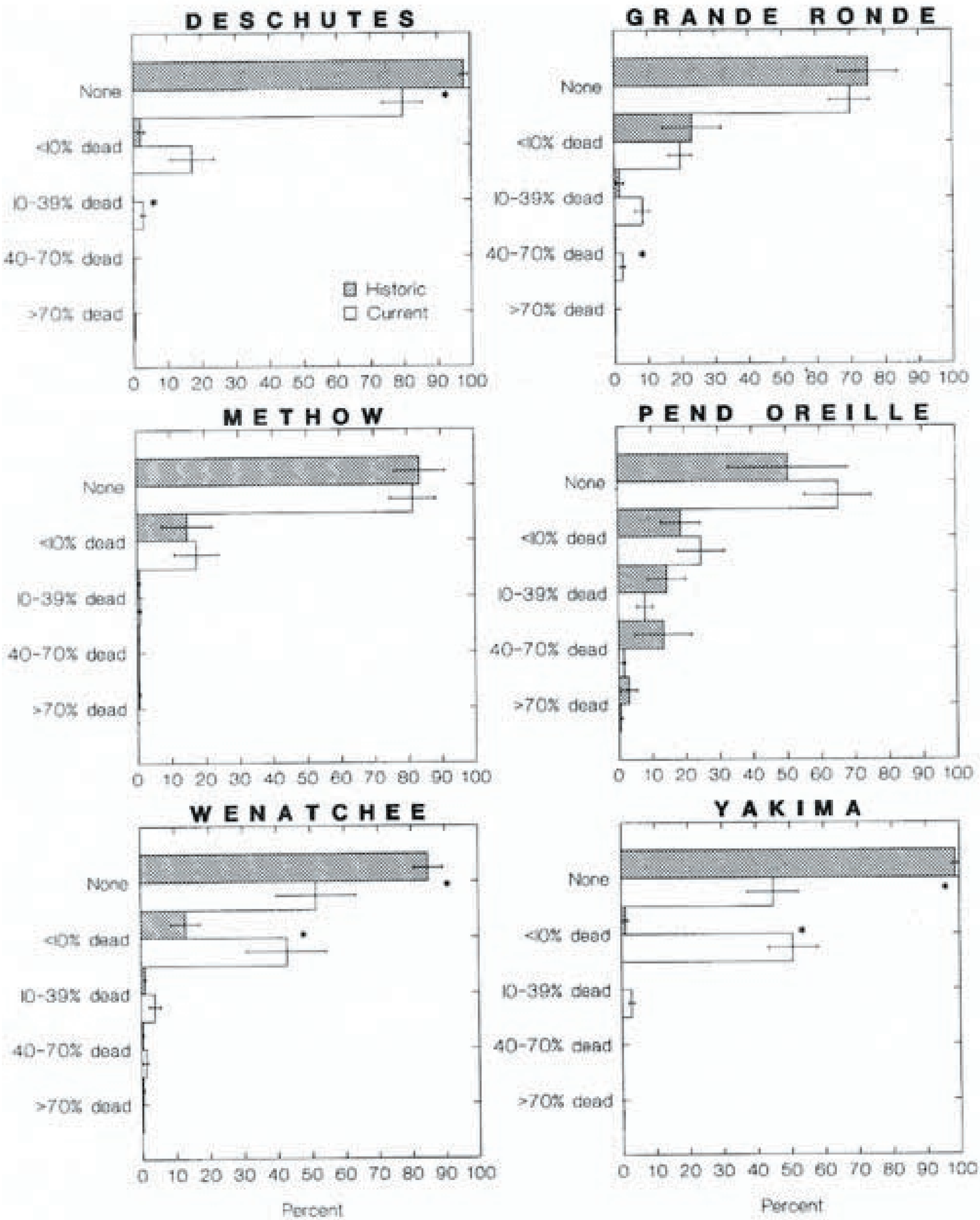


**Figure 20—Historical and current percentages of dead trees in forested stands expressed as a percentage of total area on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences (P≤0.10) between historical and current basin conditions.

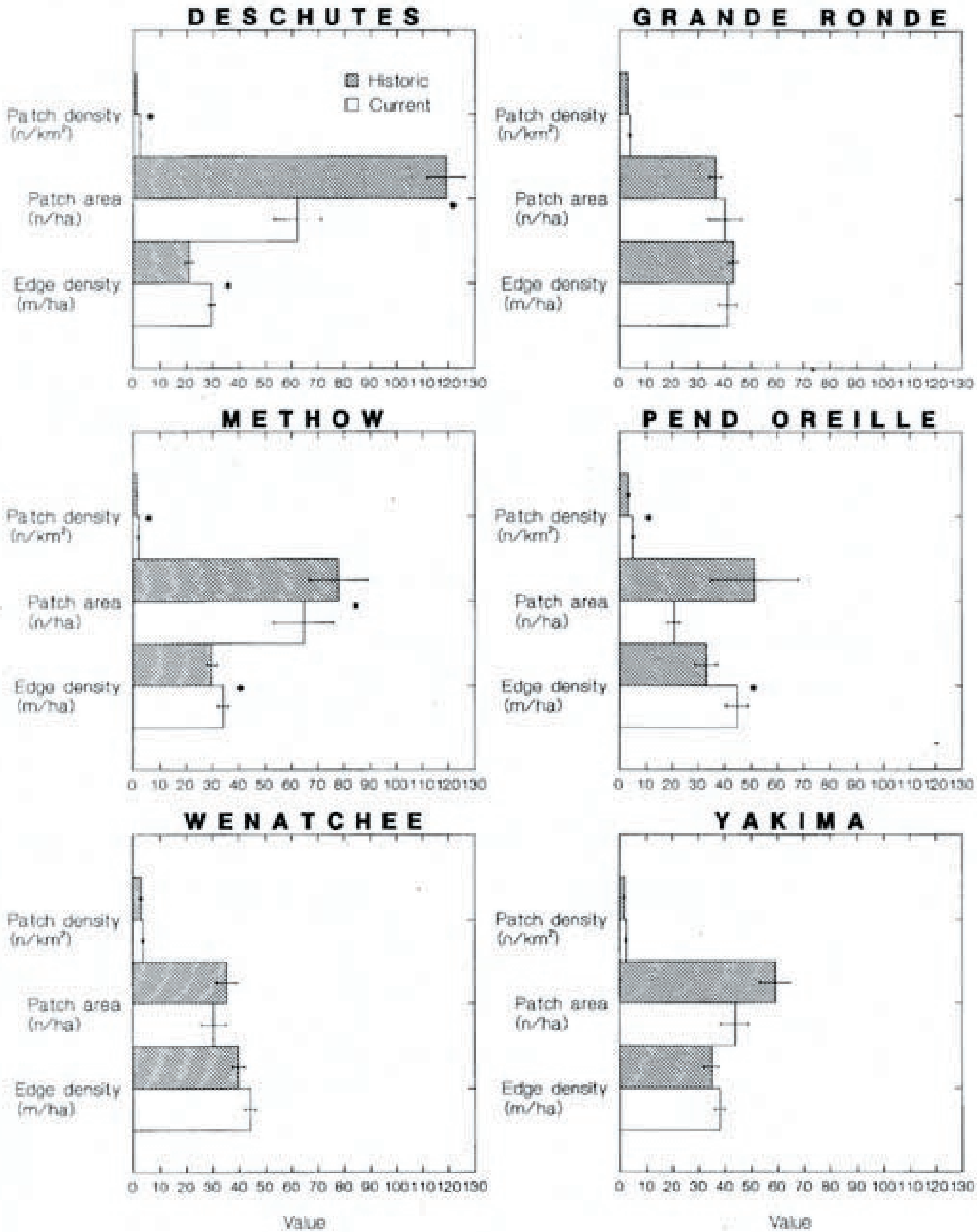


**Figure 21a—Historical and current vegetation patch density (n/km²), mean patch area (ha), and edge density (m/ha) on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences (P≤0.10) between historical and current basin conditions.

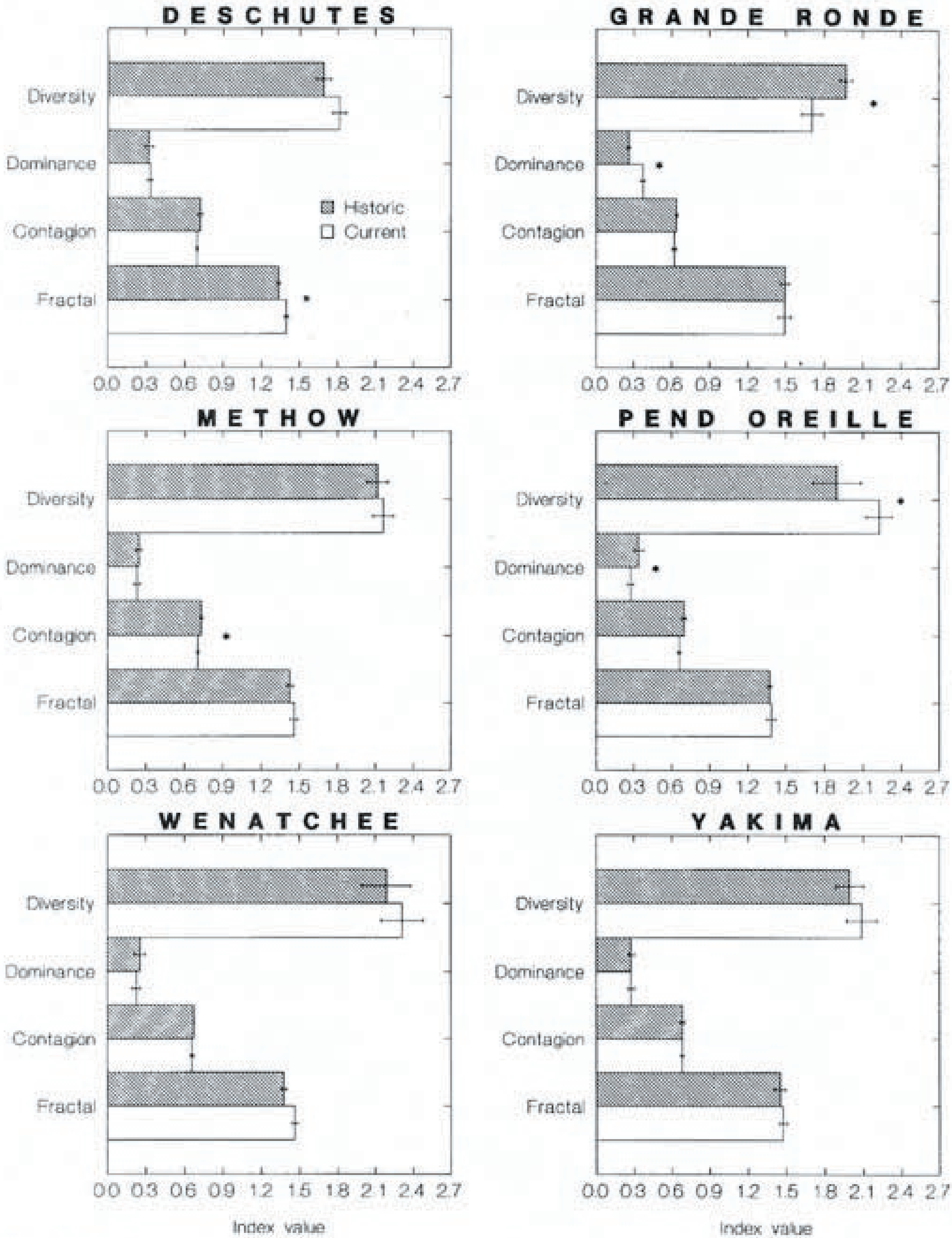


**Figure 21b—Historical and current vegetation pattern indices on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**

Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences (P≤0.10) between historical and current basin conditions.

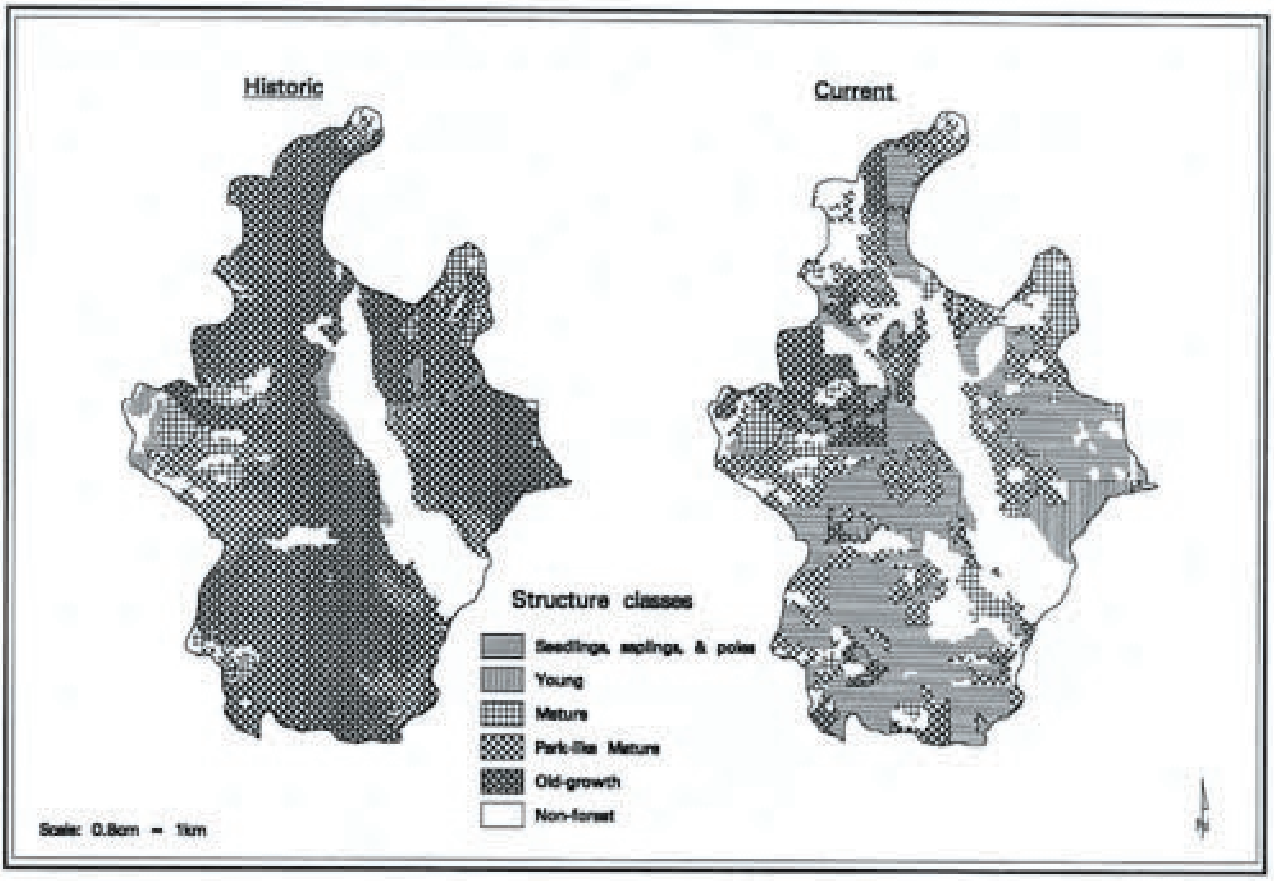


Figure 22—Historical and current maps of overstory vegetation structure/age classes for sample watershed 30 in the Yakima River basin, eastern Washington.

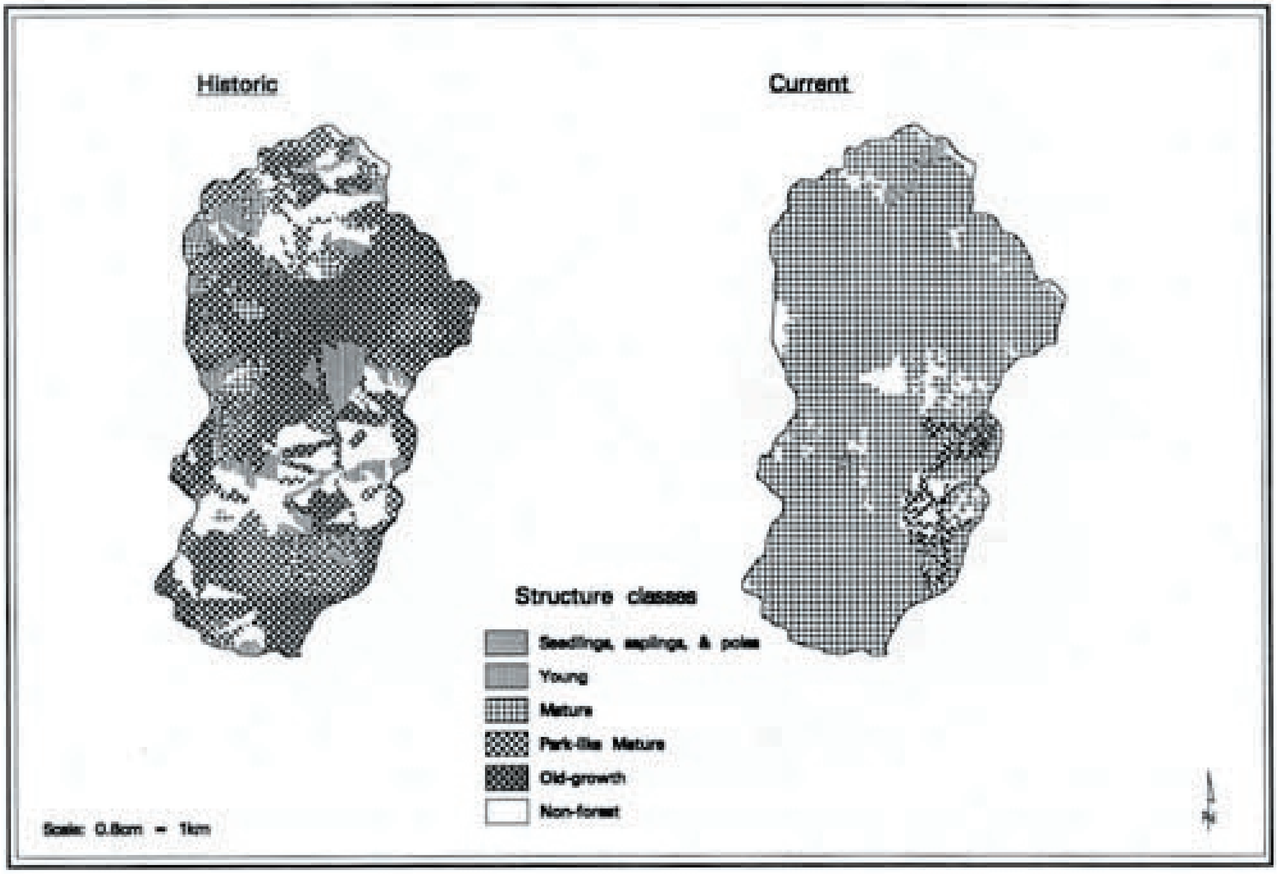


Figure 23—Historical and current maps of overstory vegetation structure/age classes for sample watershed 55 in the Grande Ronde River basin, eastern Oregon.

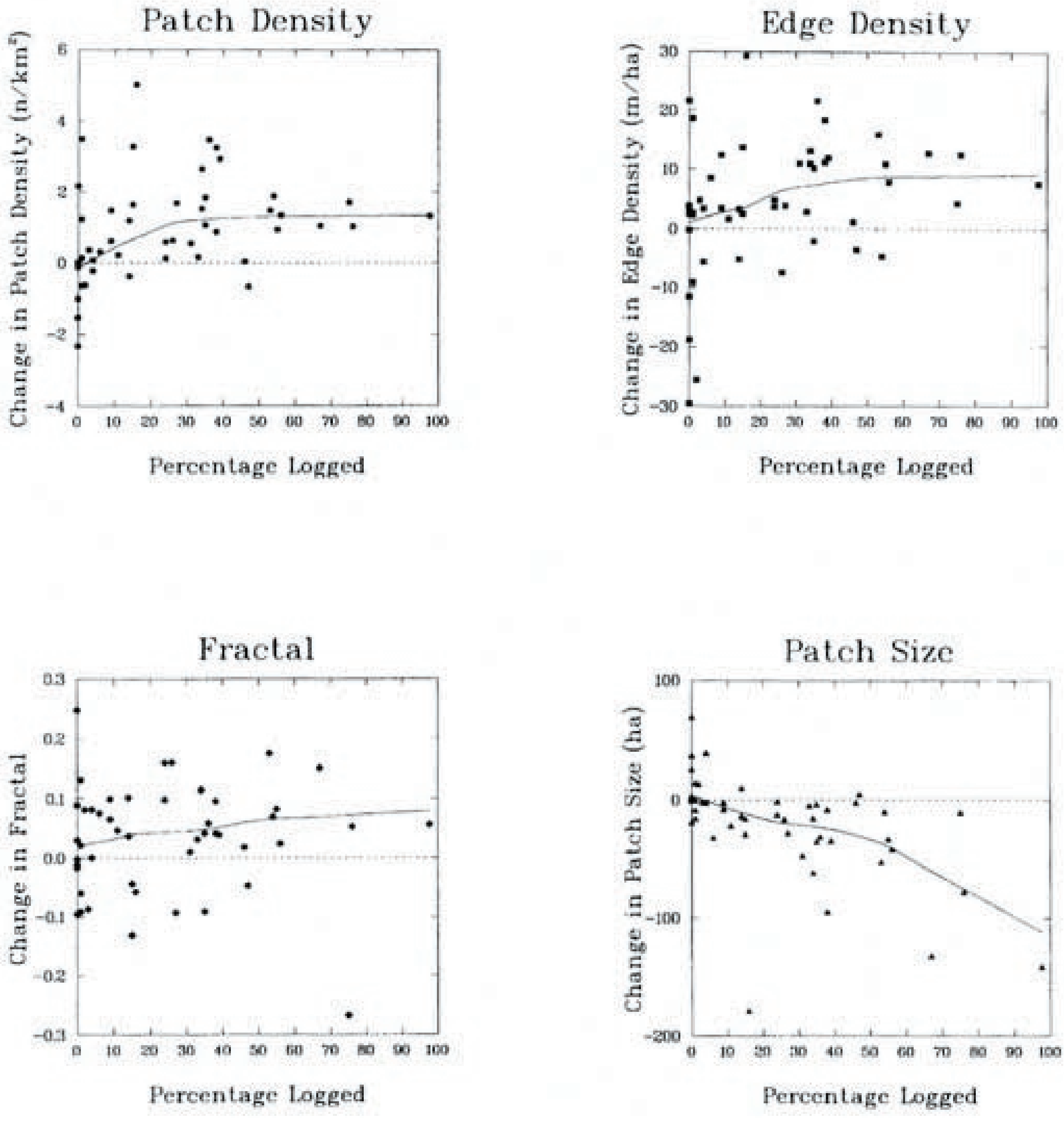


**Figure 24—Percentage change from historical to current times in patch density, edge density, fractal index of patch shape complexity, and patch size vs. the percentage area logged in 49 watersheds in six river basins, eastern Oregon and Washington.** Curve was fitted by weighted average (Lowess) smoothing.

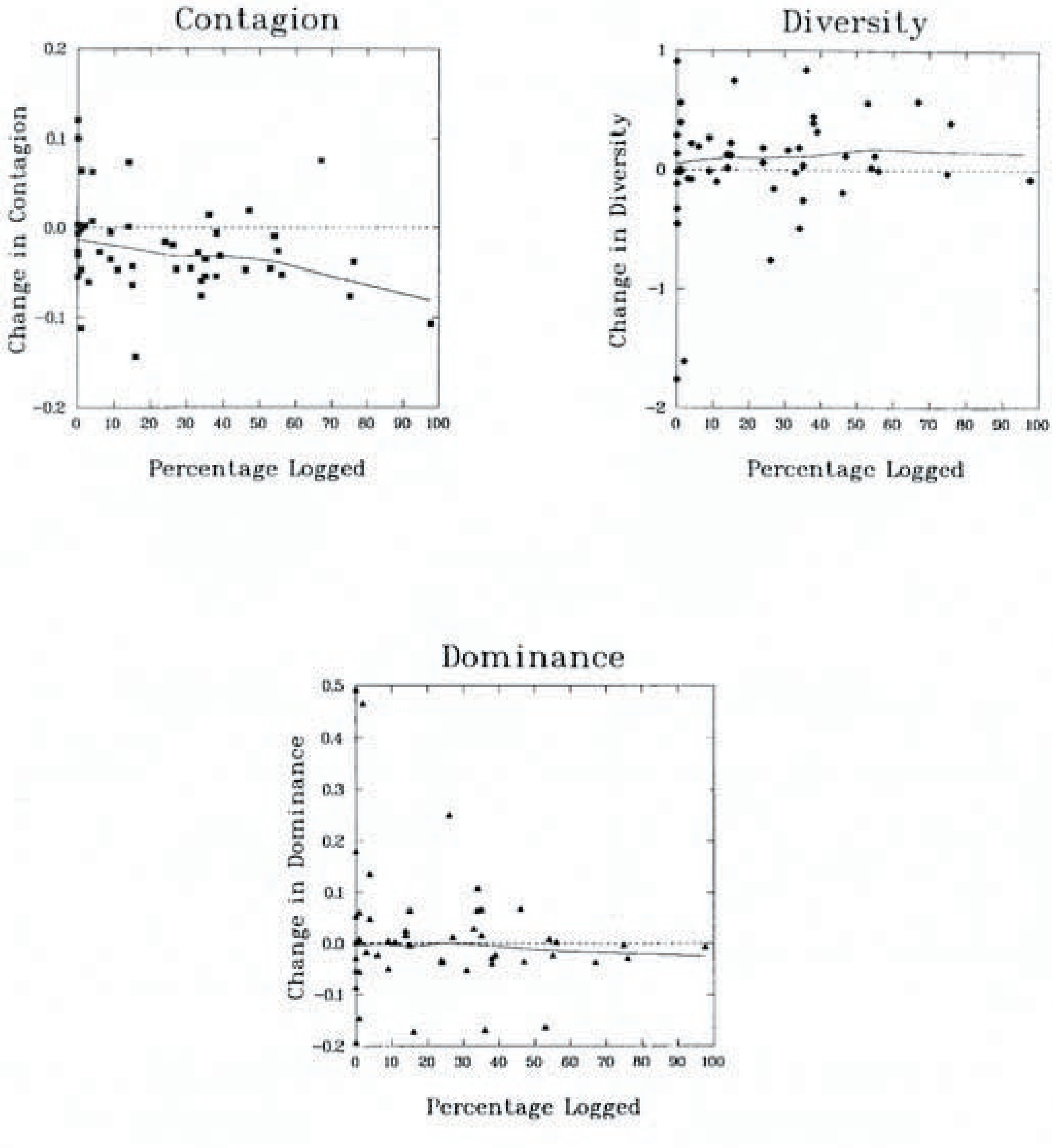


**Figure 25—Percentage change from historical to current times in contagion, diversity, and dominance vs. the percentage area logged in 49 watersheds in six river basins, eastern Oregon and Washington.** Curve was fitted by weighted average (Lowess) smoothing.

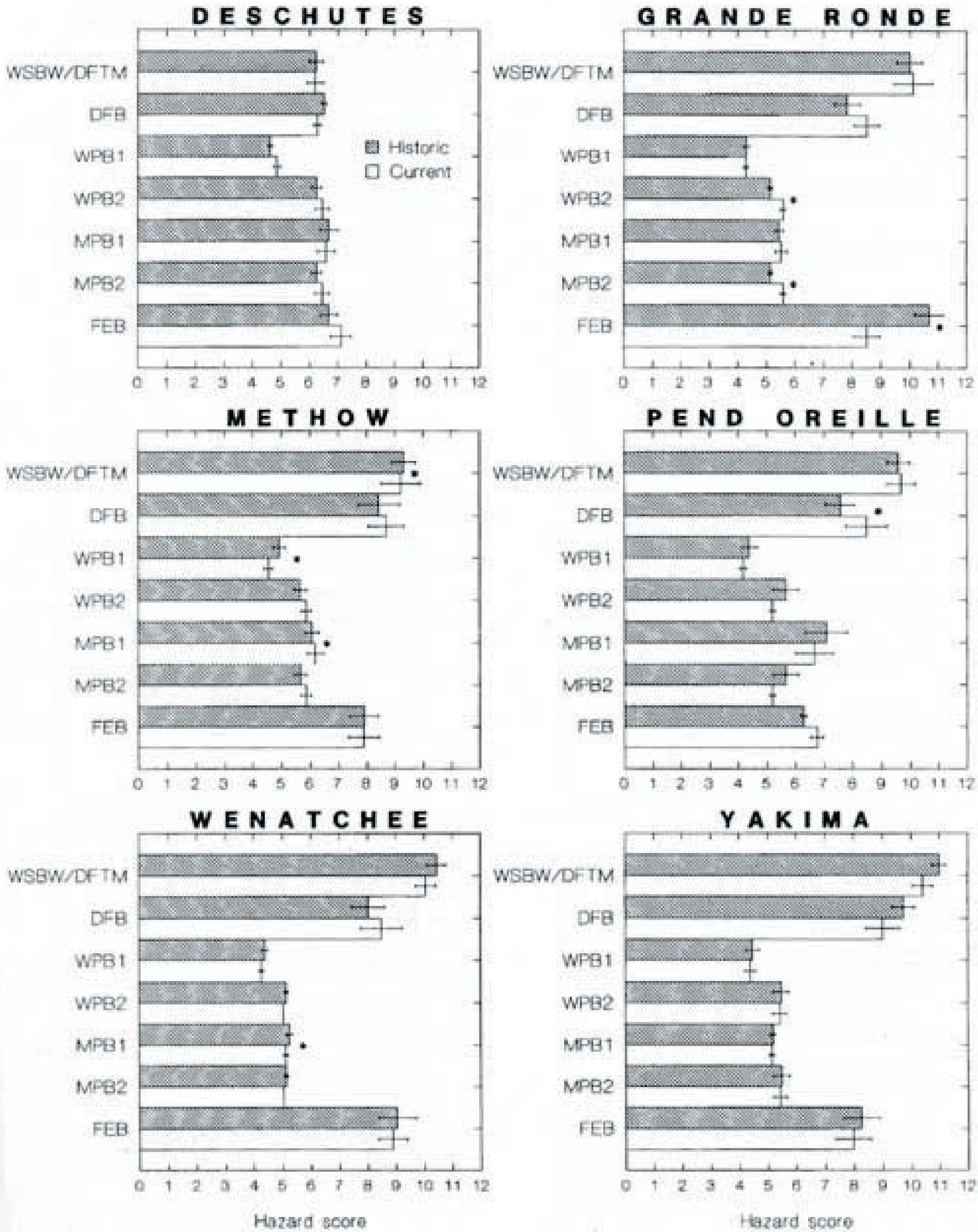


**Figure 26a—Historical and current indices of insect and disease hazard on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences ($P \leq 0.10$) between historical and current basin conditions. Species codes: WSBW/DFTM = western spruce budworm or Douglas-fir tussock moth; DFB = Douglas-fir beetle; WPB1 = western pine beetle type 1; WPB2 = western pine beetle type 2; MPB1 = mountain pine beetle type 1; MPB2 = mountain pine beetle type 2; FEB = fir engraver beetle.

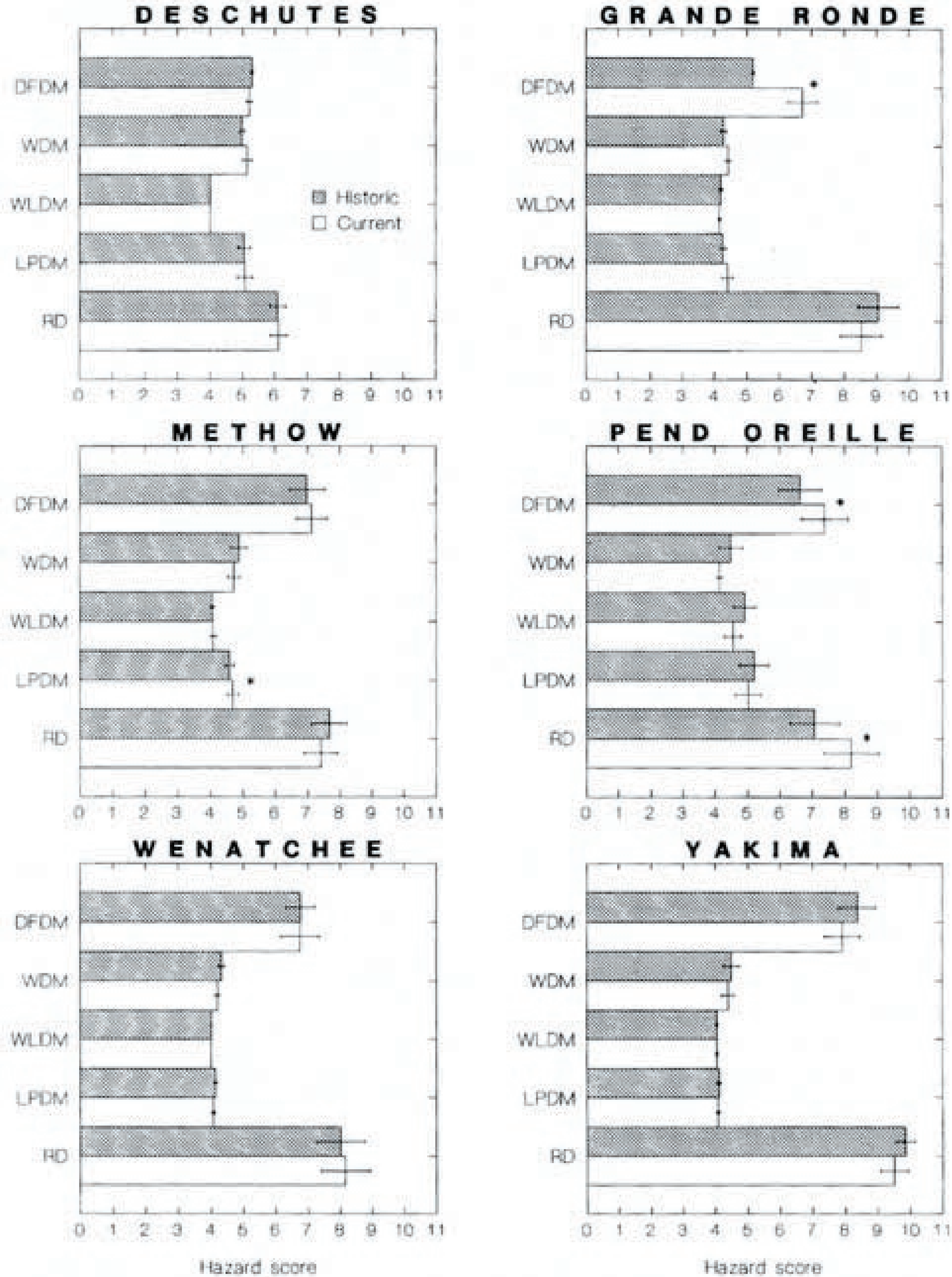


**Figure 26b—Historical and current indices of insect and disease hazard on lands within National Forest boundaries in river basins of eastern Oregon and Washington.**
Error bars are the standard error of the stratified mean estimate. Asterisks indicate significant differences (P≤0.10) between historical and current basin conditions. Species codes: DFDM = Douglas-fir dwarf mistletoe; WDM = western dwarf mistletoe; WLDM = western larch dwarf mistletoe; LPDM = lodgepole pine dwarf mistletoe; RD = root disease.

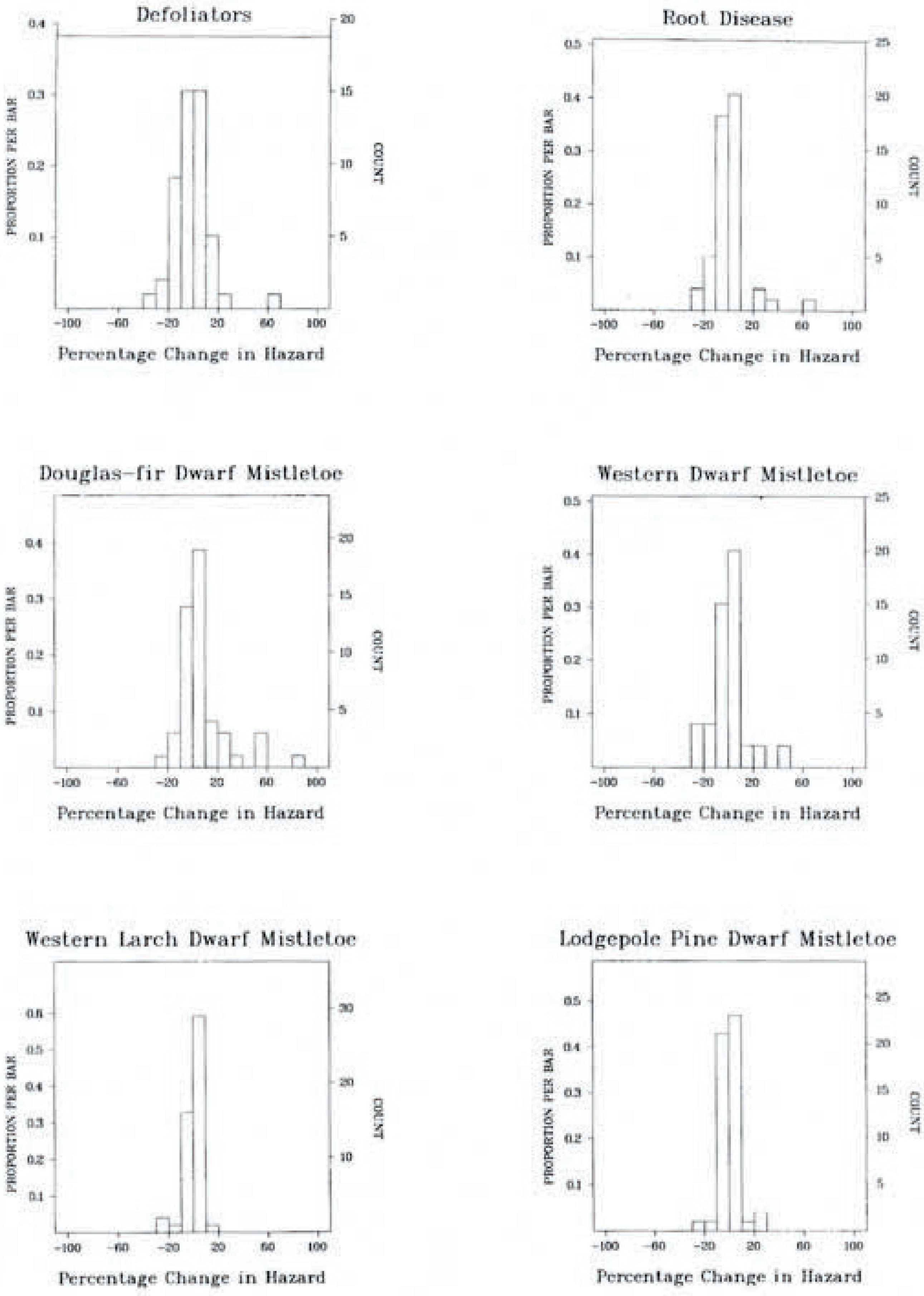


**Figure 27— Distributions of percentage change from historical to current times for insect defoliator, root disease, and mistletoe hazard in 49 watersheds in 6 river basins, eastern Oregon and Washington.**

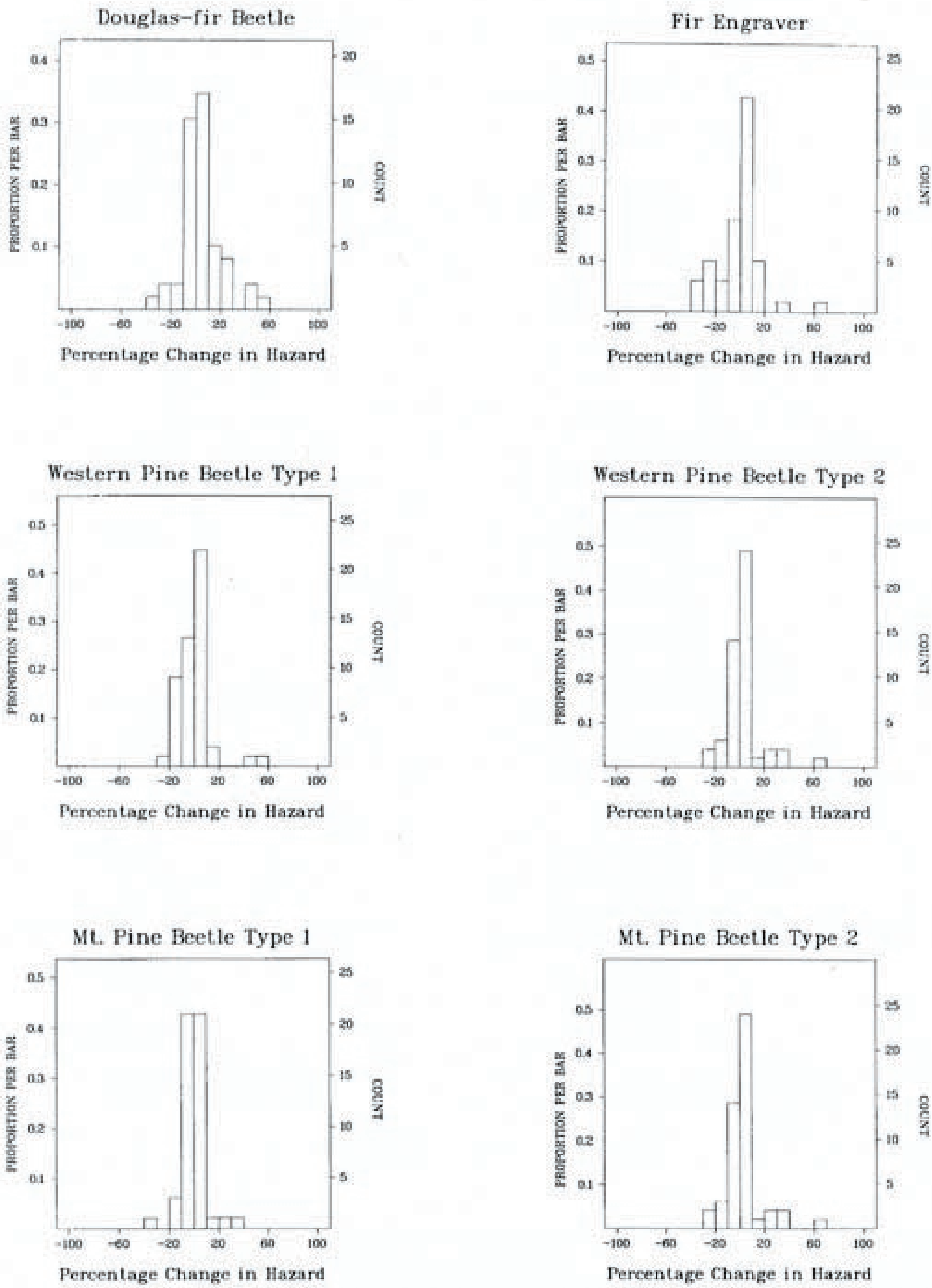


**Figure 28—Distributions of percentage change from historical to current times for bark beetle hazard in 49 watersheds in 6 river basins, eastern Oregon and Washington.**

# DISCUSSION

## Measuring Ecosystem Change

Detection of significant change in river basins would require that change in a variable be similar among sample watersheds and sample strata. In hindsight, this expectation was unrealistic. Vegetation and insect and disease hazard were developed from a population of sample watersheds that have different management and disturbance histories, and different vegetative composition and structural characteristics. Because the data were based on vegetation composition and structure, past histories of the sample watersheds were often responsible for much of the underlying variability. Although the two periods, historical and current, were reasonably fixed within a river basin, obviously the historical landscape settings (starting points), which were our basis for detecting change, varied greatly among the sample watersheds. For example, some sample watersheds had evidence of large wildfires in the past and other watersheds, with reasonably similar climates and geology, exhibited little evidence of fires during the same period (Huff and others, in press). A large fire sets a sample watershed into a successional stage that is substantially different from the successional stage of the watershed that didn't burn; consequently, their starting points and patterns from a landscape perspective were quite different.

No significant difference of many variables between historical and current river basins could be related to factors other than site-specific fire histories. Ecologically diverse systems have high natural variability within and among watersheds and strata. Between six and ten watersheds were sampled within each river basin, with one or two sample watersheds per stratum. Even at 15-percent of the area, this sample size is still relatively small considering geographic extent and spatial heterogeneity of the different river basins. Seventy-two additional sample watersheds have been photo-interpreted and data-entered to bolster the sample size to 26-percent within each river basin. They will be included in subsequent analyses.

Land management objectives also differed considerably among sample watersheds-from unlogged wilderness to areas intensively managed with more than 50-percent of the area logged. The amount and type of management activities are difficult factors to control in designing landscape-scale studies. Landscapes managed primarily for wilderness are expected to change at different rates and in different directions, than ones managed more intensively for forest products. Any sample of watersheds within river basins with multiple-use land management objectives would be expected to have high variability. One approach in subsequent analyses with more sample watersheds will be to compare wilderness-dominated landscapes with intensively managed ones. Wilderness areas tend to be in middle and high-elevation ecosystems, however, and harvesting and other management activities have been more concentrated at lower and middle elevations. Some comparisons may not be practical if vegetation composition, structure, and other ecosystem attributes differ significantly between wilderness and nonwilderness areas. Furthermore, the effects of management activities such as fire suppression, that are more subtle than those produced by tree harvesting, could also differ significantly among sample watersheds.

The quality of the aerial photographs available to photo interpreters might be another source of variation between historical and current conditions. Certain attributes on the black and white photographs taken 35 to 50 years ago, such as snags and understory composition, were somewhat difficult to distinguish, and some photo sets were taken in different years under different conditions, adding another possible source of variation. These photos and the data interpreted from them, however, were the best available.

Given the relatively small sample of watersheds and the high variability among watersheds, fewer significant differences or lower power to detect differences would be expected than with a larger sample. Therefore, significant changes we have described likely are conservative.

## Vegetation Composition and Structure

Many of the predicted changes in composition and structure of eastside forest vegetation associated with fire suppression were largely borne out by the data. A causal link is difficult to establish, however, because the amount of fire suppression was not directly measurable or quantifiable. Increases in forest cover in the Deschutes, Grande Ronde, and Pend Oreille River basins suggested that effective fire suppression had resulted in a forest growing on what were previously bare or grassy areas maintained by fire or in logged areas. This encroachment on bare ground may have occurred in the Deschutes, Grande Ronde, and Pend Oreille basins, where bare ground decreased, but change in the Pend Oreille basin was likely the result of revegetation of extensive areas burned before 1930. We might also expect grass/forb cover to decrease with fire suppression, particularly where grazing reduces grass cover, vigor, and flashy litter fuel (Agee 1993). We did not find this decrease in two of three basins that exhibited increased forest cover: grass/forb cover increased in the Deschutes and Pend Oreille basins, but decreased in the Grande Ronde. Further analysis of fire and grazing histories is necessary to firmly establish the causes for changes in forest cover.

Predicted shifts from early seral species, such as ponderosa pine, to middle or late seral species, such as Douglas-fir and grand fir, with fire suppression and harvest of early-seral overstory dominants (Agee 1993, Caraher and others 1992, Gast and others 1991, Hessburg and others 1993) were shown in some areas. Fire suppression may be a partial cause of this change, but we cannot directly test this hypothesis. Moreover, examination of watersheds in wilderness or without visible logging, where fire suppression alone might be the dominant factor, exhibited very different responses within basins. For example, Grande Ronde watersheds 13 and 21 had no visible logging during the two mapping periods, but they exhibited very large increases (20-30-percent total area) in ponderosa pine cover with concurrent decreases in Douglas-fir cover. In contrast, Grande Ronde watersheds in the Wenaha-Tucanon wilderness (52, 55) exhibited marked decreases (35-50-percent of the area) in ponderosa pine cover and increases in Douglas-fir cover. A preliminary analysis of all watersheds for the effects of logging exhibited that ponderosa pine cover declined as the area of selection logging increased from 10 to 30-percent of the landscape ($r = -0.55$). Such generalizations for the entire eastside are risky, however, because variability among watersheds was high. More detailed analysis of the complete set of watershed data may address this question more adequately.

The range of variability in ecosystem attributes is an important element of the ecosystem management paradigm (Risbrudt 1992). Ranges of variation from our work in the Grande Ronde can be compared to the estimates by Caraher and others (1992) for the marine physiographic zone of the Blue Mountains ecoregion. Caraher estimated the historical ranges of natural variability of the Douglas-fir and true-fir early-seral stage as 20 to 40-percent of forest area, mature parklike stands as 20 to 40-percent, and late-seral multistory stages as 50 to 80-percent of the forested landscape.

We used our standard error of the stratified mean as an estimate of variability that includes 68-percent of the sample means at the basin scale. We estimated the range of variation that occurred about 40 years ago to be 20 to 30-percent of the basin area in early-seral stages (seedling-sapling-pole class [SSP]), similar to an estimate by Caraher and others (1992); in mature parklike structure, 10 to 25-percent, which is lower than Caraher's estimate (fig. 14). Our estimates include all forest types, including subalpine fir. Estimation of the range of late-seral multistory forest would require combining our young, mature, and old-forest categories, so our data are not directly comparable for this category.

Caraher and others (1992) estimated the current area of early-seral forest was less than 20-percent of the forested landscape; we found the SSP class accounted for about 10-percent of the basin area. Likewise, they found that parklike stands were below the range of historical variation, mostly about 10-percent of the forested landscape; we found these stands accounted for a much smaller 1-percent of the total forest area in the Grande Ronde basin.

Caraher and others (1992) also estimated the historical range of variation and current area of high-density, low-vigor ponderosa pine and lodgepole pine stands in the Grande Ronde. High-density ponderosa pine stands were estimated to have been from 0 to 10-percent and lodgepole pine stands from 20 to 30-percent of historical forest landscapes. Current estimates of area for ponderosa pine are above the range of variation at 10 to 30-percent total area, but lodgepole pine is estimated to be within the 20 to 30-percent range of variation. Caraher and others definition of a “high-density stand” is not defined in terms of overstory and understory structure that can be translated easily for comparison with our data. Moreover, we did not estimate standard errors for stratified samples for structure classes of the individual overstory dominant species (appendix B) because the procedure was too lengthy for this report.

For a preliminary estimate of variability in high-density stands, we calculated the standard error of our sample mean using random sampling methods instead of stratified sampling methods. Our estimates of variability for ponderosa pine are 0.6 to 2.3-percent for the single canopy SSP class; 0.2 to 1.3-percent for the two-layered young class; and 4.5 to 10.6-percent for the two-layered mature stage. These values are within the historical range defined by Caraher and others (1992) for ponderosa pine. The first two classes are probably most similar to what Caraher considers high-density stands, but further definition of high-density using canopy closure might yield different, but probably not much different, estimates. Current estimates of percentage area exhibited the SSP and young stands were above the range of historical variation, as were Caraher’s estimates but the mature class was below the historical range. Lodgepole pine in all size classes was less than 5-percent of historical and current landscape area in the Grande Ronde, which was far smaller than the 20 to 30-percent historical range of variability and current estimates of Caraher and others.

## Landscape Pattern

Fire exclusion in the Grande Ronde appears to have simplified landscapes as hypothesized. Wilderness watersheds became less diverse and more contiguous, and managed watersheds became more diverse and fragmented. Analysis of change in patterns in all watersheds from all basins revealed clear relations between increased logging and decreased patch sizes and contagion (increased fragmentation), as well as increased patch and edge density. Substantial change in pattern occurred even in the absence of logging. Where logged area was high, the predictability of pattern change was low, that is, much residual variation was present, and variation occurred in both positive and negative directions. These results might be explained in terms of the underlying environmental gradients; other disturbances, or sampling methods.

Pattern is partially determined by environmental gradients, which constrain the effects of disturbance in altering pattern (Turner 1989). Environmental gradients influence the basic landscape pattern by way of the interactions of landform, soils, and climate. As environmental gradients change across a river basin, the underlying vegetation pattern also changes. If patch sizes of logged areas match the patch size determined by background gradients, then little change in the whole pattern will be recorded in terms of patch size and density. This approach was taken in some “new forestry” plans for watershed management and fire recovery, such as the Shasta Costa Timber Sale and Integrated Management Plan (Siskiyou National Forest 1991), and the Silver Fire Recovery Plan (1990) of the Siskiyou National Forest. Logged patches that do not match the “grain” of the landscape will result in fragmentation. Fragmentation or changes in the distribution of vegetation and pattern may be acceptable, however, within limits of variation determined from studies of disturbance regimes in similar landscapes that have natural conditions, however these might be defined. No doubt, much of the residual variation also could be explained by disturbance from insects and diseases (Caraher and others 1992; Gast and others 1991; Hessburg and others 1993).

Some of the effects we observed may also be a result of sample size and distribution. A larger sample of wilderness areas in all the basins would allow better analysis of the effects of timber harvest and other management that follows from a well-developed road system. Different analysis techniques would also allow for a more sophisticated analysis of our sample data. Our stratified random sampling design by subbasins was the best design for assessing basin-wide changes. Further stratification of the data by wilderness and managed forest or by elevation zones presented an unconventional "post-stratification" statistical analysis that was not resolved for this report. We have 36 additional pairs of sample watersheds already mapped by the original Forest mapping teams, but these data have not been entered for analysis in GIS for lack of time and resources.

## Wildlife habitat

Changes in habitat area can be expected to affect species that depend on those habitats. Loss of old-forest and late-seral stands may affect species such as the goshawk and pine marten, that are associated with those habitats (Thomas 1979). Likewise, species associated with early successional stages may decline with increasing successional advancement of landscapes. A detailed assessment of the effects of landscape change on animal communities could now be completed and would require a complex analysis that combines habitat areas determined in this assessment and information on wildlife habitat relations (for example, Raphael 1988, Raphael and others 1988). Detailed wildlife-habitat relations data, including density of species, do not exist for most eastside vertebrate species, but wildlife habitat relations data for the Blue Mountains (Thomas 1979) might be used to make assessments of relative change in the abundance of species or groups of species with changes in habitat area. The implications of change in landscape pattern will necessitate a separate analysis based on life history and population structure of individual species or groups (for example, Hansen and Urban 1992; Lehmkuhl and Ruggiero 1991).

A basic assessment of risk to wildlife associated with changes in vegetation pattern can be made from the empirical and theoretical literature on population viability analysis (Gilpin and Soule 1986) and risk analysis Gurgensen and others 1993; Marcot 1986). In general, the primary consideration in determining wildlife risk to landscape change is the rarity of the species in terms of relative abundance and geographical distribution. Rare or uncommon species will more likely be susceptible to fragmentation simply from the loss of habitat but also from isolation of subunits of the populations when habitats become fragmented. After rarity, two primary considerations are body size, which influences population density, and mobility, which determines how well the species overcomes isolation of habitat patches. Lehmkuhl and Ruggiero (1991) contended that small species such as amphibians and small mammals are susceptible to fragmentation because they are relatively less mobile than large animals and are more susceptible to isolation in fragmented patches. Their small size allows for relatively large population densities in small patches, however, which allows populations to persist longer in isolation. Large mammals and birds, to the extent they depend on specific habitat, are susceptible from the standpoint that large body size requires large habitat area, but their high mobility allows them to more easily overcome fragmentation of habitat patches. Medium-size birds and mammals, such as pine marten, and forest owls, are most susceptible to fragmentation. Relatively large body size dictates greater resource requirements and smaller population sizes than small species, hence less ability to persist in isolation. Also, intermediate mobility relative to the larger species suggests that habitat fragmentation and isolation will require greater effort and risk to predation in finding adequate resources.

Eastside wildlife are adapted to a landscape made diverse by environmental and disturbance gradients. A critical question to answer before setting goals for wildlife in relation to landscape pattern is whether current eastside conditions are more or less diverse today than 100 years ago before fire suppression began to alter landscape pattern. We are now seeing landscape patterns quite different from those occurring before fire exclusion and other human intrusion. Another point to consider is that timber harvest and insect outbreaks, and disease infestations have partially altered or reversed the homogenizing effect fire suppression has had on landscape patterns during the last 90 years. The question surrounding eastside forest diversity could be better answered by modeling landscape change retrospectively.

## Vegetation Management

Identification of ecosystem attributes, processes, scale, and range of variation are critical aspects of managing vegetation and ecosystems in general (Diaz and Apostol 1992, Risbrudt 1992). We have identified elements of eastside forested landscapes and patterns of change over the last 35 to 50 years, and estimated the range of variation occurring then. Estimating the range of variation for an earlier period before fire suppression will require reconstructing landscapes, most likely by analysis of age-class distributions.

An important question is: What estimate of variation is most appropriate for management? We used the standard error of the stratified sampling mean but could have used other estimators to define the range of variability. The range of values (minimum and maximum), standard deviation, or confidence intervals with specified probabilities of error (for example, 90 or 95-percent) could alternatively be used to define the range of variability. We believe that the range is too strongly influenced by outliers, or extreme values, to be useful except in a general sense; this belief was borne out by our data, which showed that watershed samples varied widely in vegetation attributes. Estimating the standard deviation of an attribute from a stratified random sample such as ours is problematic because the variance of a variable is composed of variation within subbasins and among subbasins. Thus, choosing which estimate of variability was most relevant to managing a particular ecosystem would be essential. Moreover, estimating stratified sampling variation requires techniques more complex than commonly used in standard statistical analysis based on simple random sampling. The standard error, which we have used to estimate ranges of variation, is more simply calculated for stratified samples than is the standard deviation. Because most ecosystem assessment for management will be sample-based, the standard error is perhaps the most appropriate estimate of variation with which to compare current and historical conditions.

## Insect and Disease Hazard

Insect and disease hazards have changed in response to several management practices. Fire and insect defoliator suppression and selective harvesting appear to be primary causes of change in vegetation conditions and associated hazards (Agee 1993, Hessburg and others 1993, Oliver and others 1993). Management practices have increased insect or pathogen hazards relative to historical baseline conditions in some watersheds and have decreased them in others. With few exceptions, basin-scale analysis of insect and disease hazards is clearly less useful than analysis of watershed conditions. Future analyses should focus at the watershed scale.

Trends reported here are probably conservative compared with the scale of change in vegetation conditions that may have actually occurred since the turn of the century when active fire suppression began. The oldest available aerial photographs used to interpret historical vegetation conditions in any watershed or basin came from the mid-1930s; most photos were from the 1940s and 1950s. Unfortunately, we were unable to locate older photos that would show change from 1890. Such photos would likely provide evidence that changes in vegetation conditions and associated hazards since 1900 are much greater than we are currently able to show.

**Defoliators**—As was expected, the watersheds with the greatest defoliator hazard occurred in the Douglas-fir and grand (white) fir series. Increases in hazard were associated with increased host abundance, increased canopy layering and host density, and increased continuity among host stands. Hazard increased in about 20-percent of the sample watersheds but decreased in about 25-percent. Watersheds with decreased hazard had Douglas-fir and grand fir overstories that had been harvested in recent decades, influencing canopy layering, host abundance, and host type continuity. Also, numerous stands had been regenerated, as was particularly apparent in the Grande Ronde basin. We intend to explore in more detail the bases for hazard increases and declines in future analyses.

Hazard data suggested that defoliator hazard stayed roughly constant on about 55-percent of the sample watersheds over the last 40 to 50 years. We suspect this means two things: that a fair amount of defoliator hazard was normal in some landscapes of the Douglas-fir and grand fir series; and that change in vegetation conditions occurred before the period we have examined resulting in high defoliator hazard all during our sample period. We also suspect that examination of vegetation conditions on the eastside of the Cascades before the turn of this century would reveal dramatically different landscape composition and structure. Study of specific landscape-development histories would reveal much of the needed information about former and future landscape development trajectories and associated insect and disease hazard. The clearest picture of sustainable future conditions and their range of variability will most likely come from such studies.

**Bark beetles**—Douglas-fir beetle hazard increased in about 30-percent of the sample watersheds, indicating measurable increases in size, age, abundance, and density of Douglas-fir. Our field observations of the major Douglas-fir beetle mortality areas of the last 6 years suggest that Douglas-fir in riparian zones have been hardest hit by bark beetles.

Western pine beetle hazard to mature and overmature ponderosa pines decreased to some degree in about 45-percent of the sample watersheds, most likely because of extensive harvesting of ponderosa pine over the last 100 years (Oliver and others 1993). Selective harvest and overstory removal targeted mature and overmature ponderosa pine overstories of mid- and late-seral stands (appendix B). Effective fire suppression has allowed ponderosa pine, Douglas-fir, and grand fir understories to develop under old pine overstories, resulting in greater competition for limited soil moisture and nutrients. Ultimately, old pine overstory trees become stressed and succumb to western pine beetle attack.

Changes in western pine beetle (Type 2) and mountain pine beetle (Type 2) hazards in immature, overstocked ponderosa pine were likely the result of fire exclusion and timber harvest. Bark beetle hazards in young, overstocked ponderosa pine stem from the fire events that created the stands. Regenerated areas after large fires currently have high hazard to western and mountain pine beetles. Ponderosa pine seeded in at high densities after fire, and densities have remained high in some watersheds to the present day. Other watersheds have been thinned, and bark beetle hazards have been reduced. A good example of this is the "Blackbark Project" on the Deschutes National Forest, where over 55,000 ha of overcrowded, young ponderosa pine were thinned under an accelerated program to avoid catastrophic losses to beetles.

Mountain pine beetle, Type 1 hazard, increased substantially in only 10-percent of the watersheds. Likewise, only 10-percent of sample watersheds displayed a substantial reduction in Type 1 hazard. In general, mountain pine beetle outbreaks have been somewhat longer, more extensive, and more frequent in this century than historically (Hessburg and others 1993). As a result, much of the lodgepole pine mortality that might have occurred, has already occurred, especially in the lodgepole dominated watersheds of the Grande Ronde and Deschutes basins. Type 1 mountain pine beetle hazard depends primarily on lodgepole pine size, age, and density. In mixed and pure stands of lodgepole pine, many of the large-diameter trees have already been killed by beetles. In watersheds of the Pend Oreille and Methow basins, where Type 1 hazards were moderate, dense lodgepole pine stands are common, but tree diameters are not yet sufficiently large to support a catastrophic outbreak.

Fir engraver hazards declined in 70-percent of Grande Ronde watersheds, which may be attributed to recent extensive harvest of sawtimber grand fir (Oliver and others 1993). The decline in fir engraver hazard in the Grande Ronde basin has not come without cost. Grand fir stumps are readily infected by spores of annosum root disease (S-group), and we can assume that future S-group annosum root disease incidence will be correspondingly high, unless stumps were treated with borax immediately after harvest (Hessburg and others 1993).

**Dwarf mistletoes**—Douglas-fir dwarf mistletoe hazard is greatest on poor sites where Douglas-fir is abundant, and canopies are layered. This mistletoe is among the most widespread and damaging of all forest diseases (Hessburg and others 1993). In this hazard analysis, only one watershed received a score that rated as high hazard, four others were at the top end of moderate; all others were low or moderate hazard. Unless Douglas-fir dwarf mistletoe is exceedingly widespread and severe, it can probably be considered at best a watershed-scale hazard. Stands and subbasins are influenced by its widespread occurrence, but rarely is the influence of this disease itself of landscape proportions. As a "ladder" fuel that carries surface fire to crowns, the severity of Douglas-fir dwarf mistletoe may be an important landscape consideration.

Western dwarf mistletoe occurs in only about 25-percent of ponderosa pine stands, and is likewise not a watershed scale hazard (Hessburg and others 1993). Hazards only increased in Grande Ronde and Deschutes watersheds where ponderosa pine understones had developed because of the lack of regular underburning. All watersheds rated a score of low hazard for this insect, and all changes were within the low hazard rating. Similarly, few changes occurred in either western larch or lodgepole pine dwarf mistletoe hazard. Mountain pine beetle mortality over the years has created multicohort stands, thereby increasing hazard. Reductions in larch dwarf mistletoe hazard in a few watersheds of the Grande Ronde and Pend Oreille basins appear to be associated with harvest removal of larch overstories.

**Root diseases**—In general, Douglas-fir and grand fir have increased in abundance in most watersheds, and root disease has increased accordingly where it was present in historical infection centers. Management has increased the scale of effects of S-group annosum root disease as a disturbance within the grand fir series. By having the capacity to spread to new sites by spores,.grand fir stumps created by harvesting are new future foci of this disease. This effect can be negated, if seral species are grown. If grand fir is to be an important part of these future stands, we can expect substantial increases in mortality from this root disease, which should be considered when developing alternative management strategies.

Clearly, the effects of insects and diseases have increased in some watersheds and decreased in others. Under ecosystem management, insect and pathogen populations and effects should be managed within historical ranges of variability. Pathogen and insect disturbance effects would ordinarily be important enhancements to a wide variety of essential ecological processes; that is currently not the case. Landscape structure and composition should be managed within historical ranges of variability to properly rescale insect and pathogen disturbances. Pathogens and insects are currently responding to the increasing abundance of their hosts. When fire or its effects are restored, landscapes will take on many of the characteristics common to historical landscapes that naturally regulated the extent and effects of insect and pathogen disturbances.

## Additional Research Needs and Opportunities

To develop management strategies for ecosystems that approximate natural processes, managers will need to be knowledgeable of the ecological effects of natural disturbances such as fire, insects, and diseases. Plan development and implementation to sustain ecosystem processes and to approximate their effects will require intensive ecological characterization of planning areas.

This report is a first attempt at such an ecological assessment and it describes basic variability in forest composition, structure, patterns of change, and associated hazards. Many research and management questions are still to be answered. Further analysis of these data, and collection of supporting data will, no doubt, reveal new information useful in ecosystem management.

With a small investment, the current data base could be both doubled and vastly improved-simply by digitizing into GIS the second-priority watersheds, which were mapped by Forest Service teams for this assessment, but not yet digitized. The structure and methods for completing more comprehensive analyses have been formulated through this initial analysis of the data base; further work could begin immediately and move ahead quickly. We propose the following additional research than can be accomplished by building onto the base already established.

**Additional research related to vegetation—**

- Validate qualitative, large-scale, and less-costly ecosystem assessments, such as Caraher and others (1992) approach used for the Blue Mountains; or use the data for a double-sampling approach to other such large-scale assessments.
- Examine in detail the variation in ecosystem properties by vegetation series and management history, such as, wilderness vs. managed forest.
- Examine pathways of vegetation change through more detailed analyses of vegetation composition and structure, and through estimation of transition frequencies from historical to current times to better model landscape change.
- Determine how the scale of vegetation pattern within watersheds has changed—that is, the scale of similarity from historical to current times.
- Identify ecological landscape units in conjunction with existing plant association data collected extensively throughout the eastside region by National Forest ecologists.
- Use data to assess different alternative landscape management configurations, or desired future conditions, for ecosystem management.
- Examine how changes in landscape pattern have affected the potential spread of disturbances, such as insects, diseases, and fire, across the landscape.
- Analyze the effect of landscape change on wildlife habitat and species diversity.

## SUMMARY

We analyzed historical and current vegetation composition and structure in 49 sample watersheds, primarily on National Forests, within the Deschutes and Grande Ronde river basins in eastern Oregon, and in the Methow, Wenatchee, and Yakima river basins in eastern Washington. Historical vegetation patterns were mapped from aerial photographs taken primarily from 1932 to 1959; current vegetation patterns were mapped from aerial photographs taken from 1985 to 1992. We described vegetation attributes, landscape patterns, the range of historical variability, and scales of change.

Forest cover has increased in the Deschutes, Grande Ronde, and Pend Oreille river basins by 8-percent from historical cover, but it remains relatively unchanged in the other three river basins. Forests have become more dense in vertical and horizontal canopy structure. Open bare-ground and grass-forb understories have declined, as understory cover increased with regeneration of shade-tolerant understory species. Horizontal stand density increased in some areas, as shown by increasing size and density of tree clumps within stands. The distribution of forest age classes and structure changed as a result of decreases in early-seral and old-forest structural stages and increases in multiple-canopy, young and mature stands.

The percentage of visible dead trees increased in all river basins. High concentrations of dead trees (10 to 70-percent dead) were mostly found in the Deschutes and Grande Ronde basins, but the affected areas were less than 20-percent of the basin areas. In the Wenatchee and Yakima basins, however, dead trees were less concentrated, accounting for a smaller percentage of the trees in a stand (< 10-percent dead), but this condition was more widespread, occurring in 40 to 50-percent of the basin areas.

Landscape pattern has become more diverse and fragmented over time in five of the six river basins. Current patch sizes are smaller, and edge and patch densities are greater than 50 years ago. Diversity either changed little over time, or changed inconsistently among watersheds. Change in landscape pattern in the Grande Ronde was entirely different, and more closely followed the pattern of change expected with fire suppression. Pattern in wilderness watersheds became more homogeneous rather than fragmented. Diversity decreased primarily because of the 325-percent increase in the area of mid-seral stands. Other landscape pattern attributes varied widely among Grande Ronde watersheds.

Insect and disease hazards changed little at the river basin scale because of considerable variation at the watershed scale. Basin-wide changes were usually less than 10-percent different than historical levels. Moreover, changes in hazard among basins were often inconsistent in the direction, except perhaps for western dwarf mistletoe hazard, which increased in the Grande Ronde (29-percent) and Pend Oreille (11-percent) basins. Large changes in insect and disease hazards were common in individual watersheds, however, which indicated watersheds were the appropriate scale for many insect and disease hazard analyses.

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**Conversion factors**

| Multiply | by | to obtain |
|---|---|---|
| *METRIC* | | *ENGLISH* |
| cm | 0.3937 | inches |
| hectares | 2.471 | acres |
| meters | 3.281 | feet |
| meters | 0.0497 | chains |
| kilometers | 0.6214 | miles |

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# APPENDIX A: ASSESSING LANDSCAPE SUSCEPTIBILITY TO INSECTS AND DISEASES: A SUMMARY OF HAZARD VARIABLES AND ANALYSIS METHODS

## INTRODUCTION

In this section, we summarize hazard analyses used in the terrestrial landscape assessment to evaluate historical and current susceptibility of vegetation to insects and diseases, in selected river basins. Sample watersheds from the Deschutes, Grande Ronde, Yakima, Wenatchee, Methow, and Pend Oreille river basins were evaluated. Aerial photo interpretation yielded maps of both historical and current vegetation composition and structure for each sample watershed.

### Insects

**Defoliators**—The principal lepidopteran defoliators of eastern Oregon and Washington coniferous forests are the western spruce budworm' and the Douglas-fir tussock moth. Eastside forests are primarily comprised of areas of low-to-moderate budworm outbreak frequency (Kemp 1985a, 1985b), although small areas of high outbreak frequency are interspersed throughout. Areas of high outbreak frequency are characterized by low annual precipitation, droughty growing seasons, cold winters, and cool spring and fall temperature regimes. Low outbreak-frequency areas are characterized by high annual precipitation, mild winters, and warmer spring and fall temperature regimes. The Deschutes and Pend Oreille River basins, and the southern half of the Yakima River basin are in love frequency areas. The Methow, Wenatchee, and Grande Ronde River basins, and the northern half of the Yakima basin are in moderate frequency areas.

**Mapping susceptibility to budworm**—Western spruce budworm (WSB, see table 1) and Douglas-fir tussock moth (DFTM) hazards were combined, although the hazard variables we used were most appropriate to the budworm. Defoliator hazard was mapped for stand polygons containing one or more host species. Stand polygons that did not contain any host species in the understory or overstory were given the lowest possible score fox each of the variables. Defoliator hosts are: Douglas-fir, PSME; grand fir, ABGR; white fir, ABCO; subalpine fir, ABLA2; Pacific silver fir, ABAM; Shasta red fir, ABMA; noble fir, ABPR; Engelmann spruce, PIEN; and western larch, LAOC. Defoliator hazard was scored for each polygon from stand attributes associated with five hazard variables: site quality—overstory and understory species composition; host abundance—host crown cover percent; canopy structure—number of canopy layers; density—total crown cover percent; and continuity of host types—according to host - host transition frequencies.

*Ranking site quality:* 1 = ABAM, ABPR, ABMA, TSHE, THPL, and TSME sites; 2 = ABLA2, PIEN, LAOC, PICO sites; 3 = PSME, ABGR, ABCO sites. Site quality was determined by using the most shadetolerant species, which were identified in the classification of understory and overstory species composition.

*Ranking host abundance:* 1 = Nonhost species or < 30-percent crown cover of host species; 2 = 30-50-percent crown cover of host species; 3 = > 50-percent crown cover of host species. Host abundance was calculated by using total crown cover and overstory crown cover polygon data, and overstory and understory species data. Overstory crown cover was subtracted from total crown cover, to obtain apparent understory crown cover. (Maximum crown cover from photo interpreted data was 100 percent.

[1] **Scientific names for all taxa mentioned are given in appendix C.**

In reality, some overstory and understory crown covers would sum to a value greater than 100 percent.) Polygon overstories and understories were classified as having one, two, or three species. When an overstory or understory was classified as having more than one species, they were assumed equal in abundance, which is consistent with instructions provided to photo-interpretive teams. Host abundance was obtained by computing the overstory and understory crown cover in all defoliator host species.

*Ranking canopy structure:* 1 = one layer of a host species; 2 = two layers of host species; 3 = more than two layers of host species. Canopy structure was taken from overstory and understory species and from canopy-layering data.

*Ranking density:* 1 = < 30-percent total crown cover; 2 = 30 to 60-percent total crown cover; 3 = > 60-percent total crown cover. Density was taken directly from total crown cover data.

*Ranking continuity of host types:* 1 = < 20-percent of the total cell edges in a watershed as host-host edges; 2 = 20 to 40-percent of the total cell edges in a watershed as host-host edges; 3 = > 40-percent of the total cell edges in a watershed as host-host edges. Continuity of host types was estimated for polygons using host - host transition frequencies and rasterized watershed data in GIS.

Carlson and others (1985) also used host age and an index of vigor to rate stand susceptibility to budworm. Given the data sources available to this assessment, we could not compute a comparable measure of relative density from our photo-interpreted data. Our measures of stand density using total crown cover and canopy layering should give some indication of relative differences in stand vigor. In eastern Oregon and Washington, stand age and vigor appear to influence the extent of damage associated with budworm outbreaks, but the relation between stand age, vigor, and susceptibility is less clear. We do not include host age or vigor variables in this hazard rating.

Once values for the first four hazard variables were computed for every stand polygon in a watershed, the four ratings were summed for the individual polygons. This sum was the polygon defoliation hazard rating. Partial watershed hazard ratings were computed as the weighted sum of the polygon ratings for hazard variables 1 to 4. Weighting factors were derived by computing the ratio of individual polygon area to total sample watershed area. Partial watershed hazard ratings were completed by adjusting for continuity of host species.

Continuity of host species was scored for whole watersheds by using length-of-edge analyses. Watershed polygon maps were converted to raster format in GIS, based on the presence of host species in the overstory or understory. The total number of edges between host species (host-host edges) cells was divided by the total number of cell edges in each sample watershed. Low continuity (ranking = 1) was indicated by less than 20-percent of the total cell edges in a watershed as host-host edges. Moderate continuity (ranking = 2) was indicated by 20 to 40-percent of the total cell edges in a watershed as hosthost edges. Watersheds with high continuity (ranking = 3) of host types were indicated by more than 40-percent of the total cell edges as host-host edges. This index of host continuity was sensitive to the proportion of watershed areas in host types, as well as to the size and spatial distribution of host species stands. Watershed host continuity scores were added to partial watershed hazard ratings to yield complete watershed defoliator hazard ratings.

Watershed scores of 7 or less had LOW susceptibility to defoliation. Watershed scores of 8 to 10 had MODERATE susceptibility to defoliation. Scores greater than 11 indicated HIGH susceptibility to defoliation.

**Bark Beetles**—Bark beetle hazards were assessed for the Douglas-fir beetle, western pine beetle, mountain pine beetle, and fir engraver. Spruce beetle hazard was not evaluated. Without recent fire or windthrow, hazard for spruce beetle in Engelmann spruce could not be readily identified and mapped.

**Douglas-fir beetle**—Douglas-fir beetle outbreaks are primarily associated with large wind, fire, drought, and defoliation events. Areas with abundant dwarf mistletoe and root disease in Douglas-fir also support higher Douglas-fir beetle populations in eastern Oregon and Washington. At least 40-percent of the Douglas-fir in eastern Oregon and Washington are infected with Douglas-fir dwarf mistletoe (Bolsinger 1978). An additional 5 to 10-percent are root diseased (Byler 1988). The Douglas-fir beetle is routinely responsible for the demise of Douglas-fir severely infected with dwarf mistletoe and root disease.

**Mapping susceptibility to Douglas-fir beetle-Douglas**—fir beetle hazard on the eastside is correlated with the incidence and severity of Douglas-fir dwarf mistletoe, Armillaria root disease, laminated root rot, drought, and defoliation. Douglas-fir beetle hazard was mapped for polygons containing Douglas-fir 9 in. d.b.h. and larger. Stand polygons that did not contain any host species in the understory or overstory, were given the lowest possible score for each of the variables. In this analysis, Douglas-fir beetle hazard was scored for each polygon from stand attributes associated with six hazard variables: site quality—overstory and understory species composition; host abundance—host crown cover percent; canopy structure—number of—canopy layers; host age—overstory and understory size class; density—total crown cover percent; and continuity of host types for defoliators—according to the continuity index used for defoliators above.

*Ranking site quality:* 1 = ABAM, ABPR, ABMA, TSHE, TSME, THPL sites; 2 = ABLA2, PIEN sites; 3 = PSME, ABGR, ABCO sites. Site quality was determined as with the defoliators above.

*Ranking host abundance:* 1 = other species or < 30-percent crown cover in PSME; 2 = 30 to 50-percent crown cover in PSME; 3 = > 50-percent crown cover in PSME. Host abundance was calculated by using total crown cover as well as overstory crown cover polygon data, and overstory and understory species data. Overstory crown cover was subtracted from total crown cover to obtain apparent understory crown cover. Host abundance was obtained by computing the overstory and understory crown cover in PSME greater than 9 in. d.b.h..

*Ranking canopy structure:* 1 = 1 mixed species layer including PSME; 2 = 1 PSME layer; 3 = 2 or more PSME layers. Canopy structure was computed from overstory and understory species and from canopy-layering data.

*Ranking host age:* 1 = small sawtimber PSME (9 to 15.9 in. d.b.h.) overstory and understory; 2 = medium or large sawtimber PSME (16 to 25 in. d.b.h.) overstory and understory; 3 = mature or overmature sawtimber PSME (>25 in. d.b.h.) overstory and understory. Host age was approximated from overstory and understory size-class data.

*Ranking density:* 1 = < 50-percent total crown cover; 2 = 50 to 80-percent total crown cover; 3 = > 80-percent total crown cover. Density was taken directly from total crown cover data.

*Ranking continuity of host types for defoliators:* 1 = < 20-percent of the total cell edges in a watershed as host-host edges; 2 = 20 to 40-percent of the total cell edges in a watershed as host-host edges; 3 = > 40-percent of the total cell edges in a watershed as host-host edges. Continuity of host types was estimated for polygons using length of edge analyses and rasterized watershed data in GIS.

Once values for the six hazard variables were computed for every stand polygon in a watershed, the ratings were summed for the individual polygons. This sum was the stand polygon Douglas-fir beetle hazard rating. Watershed hazard ratings were computed as the weighted sum of the polygons. Polygon weighting factors were derived by computing the ratio of individual polygon acres to total sample watershed acres. Watershed scores of 6 to 9 had LOW susceptibility to Douglas-fir beetle. Watershed scores of 10 to 13 had MODERATE susceptibility. Scores 14 indicated HIGH susceptibility.

**Western pine beetle**—Western pine beetle affects ponderosa pine (PIPO) in eastern Oregon and Washington. Large overmature ponderosa pine are susceptible as are immature, overstocked pole- and sawtimber-sized pine. The western pine beetle is often responsible for killing ponderosa pine severely infected by mistletoe, by P-group annosum root disease, by Armillaria root disease, as well as trees severely stressed by persistent drought.

**Mapping susceptibility to western pine beetle**—Western pine beetle hazards are correlated with stand age, tree vigor, stand density, the incidence and severity of western dwarf mistletoe, Armillaria root disease, P-group annosum root disease, and drought susceptibility. Western pine beetle hazard was mapped for polygons containing ponderosa pine 9 in. d.b.h. and larger. Stand polygons that did not contain any host species in the understory or overstory, were given the lowest possible score for each of the variables. In this analysis, two types of Western pine beetle hazard were scored for each polygon from stand attributes associated with four or five hazard variables: site quality—overstory and understory species;. host abundance—host crown cover percent; host age—overstory size class; density—total crown cover percent; and density—degree of crown differentiation.

**Type 1 western pine beetle hazard - Damage to mature and overmature PIPO—**
*Ranking site quality:* 1 = ABGR, ABCO, PICO; 2 = PSME; 3 = PIPO, also PSME-PIPO. Site quality was determined by using the most shade-tolerant species identified in the classification of understory and overstory species.

*Ranking host abundance:* 1 = other species or < 30-percent crown cover in PIPO; 2 = 30 to 50-percent crown cover in PIPO; 3 = > 50-percent crown cover in PIPO. Host abundance was obtained by computing the overstory and understory crown cover in PIPO.

*Ranking host age:* 1 = small sawtimber PIPO (9 to 15.9 in. d.b.h.) overstory and understory; 2 = medium or large sawtimber PIPO (16 to 25 in. d.b.h.) overstory and understory; 3 = mature or overmature sawtimber PIPO (> 25 in. d.b.h.) overstory and understory. Host age was approximated from overstory size-class data.

*Ranking density:* 1 = < 50-percent total crown cover; 2 = 50 to 80-percent total crown cover; 3 = > 80-percent total crown cover. Density was taken directly from total crown cover data.

Once values for the four hazard variables were computed for every stand polygon in a watershed, the ratings were summed for the individual polygons. This sum was the stand polygon Type 1 western pine beetle hazard rating. Watershed hazard ratings were computed as the weighted sum of the polygons. Polygon weighting factors were derived by computing the ratio of individual polygon acres to total sample watershed acres.

Watershed scores of 4 to 6 had LOW susceptibility to western pine beetle. Watershed scores of 7 to 9 had MODERATE susceptibility. Scores of 10 to 12 indicated HIGH susceptibility.

**Type 2 WPB Hazard - Damage to immature, overstocked PIPO 16 in. d.b.h. and smaller—**
*Ranking site quality:* 1 = ABGR, ABCO; 2 = PSME; 3 = PIPO, also PSME-PIPO.

*Ranking host abundance:* 1 = other species or < 30-percent crown cover in PIPO; 2 = 30-50-percent crown cover in PIPO; 3 = > 50-percent crown cover in PIPO.

*Ranking host age:* 1 = seedling and sapling PIPO (< 5 in. d.b.h.); 2 = poletimber PIPO (5 to 8.9 in. d.b.h.); 3 = small sawtimber PIPO (9 to 15.9 in. d.b.h.).

*Ranking density by degree of crown differentiation:* 1 = highly differentiated (> 100-percent difference in crown diameters); 2 = moderately differentiated (30 to 100-percent difference in crown diameters); 3 = poorly differentiated (< 30-percent difference in crown diameters).

*Ranking density by total crown cover:* 1 = < 50-percent total crown cover; 2 = 50 to 80-percent total crown cover; 3 = > 80-percent total crown cover.

Site quality, host abundance, and host age were approximated from data as before. Density was taken directly from total crown cover and crown differentiation data. The cumulative Type 2 western pine beetle hazard rating for the watershed was calculated as for the Type 1 hazard.

Watershed scores of 5 to 7 had LOW susceptibility to western pine beetle. Watershed scores of 8 to 10 had MODERATE susceptibility. Scores of 11 to 15 indicated HIGH susceptibility.

**Mountain pine beetle**—Mountain pine beetles primarily attack ponderosa pine, lodgepole pine - PICO, and western white pine in eastern Oregon and Washington. Western white pine 14 inches d.b.h. and larger, having more than 140 sq. ft. of associated basal area, and older than 140 years are routinely massattacked and killed by the mountain pine beetle. Mountain pine beetle hazard for western white pine was not addressed in this hazard assessment because methods of stratifying hazard variables in acceptable detail were unavailable. Poletimber and small sawtimber-sized ponderosa pine and overstocked lodgepole pine are also susceptible. The mountain pine beetle also kills mature and overmature lodgepole pine and trees severely stressed by persistent drought.

**Mapping susceptibility to mountain pine beetle**—Mountain pine beetle hazards in lodgepole pine (PICO) and ponderosa pine are highly correlated with stand age, overstory size class, and density. Mountain pine beetle hazard was mapped for stand polygons containing host species. Mountain pine beetles hosts in this analysis are lodgepole pine and ponderosa pine. Stand polygons that did not contain any host species in the understory or overstory, were given the lowest possible score for each of the variables. In this analysis, two types of mountain pine beetle hazard were scored for each polygon from stand attributes associated with five hazard variables: site quality—overstory and understory species; host abundance - host crown cover percent; host size—overstory size class; density—total crown cover percent; and density—degree of crown differentiation.

**Type 1 MPB Hazard - Damage to overstocked PICO only—**
*Ranking site quality:* 1 = ABLA2, PIEN, TSME; 2 = ABGR, ABCO; 3 = PICO, PSME.

*Ranking host size:* 1 = seedling and sapling PICO (< 5 in. d.b.h.); 2 = poletimber PICO (5 to 8.9 in. d.b.h.); 3 = small sawtimber PICO (9 to 15.9 in. d.b.h.).

*Ranking host abundance:* 1 = other species or < 30-percent crown cover in PICO; 2 = 30 to 50-percent

crown cover in PICO; 3 = > 50-percent crown cover in PICO.
*Ranking density by degree of crown differentiation:* 1 = highly differentiated (> 100-percent difference in crown diameters); 2 = moderately differentiated (30 to 100-percent difference in crown diameters); 3 = poorly differentiated (< 30-percent difference in crown diameters).

*Ranking density by total crown cover.* 1 = < 50-percent total crown cover; 2 = 50 to 80-percent total crown cover; 3 = > 80-percent total crown cover.

Site quality, host abundance, and host age were approximated from data, as before. Density was taken directly from total crown cover and crown differentiation data. The cumulative Type 1 mountain pine beetle hazard rating for the watershed was calculated as for the Type 1 western pine beetle hazard above.

Watershed scores of 5 to 7 were LOW susceptibility to mountain pine beetle. Watershed scores of 8 to 10 had MODERATE susceptibility. Scores of 11 to 15 indicated HIGH susceptibility.

**Type 2 MPB hazard - Damage to immature, overstocked PIPO only**—Analysis is identical to that used for Type 2 western pine beetle hazard above.

**Fir engraver**—All true firs are host to the fir engraver. Fir engraver beetles are often described as secondary bark beetles: beetles lacking a means of overcoming robust trees, that instead attack and overcome trees stressed by drought or pathogens. Grand fir and white fir are primarily affected by fir engraver because they are sensitive to extended drought, and extremely susceptible to three major root diseases: laminated root rot, S-type annosum root disease, and Armillaria root disease. During drought-free periods, fir engraver mortality is an excellent indicator of root disease distribution and severity within the grand and white fir zones.

**Mapping susceptibility to fir engraver**—Fir engraver stand hazard is correlated with the incidence and severity of Armillaria root disease, laminated root rot, S-type annosum root disease, stand drought susceptibility, and defoliation severity. Fir engraver hazard was mapped for stand polygons containing one or more host species. Fir engraver hosts in this analysis are ABGR, ABCO, ABLA, ABAM, ABPR, and ABMA. Stand polygons that did not contain any host species in the understory or overstory were given the lowest possible score for each of the variables. In this analysis, fir engraver hazard was scored for each stand polygon from stand attributes associated with six hazard variables: site quality—overstory and understory species composition; host abundance—host crown cover percent; canopy structure—number of canopy layers; host age—overstory size class; density—total crown cover percent; and continuity of host types for defoliators—according to the continuity index used for defoliators above.

*Ranking site quality:* 1 = ABAM, ABPR, ABMA, TSHE, TSME, THPL sites; 2 = ABLA2, PIEN sites; 3 = ABGR, ABCO sites.

*Ranking host abundance:* 1 = nonhost species or < 30-percent crown cover in fir engraver host species; 2 = 30-50-percent crown cover in fir engraver host species; 3 = > 50-percent crown cover in fir engraver host species.

*Ranking canopy structure:* 1 = 1 layer of a fir engraver host species; 2 = 2 layers of fir engraver host species; 3 = > 2 layers of fir engraver host species.

*Ranking host age:* 1 = seedlings, saplings, and poles (< 9 in. d.b.h.); 2 = small sawtimber (9 to 15.9 in. d.b.h.); 3 = medium and large sawtimber (16 to 24 in. d.b.h.) and larger.

*Ranking density by total crown cover.* 1 = < 50-percent total crown cover; 2 = 50 to 80-percent total crown cover; 3. = > 80-percent total crown cover.

*Ranking continuity of host types for defoliators*: 1 = < 20-percent of the total cell edges in a watershed as host-host edges; 2 = 20 to 40-percent of the total cell edges in a watershed as host-host edges; 3 = > 40percent of the total cell edges in a watershed as host-host edges.

All stand polygons in a sample watershed were hazard rated according to site quality, host abundance, canopy structure, host age, density, and continuity of host types for defoliators as above. Once values for the six hazard variables were computed for every polygon in a watershed, ratings were summed for the individual polygons. This sum was the polygon fir engraver hazard rating. Watershed hazard ratings were computed as the weighted sums of the polygons.

Watershed scores of 6 to 9 had LOW susceptibility to fir engraver. Watershed scores of 10 to 12 had MODERATE susceptibility. Scores of 13 indicated HIGH susceptibility.

## Diseases

**Dwarf mistletoes**—The four principal dwarf mistletoes of the eastside are specific to Douglas-fir, ponderosa pine, lodgepole pine, and western larch. Ponderosa pine, western larch, and lodgepole pine are the major pioneering conifer species in most of the low- and mid-elevation plant associations of eastern Oregon and Washington. Under natural fire regimes, dwarf mistletoes exert a stabilizing influence on the persistence of early-seral tree species. Frequent fires favor the establishment and perpetuation of seral-tree species, maintaining favorable conditions for the persistence of each host-specific mistletoe. Moderately severe mistletoe infestations favor the torching of the most infested trees, and, with the right fuel and wind conditions, stand replacement crowning fires. By this mechanism, dwarf mistletoes of seral species were historically widely distributed, but at low or moderate severity within their host populations. Dwarf mistletoes of mid- and late-successional species like Douglas-fir, are destabilizing with respect to those specific transitional communities. Crowning fires influenced by mistletoe severity, regenerated seral plant communities rather than mid- and late-successional communities, drastically reducing or eliminating for a period the availability of susceptible host material (Douglas-fir) and an inoculum source of the parasite (Douglas-fir dwarf mistletoe).

**Douglas-fir dwarf mistletoe**—At least 40-percent of the Douglas-fir in eastern Oregon and Washington are infected with dwarf mistletoe (Bolsinger 1978). Douglas-fir dwarf mistletoe hazard is correlated with the abundance of Douglas-fir, stand structural complexity, site quality, and the presence of other damaging agents that depress tree vigor and render mistletoe-infected Douglas-fir susceptible to mortality by other agents (root diseases, bark beetles, drought, and defoliators). Douglas-fir dwarf mistletoe hazard was mapped for polygons containing Douglas-fir. Stand polygons that did not contain any host species in the understory or overstory, were given the lowest possible score for each of the variables. In this analysis, Douglas-fir dwarf mistletoe hazard was scored for each stand polygon from stand attributes associated with five hazard variables: site quality—overstory and understory species composition; host abundancehost crown cover percent; canopy structure—number of canopy layers; host age—overstory size class; and continuity of host types for defoliators—according to the continuity index used for defoliators above. Actual inventory data on the distribution and extent of dwarf mistletoe is needed for accurate hazard assessment. Lacking these data, only the presence of susceptible hosts in susceptible arrangements can be assessed.

*Ranking site quality*: 1 = ABLA2, PIEN, ABAM, ABPR, ABMA, TSHE, TSME, THPL sites; 2 = ABGR, ABCO sites; 3 = PSME-PIPO, PSME sites.

*Ranking host abundance:* 1 = other species or < 30-percent crown cover in PSME; 2 = 30 to 50-percent crown cover in PSME; 3 = > 50-percent crown cover in PSME.

*Ranking canopy structure:* 1 = 1 layer of PSME; 2 = 2 layers PSME in mixed species layers; 3 = 2 layers of PSME.

*Ranking host age:* 1 = small sawtimber PSME (9 to 15.9 in. d.b.h.) overstory or smaller; 2 = medium or large sawtimber PSME (16 to 25 in. d.b.h.) overstory; 3 = mature or overmature sawtimber PSME (>25 in. d.b.h.) overstory.

*Ranking continuity of host types for defoliators:* 1 = < 20-percent of the total cell edges in a watershed as host-host edges; 2 = 20 to 40-percent of the total cell edges in a watershed as host-host edges; 3 = > 40percent of the total cell edges in a watershed as host-host edges.

All stand polygons in a sample watershed were hazard rated according to site quality, host abundance, canopy structure, host age, and continuity of host types for defoliators as above. Once values for the five hazard variables were computed for every polygon in a watershed, ratings were summed for the individual polygons. This sum was the polygon Douglas-fir dwarf mistletoe hazard rating. Watershed hazard ratings were computed as the weighted sums of the polygons.

Watershed scores of 5 to 7 had LOW susceptibility to Douglas-fir dwarf mistletoe. Watershed scores of 8 to 10 had MODERATE susceptibility. Scores of 11 indicated HIGH susceptibility.

**Western dwarf mistletoe**—About one-quarter of the ponderosa pine in eastern Oregon and Washington are infected with dwarf mistletoe (Bolsinger 1978). Western dwarf mistletoe hazard is correlated with the abundance of ponderosa pine, stand structural complexity, site quality, and the presence of other damaging agents: root diseases, bark beetles, drought, and defoliators (pine butterfly and Pandora moth). Western dwarf mistletoe hazard was mapped for polygons containing PIPO. Stand polygons that did not contain any host species in the understory or overstory were given the lowest possible score for each of the variables. In this analysis, western dwarf mistletoe hazard was scored for each stand polygon from stand attributes associated with four hazard variables: site quality—overstory and understory species composition; host abundance—host crown cover percent; canopy structure—number of canopy layers; and host age—overstory size class. Actual inventory data on the distribution and extent of dwarf mistletoe is needed for accurate hazard assessment. Lacking these data, only the presence of susceptible hosts in susceptible arrangements can be assessed.

*Ranking site quality:* 1 = ABLA2, PIEN, ABAM, ABPR, ABMA, TSHE, TSME, THPL sites; 2 = ABGR, ABCO, PICO sites; 3 = PIPO, PSME-PIPO, PSME sites.

*Ranking host abundance:* 1 = other species or < 30-percent crown cover in PIPO; 2 = 30 to 50-percent crown cover in PIPO; 3 = > 50-percent crown cover in PIPO.

*Ranking canopy structure:* 1 = 1 layer of PIPO; 2 = 2 layers PIPO in mixed species layers; 3 = 2 layers of PIPO.

*Ranking host age:* 1 = small sawtimber PIPO (9 to 15.9 in. d.b.h.) overstory or smaller; 2 = medium or large sawtimber PIPO (16 to 25 in. d.b.h.) overstory; 3 = mature or overmature sawtimber PIPO (> 25 in. d.b.h.) overstory.

All stand polygons in a sample watershed were hazard rated according to site quality, host abundance, canopy structure, and host age as above. Once values for the four hazard variables were computed for every polygon in a watershed, ratings were summed for the individual polygons. This sum was the polygon western dwarf mistletoe hazard rating. Watershed hazard ratings were computed as the weighted sums of the polygons.

Watershed scores of 4 to 7 had LOW susceptibility to western dwarf mistletoe. Watershed scores of 8 to 9 had MODERATE susceptibility. Scores of 10 indicated HIGH susceptibility.

**Mapping susceptibility western larch dwarf mistletoe**—About one-half of the western larch in eastern Oregon and Washington are infected with dwarf mistletoe (Bolsinger 1978). As with the two preceding mistletoes, western larch dwarf mistletoe hazard is correlated with the abundance of the hostwestern larch-stand structural complexity, site quality, and the presence of other damaging agents that depress tree vigor and render dwarf mistletoe-infected larch susceptible to mortality by other agents. western larch dwarf mistletoe hazard was mapped for polygons containing LAOC. Stand polygons that did not contain any host species in the understory or overstory, were given the lowest possible score for each of the variables. In this analysis, western larch dwarf mistletoe hazard was scored for each stand polygon from stand attributes associated with four hazard variables: site quality—overstory and understory species composition; host abundance—host crown cover percent; canopy structure—number of canopy layers; and host age—overstory size class. Actual inventory data on the distribution and extent of dwarf mistletoe is needed for accurate hazard assessment. Lacking these data, only the presence of susceptible hosts in susceptible arrangements can be assessed.

*Ranking site quality:* 1 = ABAM, ABPR, ABMA, TSHE, TSME, THPL sites; 2 = ABGR, ABCO, ABLA2, PIEN, PICO, LAOC sites; 3 = PSME sites.

*Ranking host abundance:* 1 = other species or < 30-percent crown cover in LAOC; 2 = 30 to 50-percent crown cover in LAOC; 3 = > 50-percent crown cover in LAOC.

*Ranking canopy structure:* 1 = 1 layer of LAOC; 2 = 2 layers LAOC in mixed species layers; 3 = 2 layers of LAOC.

*Ranking host age:* 1 = small sawtimber LAOC (9 to 15.9 in. d.b.h.) overstory or smaller; 2 = medium or large sawtimber LAOC (16 to 25 in. d.b.h.) overstory; 3 = mature or overmature sawtimber LAOC (> 25 in. d.b.h.) overstory.

All stand polygons in a sample watershed were hazard rated according to site quality, host abundance, canopy structure, and host age as above. Once values for the four hazard variables were computed for every polygon in a watershed, ratings were summed for the individual polygons. This sum was the polygon western larch dwarf mistletoe hazard rating. Watershed hazard ratings were computed as the weighted sums of the polygons.

Watershed scores of 4 to 6 had LOW susceptibility to western larch dwarf mistletoe. Watershed scores of

7 to 9 had MODERATE susceptibility. Scores of 10 indicated HIGH susceptibility.,

**Lodgepole pine dwarf mistletoe**—More than 40-percent of the lodgepole pine in eastern Oregon and Washington are infected with dwarf mistletoe (Bolsinger 1978). Lodgepole pine dwarf mistletoe hazard is correlated with the abundance of the host, stand structural complexity, site quality, and the presence of other damaging agents. Lodgepole pine dwarf mistletoe hazard was mapped for polygons containing PICO. Stand polygons that did not contain any host species in the understory or overstory, were given the lowest possible score for each of the variables. In this analysis, lodgepole pine dwarf mistletoe hazard was scored for each stand polygon from stand attributes associated with four hazard variables: site quality—overstory and understory species composition; host abundance—host crown cover percent; canopy structure—number of canopy layers; and host age—overstory size class. Actual inventory data on the distribution and extent of dwarf mistletoe is needed for accurate hazard assessment. Lacking these data, only the presence of susceptible hosts in susceptible arrangements can be assessed.

*Ranking site quality:* 1 = ABLA2, PIEN, ABAM, ABPR, ABMA, TSHE, TSME, THPL sites; 2 = ABGR, ABCO sites; 3 = PICO, PSME sites.

*Ranking bost abundance:* 1 = other species or < 30-percent crown cover in PICO; 2 = 30 to 50-percent crown cover in PICO; 3 = > 50-percent crown cover in PICO.

*Ranking canopy structure:* 1 = 1 layer of PICO; 2 = 2 layers PICO in mixed species layers; 3 = 2 layers of PICO.

*Ranking bost age:* 1 = seedling and sapling PICO (< 5 in. d.b.h.); 2 = poletimber PICO (5 to 8.9 in. d.b.h.); 3 = small sawtimber PICO (9 to 15.9 in. d.b.h.) and larger..

All stand polygons in a sample watershed were hazard rated according to site quality, host abundance, canopy structure, and host age as above. Once values for the four hazard variables were computed for every polygon in a watershed, ratings were summed for the individual polygons. This sum was the polygon lodgepole pine dwarf mistletoe hazard rating. Watershed hazard ratings were computed as the weighted sums of the polygons.

Watershed scores of 4 to 7 had LOW susceptibility to lodgepole pine dwarf mistletoe. Watershed scores of 8 to 9 had MODERATE susceptibility. Scores of 10 indicated HIGH susceptibility.

**Root diseases**—Susceptibility of stands and landscapes to root diseases was evaluated for laminated root rot, Armillaria root disease, and the S-group annosum root disease. Collectively, they are highly damaging to Douglas-fir, grand fir, and white fir. Throughout the Douglas-fir, grand fir, and white fir zones, root diseases have increased dramatically in distribution and severity in this century, mostly attributable to the marked increase in abundance of susceptible shade-tolerant, fire-sensitive hosts. Root disease mortality annually produces abundant small gaps in forest canopies throughout the east side. This gradual and continuous thinning favors the release and regeneration of additional susceptible shade-tolerant species. Mountain hemlock is also highly susceptible to laminated root rot; other true firs, spruce, and western hemlock are susceptible at maturity to butt defect associated with S-group annosum and laminated root rot.

Hazard for these three root diseases is correlated with site quality, successional stage, stand structural complexity, number of prior logging entries, and the presence of other agents that render root disease hosts susceptible to other mortality factors. Root disease hazard was mapped for polygons containing PSME, ABGR, and.ABCO. Stand polygons that did not contain any host species in the understory or overstory were given the lowest possible score for each of the variables. In this analysis, root disease hazard was scored for each stand polygon from stand attributes associated with five hazard variables: site quality—overstory and understory species composition; host abundance—host crown cover percent; canopy structure—number of canopy layers; host age—overstory size class; and continuity of host types for defoliators—according to the continuity index used for defoliators above. Actual inventory data on the distribution and extent of root disease is needed for accurate hazard assessment. Lacking these data, only the presence of susceptible hosts in susceptible arrangements can be assessed.

*Ranking site quality:* 1 = ABPR, ABMA sites; 2 = ABLA2, PIEN, ABAM, TSHE, THPL, TSME sites; 3 = PSME, ABGR, ABCO sites.

*Ranking bost abundance:* 1 = other species or < 30-percent crown cover in PSME and/or ABGR and/or ABCO; 2 = 30 to 50-percent crown cover in PSME and/or ABGR and/or ABCO; 3 = > 50-percent crown cover in PSME and/or ABGR and/or ABCO.

*Ranking canopy structure:* 1 = 1 layer of PSME and/or ABGR and/or ABCO; 2 = 2 layers PSME and/or ABGR and/or ABCO in mixed species layers; 3 = 2 layers of PSME and/or ABGR and/or ABCO.

*Ranking host age.* 1 = small sawtimber (9 to 15.9 in. d.b.h.) or smaller; 2 = medium or large sawtimber (16 to 25 in. d.b.h.); 3 = mature or overmature sawtimber (> 25 in. d.b.h.).

*Ranking continuity of host types for defoliators:* 1 = < 20-percent of the total cell edges in a watershed as host-host edges; 2 = 20 to 40-percent of the total cell edges in a watershed as host-host edges; 3 = > 40percent of the total cell edges in a watershed as host-host edges.

All stand polygons in a sample watershed were hazard rated according to site quality, host abundance, canopy structure, host age, and continuity of host types for defoliators as above. Once values for the five hazard variables were computed for every polygon in a watershed, ratings were summed for the individual polygons. This sum was the polygon root disease hazard rating. Watershed hazard ratings were computed as the weighted sums of the polygons.

Watershed scores of 5 to 8 had LOW susceptibility to root diseases. Watershed scores of 9 to 11 had MODERATE susceptibility. Scores of 12 to 15 indicated HIGH susceptibility.

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**Appendix B: Historical and current percentage area, patch density and patch area of vegetation types on National Forest land in river basins of eastern Oregon and Washington. Historical years for assessment ranged from 1932-59; current years ranged from 1985 to 1990. Area is expressed as the percentage of total basin area.**

| | | Percent area | | | Patch density ($n/km^2$) | | | Mean patch area (ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| River basin & overstory cover | Structure[a] | H[b] | C | %D | H | C | %D | H | C | %D |
| **DESCHUTES** | | | | | | | | | | |
| Agric/urban | — | 0.01 | 0.19 | 1761% | 0.004 | 0.015 | 248% | 3.0 | 25.7 | 757% |
| Bare round | — | 19.60 | 10.49 | -46% | 0.107 | 0.258 | 141% | 176.2 | 57.3 | -67% |
| Water | — | 1.41 | 1.45 | 2% | 0.057 | 0.034 | -40% | 111.2 | 236.7 | 113% |
| Grass/forb | — | 0.80 | 2.96 | 268% | 0.032 | 0.217 | 574% | 20.9 | 14.6 | -30% |
| Shrub | — | 0.31 | 0.68 | 118% | 0.022 | 0.041 | 84% | 12.6 | 14.3 | 13% |
| PIPOC | SSP | 6.27 | 3.68 | -41% | 0.085 | 0.157 | 86% | 36.8 | 20.2 | -45% |
| | Young | 6.93 | 10.91 | 57% | 0.082 | 0.231 | 182% | 277.8 | 46.3 | -83% |
| | Mature | 6.96 | 10.58 | 52% | 0.082 | 0.265 | 224% | 149.5 | 84.9 | -43% |
| | Park-like | 0.81 | 0.89 | 11 % | 0.022 | 0.045 | 105% | 54.0 | 17.2 | -68% |
| | Old forest | 2.18 | 0.79 | -64% | 0.032 | 0.018 | -42% | 66.3 | 25.3 | -62% |
| PIMO/PILA | SSP | 0.00 | 0.01 | na | 0.000 | 0.007 | na | 0.0 | 7.7 | na |
| | Young | 0.28 | 0.09 | -66% | 0.021 | 0.032 | 51% | 40.2 | 28.5 | -29% |
| | Mature | 0.24 | 0.49 | 103% | 0.036 | 0.161 | 352% | 21.2 | 16.3 | -23% |
| | Old forest | 0.00 | 0.01 | na | 0.000 | 0.014 | na | 0.0 | 11.0 | na |
| LAOC | Young | 0.04 | 0.05 | 26% | 0.004 | 0.009 | 139% | 12.5 | 13.0 | 4% |
| PICO | SSP | 4.29 | 3.57 | -17% | 0.040 | 0.135 | 235% | 52.1 | 46.4 | -11% |
| | Young | 6.52 | 5.78 | -11% | 0.092 | 0.227 | 147% | 91.5 | 48.0 | -48% |
| | Park-like | 0.01 | 0.06 | 600% | 0.019 | 0.038 | 100% | 5.8 | 20.3 | 253% |
| | Mature | 0.02 | 1.10 | 5819% | 0.002 | 0.063 | 3852% | 2.4 | 21.0 | 778% |
| PSME/ABGR | SSP | 0.26 | 0.52 | 99% | 0.018 | 0.113 | 522% | 7.2 | 8.4 | 17% |
| | Young | 2.15 | 7.21 | 235% | 0.069 | 0.234 | 242% | 71.4 | 37.9 | -47% |
| | Mature | 7.95 | 6.33 | -20% | 0.087 | 0.268 | 208% | 118.6 | 61.0 | -49% |
| | Park-like | 0.38 | 0.09 | -75% | 0.039 | 0.008 | -80% | 21.9 | 21.6 | -1% |
| | Old forest | 2.27 | 0.22 | -90% | 0.041 | 0.010 | -75% | 90.3 | 77.0 | -15% |
| ABLA/PIEN | SSP | 0.12 | 0.06 | -51% | 0.004 | 0.013 | 256% | 92.6 | 42.7 | -54% |
| | Young | 0.44 | 0.31 | -30% | 0.024 | 0.039 | 58% | 42.4 | 17.8 | -58% |
| | Park-like | 0.00 | 0.08 | na | 0.000 | 0.017 | na | 0.0 | 26.6 | na |
| | Mature | 0.49 | 0.32 | -35% | 0.032 | 0.077 | 142% | 59.0 | 19.2 | -68% |
| ABAM/TSHE | SSP | 0.00 | 0.05 | na | 0.000 | 0.029 | na | 0.0 | 8.0 | na |
| | Young | 0.04 | 0.17 | 341% | 0.007 | 0.051 | 621% | 16.5 | 22.3 | 36% |
| | Mature | 0.30 | 0.43 | 44% | 0.033 | 0.161 | 393% | 51.3 | 15.7 | -69% |
| TSME | SSP | 1.84 | 1.16 | -37% | 0.050 | 0.027 | -46% | 47.6 | 20.5 | -57% |
| | Young | 17.26 | 8.34 | -52% | 0.226 | 0.176 | -22% | 120.3 | 76.1 | -37% |
| | Mature | 8.94 | 18.48 | 107% | 0.104 | 0.296 | 186% | 77.2 | 80.0 | 4% |
| | Park-like | 0.02 | 1.08 | 7127% | 0.007 | 0.019 | 184% | 4.0 | 158.9 | 3902% |
| | Old forest | 0.86 | 1.36 | 59% | 0.011 | 0.070 | 516% | 182.2 | 39.7 | -78% |

**Appendix B: Historical and current percentage area, patch density, and patch area of vegetation types on National Forest land in river basins of eastern Oregon and Washington. Historical years for assessment ranged from 1932-59; current years ranged from 1985-90. Area is expressed as the percentage of total basin area.**

| | | Percent area | | | Patch density (n/km$^2$) | | | Mean patch area (ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **River basin & overstory cover** | **Structure[a]** | **H[b]** | **C** | **%D** | **H** | **C** | **%D** | **H** | **C** | **%D** |
| **GRANDE RONDE** | | | | | | | | | | |
| Agric/urban | — | 0.63 | 0.14 | -78% | 0.048 | 0.007 | -86% | 43.4 | 20.2 | -53% |
| Bare round | — | 1.78 | 2.08 | 17% | 0.055 | 0.054 | -2% | 35.9 | 17.9 | -50% |
| Water | — | 0.28 | 0.12 | -56% | 0.041 | 0.032 | -21% | 17.0 | 19.7 | 16% |
| Grass/forb | — | 14.95 | 9.21 | -38% | 0.289 | 0.389 | 35% | 40.5 | 15.9 | -61% |
| Shrub | — | 0.70 | 0.76 | 8% | 0.035 | 0.020 | -44% | 15.3 | 35.4 | 130% |
| PIPO | SSP | 1.27 | 2.36 | 86% | 0.042 | 0.135 | 221% | 22.0 | 34.9 | 59% |
| | Young | 0.59 | 6.72 | 1034% | 0.014 | 0.275 | 1815% | 13.7 | 32.7 | 139% |
| | Mature | 5.39 | 2.72 | -50% | 0.154 | 0.209 | 36% | 31.3 | 26.6 | -15% |
| | Park-like | 2.14 | 0.32 | -85% | 0.057 | 0.020 | -66% | 24.5 | 6.8 | -72% |
| | Old forest | 1.72 | 0.20 | -88% | 0.084 | 0.027 | -68% | 34.7 | 13.1 | -62% |
| LAOC | SSP | 0.80 | 0.28 | -65% | 0.028 | 0.022 | -22% | 29.6 | 17.6 | -40% |
| | Young | 0.49 | 2.61 | 431% | 0.011 | 0.154 | 1290% | 17.4 | 27.2 | 56% |
| | Mature | 1.30 | 1.35 | 4% | 0.042 | 0.121 | 188% | 19.7 | 16.9 | -14% |
| | Park-like | 0.04 | 0.16 | 293% | 0.008 | 0.020 | 165% | 7.0 | 6.2 | -11% |
| | Old forest | 0.26 | 0.07 | -74% | 0.021 | 0.016 | -53% | 19.4 | 3.0 | -84% |
| PICO | SSP | 1.79 | 1.38 | -23% | 0.066 | 0.053 | -20% | 23.1 | 18.3 | -21% |
| | Young | 0.21 | 3.59 | 1627% | 0.013 | 0.328 | 2478% | 10.8 | 28.6 | 165% |
| | Mature | 0.00 | 0.50 | na | 0.000 | 0.061 | na | 0.0 | 60.1 | na |
| PSME/ABGR | SSP | 11.06 | 3.86 | -65% | 0.448 | 0.199 | -56% | 24.7 | 52.4 | 112% |
| | Young | 6.64 | 18.90 | 185% | 0.175 | 0.802 | 358% | 31.0 | 41.6 | 34% |
| | Mature | 20.54 | 26.92 | 31% | 0.525 | 0.766 | 46% | 37.3 | 32.2 | -14% |
| | Park-like | 7.25 | 0.37 | -95% | 0.284 | 0.029 | -90% | 24.4 | 6.5 | -74% |
| | Old forest | 5.34 | 1.09 | -80% | 0.154 | 0.028 | -82% | 45.2 | 36.6 | -19% |
| ABLA/PIEN | SSP | 4.87 | 1.57 | -68% | 0.267 | 0.057 | -78% | 33.8 | 13.4 | -60% |
| | Young | 2.43 | 6.17 | 153% | 0.120 | 0.166 | 38% | 27.8 | 41.4 | 49% |
| | Mature | 2.81 | 0.74 | -74% | 0.131 | 0.070 | -47% | 25.8 | 15.2 | -41% |
| | Park-like | 2.82 | 0.05 | -98% | 0.185 | 0.009 | -95% | 17.0 | 3.5 | -80% |
| | Old forest | 1.89 | 0.05 | -97% | 0.192 | 0.022 | -89% | 21.5 | 2.8 | -87% |
| ABAM/TSHE | Young | 0.00 | 0.07 | na | 0.000 | 0.011 | na | 0.0 | 57.6 | na |
| PIAL/LALY | SSP | 0.00 | 0.24 | na | 0.000 | 0.024 | na | 0.0 | 49.4 | na |
| | Young | 0.00 | 5.35 | na | 0.000 | 0.133 | na | 0.0 | 213.1 | na |
| | Mature | 0.00 | 0.04 | na | 0.000 | 0.016 | na | 0.0 | 23.6 | na |

**Appendix B: Historical and current percentage area, patch density, and patch area of vegetation types on National Forest land in river basins of eastern Oregon and Washington. Historical years for assessment ranged from 1932-59; current years ranged from 1985-90. Area is expressed as the percentage of total basin area.**

| | | Percent area | | | Patch density (n/km²) | | | Mean patch area (ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| River basin & overstory cover | Structure[a] | H[b] | C | %D | H | C | %D | H | C | %D |
| **METHOW** | | | | | | | | | | |
| Agric/urban | — | 0.49 | 0.65 | 32% | 0.037 | 0.048 | 29% | 22.1 | 24.0 | 8% |
| Bare round | — | 10.31 | 12.45 | 21% | 0.104 | 0.174 | 67% | 77.6 | 115.4 | 49% |
| Water | — | 0.01 | 0.12 | 789% | 0.012 | 0.012 | -1% | 2.6 | 21.5 | 727% |
| Grass/forb | — | 2.02 | 2.38 | 18% | 0.038 | 0.056 | 49% | 55.6 | 38.4 | -31% |
| Shrub | — | 1.74 | 5.89 | 239% | 0.060 | 0.147 | 147% | 54.6 | 27.3 | -50% |
| Hardwood | — | 0.28 | 0.21 | -26% | 0.021 | 0.027 | 28% | 23.9 | 8.7 | -64% |
| PIPO | SSP | 1.62 | 1.91 | 18% | 0.078 | 0.088 | 13% | 44.7 | 50.5 | 13% |
| | Young | 0.76 | 3.53 | 367% | 0.021 | 0.071 | 233% | 59.5 | 41.1 | -31% |
| | Mature | 2.62 | 3.77 | 44% | 0.126 | 0.165 | 31% | 77.3 | 75.6 | -2% |
| | Park-like | 7.60 | 2.00 | -74% | 0.148 | 0.058 | -61% | 73.7 | 34.6 | -53% |
| | Old forest | 4.92 | 0.60 | -88% | 0.092 | 0.028 | -70% | 125.9 | 40.1 | -68% |
| PIMO/PILA | SSP | 0.18 | 0.00 | -100% | 0.022 | 0.000 | -100% | 70.0 | 0.0 | -100% |
| | Young | 0.10 | 0.00 | -100% | 0.011 | 0.000 | -100% | 80.4 | 0.0 | -100% |
| | Park-like | 0.09 | 0.00 | -100% | 0.022 | 0.000 | -100% | 36.9 | 0.0 | -100% |
| LAOC | SSP | 0.06 | 0.11 | 88% | 0.010 | 0.021 | 110% | 13.2 | 13.6 | 3% |
| | Young | 0.00 | 0.08 | na | 0.000 | 0.020 | na | 0.0 | 52.1 | na |
| | Mature | 0.56 | 0.65 | 15% | 0.116 | 0.215 | 86% | 63.3 | 39.2 | -38% |
| | Park-like | 0.05 | 0.27 | 453% | 0.007 | 0.039 | 443% | 12.2 | 10.1 | -17% |
| | Old forest | 0.48 | 0.56 | 17% | 0.135 | 0.157 | 16% | 46.3 | 46.8 | 1% |
| PICO | SSP | 7.46 | 5.24 | -30% | 0.072 | 0.049 | -32% | 63.2 | 60.7 | -4% |
| | Young | 3.11 | 4.33 | 39% | 0.099 | 0.113 | 14% | 75.6 | 81.4 | 8% |
| | Mature | 0.00 | 0.11 | na | 0.000 | 0.016 | na | 0.0 | 133.9 | na |
| PSME/ABGR | SSP | 1.80 | 2.15 | 19% | 0.085 | 0.119 | 40% | 27.9 | 21.7 | -22% |
| | Young | 7.85 | 13.35 | 70% | 0.117 | 0.292 | 150% | 55.1 | 46.6 | -15% |
| | Mature | 4.74 | 8.19 | 73% | 0.081 | 0.156 | 94% | 75.8 | 73.3 | -3% |
| | Park-like | 3.34 | 1.99 | -40% | 0.079 | 0.106 | 34% | 65.3 | 30.8 | -53% |
| | Old forest | 4.99 | 2.27 | -54% | 0.055 | 0.069 | 26% | 123.0 | 31.2 | -75% |
| ABLA/PIEN | SSP | 4.21 | 2.69 | -36% | 0.080 | 0.075 | -6% | 47.5 | 39.0 | -18% |
| | Young | 11.64 | 12.05 | 4% | 0.181 | 0.260 | 43% | 83.5 | 53.5 | -36% |
| | Mature | 2.57 | 2.06 | -20% | 0.051 | 0.058 | 13% | 54.4 | 51.7 | -5% |
| | Park-like | 3.03 | 0.87 | -71% | 0.071 | 0.036 | -49% | 33.1 | 68.2 | 106% |
| | Old forest | 0.19 | 0.10 | -47% | 0.021 | 0.013 | -36% | 25.8 | 11.3 | -56% |
| ABAM/TSHE | SSP | 0.97 | 0.28 | -71% | 0.120 | 0.046 | -62% | 41.9 | 32.6 | -22% |
| | Young | 0.81 | 0.53 | -35% | 0.173 | 0.108 | -38% | 30.7 | 15.9 | -48% |
| | Mature | 1.29 | 1.18 | -9% | 0.103 | 0.108 | 4% | 49.2 | 35.6 | -28% |
| | Park-like | 1.23 | 0.40 | -68% | 0.056 | 0.036 | -35% | 48.1 | 54.9 | 14% |
| | Old forest | 0.18 | 0.30 | 65% | 0.078 | 0.117 | 50% | 30.0 | 33.0 | 16% |
| PIAL/LALY | SSP | 4.52 | 4.33 | -4% | 0.104 | 0.135 | 30% | 58.4 | 38.4 | -34% |
| | Young | 2.01 | 2.35 | 16% | 0.046 | 0.072 | 55% | 41.6 | 40.1 | -3% |
| | Mature | 0.09 | 0.05 | -43% | 0.015 | 0.017 | -36% | 32.3 | 17.1 | -47% |

**Appendix B: Historical and current percentage area, patch density, and patch area of vegetation types on National Forest land in river basins of eastern Oregon and Washington. Historical years for assessment ranged from 193259; current ears ran ed from 1985 to 1990. Area is expressed as the percentage of total basin area.**

| River basin & overstory cover | Structure[a] | Percent area H[b] | Percent area C | Percent area %D | Patch density ($n/km^2$) H | Patch density C | Patch density %D | Mean patch area (ha) H | Mean patch area C | Mean patch area %D |
|---|---|---|---|---|---|---|---|---|---|---|
| **PEND OREILLE** | | | | | | | | | | |
| Agric/urban | — | 1.49 | 1.30 | -13% | 0.121 | 0.084 | -31% | 30.6 | 26.4 | -14% |
| Bare round | — | 11.90 | 3.52 | -70% | 0.227 | 0.254 | 12% | 160.8 | 13.6 | -92% |
| Water | — | 0.30 | 0.40 | 31% | 0.018 | 0.055 | 196% | 10.7 | 8.8 | -17% |
| Grass/forb | — | 0.22 | 0.89 | 300% | 0.035 | 0.090 | 157% | 6.2 | 24.7 | 296% |
| Shrub | — | 0.20 | 0.36 | 84% | 0.020 | 0.033 | 66% | 10.9 | 9.9 | -9% |
| Hardwood | — | 0.09 | 0.30 | 235% | 0.005 | 0.041 | 795% | 3.8 | 7.8 | 106% |
| PIPO | SSP | 1.79 | 0.90 | -50% | 0.065 | 0.055 | -15% | 25.4 | 11.4 | -55% |
| | Young | 8.41 | 1.83 | -78% | 0.233 | 0.058 | -75% | 23.1 | 23.3 | 1% |
| | Mature | 0.67 | 2.40 | 258% | 0.043 | 0.104 | 141% | 16.0 | 24.3 | 52% |
| | Park-like | 0.25 | 0.27 | 15% | 0.012 | 0.021 | 69% | 6.0 | 16.7 | 177% |
| PIMO/PILA | SSP | 0.71 | 0.10 | -86% | 0.036 | 0.015 | -59% | 23.2 | 7.8 | -66% |
| | Young | 5.07 | 0.00 | -100% | 0.248 | 0.000 | -100% | 37.6 | 0.0 | -100% |
| | Mature | 1.61 | 0.00 | -100% | 0.154 | 0.000 | -100% | 24.1 | 0.0 | -100% |
| LAOC | SSP | 4.13 | 0.51 | -88% | 0.134 | 0.071 | -47% | 54.8 | 8.0 | -85% |
| | Young | 12.10 | 12.76 | 6% | 0.257 | 0.634 | 147% | 96.5 | 21.2 | -78% |
| | Mature | 2.16 | 0.64 | -70% | 0.102 | 0.041 | -60% | 14.7 | 16.6 | 13% |
| | Park-like | 0.01 | 0.04 | 296% | 0.005 | 0.009 | 99% | 1.2 | 7.9 | 536% |
| PICO | SSP | 8.41 | 4.01 | -52% | 0.238 | 0.222 | -7% | 22.6 | 23.7 | 5% |
| | Young | 7.17 | 10.79 | 51% | 0.196 | 0.555 | 183% | 29.4 | 21.1 | -28% |
| | Mature | 0.15 | 0.57 | 286% | 0.011 | 0.026 | 134% | 7.1 | 34.8 | 391% |
| | Park-like | 0.00 | 0.11 | na | 0.000 | 0.021 | na | 0.0 | 16.4 | na |
| PSME/ABGR | SSP | 3.78 | 8.43 | 123% | 0.138 | 0.489 | 255% | 44.6 | 17.3 | -61% |
| | Young | 18.23 | 21.57 | 18% | 0.650 | 1.042 | 60% | 32.2 | 19.5 | -39% |
| | Mature | 2.12 | 5.99 | 183% | 0.113 | 0.222 | 97% | 16.0 | 22.2 | 39% |
| | Park-like | 0.54 | 1.70 | 215% | 0.071 | 0.126 | 78% | 10.0 | 23.7 | 137% |
| ABLA/PIEN | SSP | 1.66 | 1.10 | -33% | 0.072 | 0.121 | 68% | 11.5 | 11.6 | 1% |
| | Young | 3.40 | 5.27 | 55% | 0.158 | 0.315 | 99% | 14.6 | 19.2 | 32% |
| | Mature | 1.39 | 2.17 | 56% | 0.057 | 0.110 | 93% | 14.4 | 28.7 | 99% |
| | Park-like | 0.29 | 0.68 | 138% | 0.056 | 0.064 | 15% | 6.2 | 18.1 | 193% |
| ABAM/TSHE | SSP | 0.08 | 2.40 | 2934% | 0.006 | 0.167 | 2621% | 4.8 | 13.0 | 171% |
| | Young | 0.38 | 5.70 | 1387% | 0.005 | 0.367 | 7084% | 21.2 | 14.7 | -31% |
| | Mature | 0.70 | 1.12 | 61% | 0.020 | 0.085 | 326% | 14.6 | 15.7 | 7% |
| | Park-like | 0.41 | 2.06 | 404% | 0.034 | 0.252 | 650% | 14.0 | 15.5 | 11% |
| TSME | SSP | 0.16 | 0.00 | -100% | 0.056 | 0.000 | -100% | 13.9 | 0.0 | -100% |
| | Park-like | 0.00 | 0.15 | na | 0.000 | 0.070 | na | 0.0 | 6.6 | na |

**Appendix B: Historical and current percentage area, patch density and patch area of vegetation types on National Forest land in river basins of eastern Oregon and Washington. Historical years for assessment ranged from 193259; current ears ran ed from 1985-90. Area is ex ressed as the percentage of total basin area.**

| River basin & overstory cover | Structure[a] | Percent area H[b] | C | %D | Patch density ($n/km^2$) H | C | %D | Mean patch area (ha) H | C | %D |
|---|---|---|---|---|---|---|---|---|---|---|
| **WENATCHEE** | | | | | | | | | | |
| Agric/urban | — | 0.25 | 0.22 | -11% | 0.044 | 0.039 | -11% | 19.8 | 20.4 | 3% |
| Bare round | — | 9.18 | 13.36 | 46% | 0.182 | 0.392 | 116% | 45.1 | 31.8 | -30% |
| Water | — | 0.72 | 0.47 | -35% | 0.100 | 0.050 | -50% | 11.5 | 11.8 | 2% |
| Grass/forb | — | 0.97 | 1.91 | 97% | 0.068 | 0.075 | 11% | 14.5 | 28.7 | 98% |
| Shrub | — | 6.78 | 6.55 | -3% | 0.164 | 0.168 | 2% | 43.8 | 38.5 | -12% |
| Hardwood | — | 0.43 | 0.39 | -18% | 0.084 | 0.042 | -50% | 11.5 | 16.8 | 46% |
| PIPO | SSP | 0.54 | 0.38 | -30% | 0.040 | 0.081 | 102% | 31.4 | 11.1 | -64% |
| | Young | 0.78 | 0.19 | -76% | 0.071 | 0.040 | -43% | 21.4 | 8.5 | -60% |
| | Mature | 7.83 | 5.60 | -28% | 0.854 | 0.711 | -17% | 28.8 | 21.9 | -24% |
| | Old forest | 4.50 | 2.14 | -52% | 0.411 | 0.200 | -51% | 25.0 | 40.5 | 62% |
| | Park-like | 1.64 | 2.32 | 42% | 0.140 | 0.232 | 66% | 35.2 | 24.2 | -31% |
| PIMO/PILA | Young | 0.02 | 0.00 | -100% | 0.008 | 0.000 | -100% | 17.0 | 0.0 | -100% |
| | Mature | 0.04 | 0.05 | 29% | 0.017 | 0.008 | -50% | 17.0 | 43.8 | 158% |
| | Old forest | 0.20 | 0.16 | -21% | 0.033 | 0.025 | -25% | 43.7 | 45.6 | 4% |
| | Park-like | 0.07 | 0.00 | -100% | 0.008 | 0.000 | -100% | 60.5 | 0.0 | -100% |
| LAOC | SSP | 0.00 | 0.01 | na | 0.000 | 0.008 | na | 0.0 | 10.5 | na |
| | Young | 0.13 | 0.00 | -100% | 0.014 | 0.000 | -100% | 47.5 | 0.0 | -100% |
| | Mature | 0.14 | 0.01 | -94% | 0.096 | 0.011 | -89% | 10.6 | 5.2 | -51% |
| | Old forest | 0.46 | 0.00 | -100% | 0.096 | 0.000 | -100% | 34.3 | 0.0 | -100% |
| PICO | SSP | 0.30 | 0.29 | -3% | 0.018 | 0.024 | 38% | 19.7 | 14.3 | -27% |
| | Young | 0.69 | 0.04 | -95% | 0.034 | 0.004 | -88% | 114.3 | 15.6 | -86% |
| | Mature | 0.11 | 0.00 | -100% | 0.012 | 0.000 | -100% | 53.9 | 0.0 | -100% |
| PSME/ABGR | SSP | 0.83 | 1.90 | 128% | 0.061 | 0.119 | 94% | 14.5 | 21.0 | 45% |
| | Young | 2.59 | 1.64 | -37% | 0.096 | 0.089 | -7% | 23.7 | 29.4 | 24% |
| | Mature | 11.02 | 12.56 | 14% | 0.488 | 0.673 | 38% | 33.9 | 28.2 | -17% |
| | Park-like | 1.06 | 2.39 | 140% | 0.037 | 0.099 | 164% | 36.5 | 30.4 | -17% |
| | Old forest | 6.89 | 7.58 | 10% | 0.189 | 0.281 | 49% | 55.5 | 33.7 | -39% |
| ABLA/PIEN | SSP | 2.97 | 2.36 | -21% | 0.122 | 0.119 | -2% | 22.2 | 19.1 | -14% |
| | Young | 13.83 | 10.39 | -25% | 0.290 | 0.308 | 6% | 35.4 | 27.4 | -23% |
| | Mature | 12.32 | 5.16 | -58% | 0.251 | 0.173 | -31% | 27.3 | 27.5 | 1% |
| | Park-like | 0.92 | 0.51 | -44% | 0.046 | 0.021 | -55% | 11.1 | 41.4 | 273% |
| | Old forest | 2.66 | 2.49 | -7% | 0.044 | 0.049 | 12% | 62.5 | 55.5 | -11% |
| ABAM/TSHE | SSP | 0.64 | 0.87 | 37% | 0.104 | 0.102 | -2% | 16.1 | 18.2 | 13% |
| | Young | 2.92 | 2.43 | -17% | 0.188 | 0.193 | 3% | 20.4 | 18.6 | -9% |
| | Mature | 3.83 | 6.62 | 73% | 0.178 | 0.267 | 50% | 20.1 | 24.8 | 24% |
| | Park-like | 0.44 | 0.66 | 52% | 0.023 | 0.038 | 65% | 8.3 | 19.2 | 132% |
| | Old forest | 0.66 | 4.02 | 508% | 0.030 | 0.131 | 332% | 22.0 | 24.7 | 12% |
| TSME | SSP | 0.00 | 0.11 | na | 0.000 | 0.086 | na | 0.0 | 6.5 | na |
| | Young | 0.00 | 0.19 | na | 0.000 | 0.057 | na | 0.0 | 17.1 | na |
| | Mature | 0.06 | 1.27 | 1930% | 0.008 | 0.169 | 1934% | 13.6 | 19.6 | 44% |
| | Park-like | 0.00 | 0.16 | na | 0.000 | 0.043 | na | 0.0 | 19.6 | na |
| | Old forest | 0.05 | 0.71 | 1448% | 0.008 | 0.072 | 762% | 10.0 | 1 9.7 | 27% |
| PIAL/LALY | SSP | 0.04 | 0.08 | 107% | 0.012 | 0.015 | 32% | 11.0 | 18.0 | 63% |
| | Young | 0.54 | 1.55 | 186% | 0.054 | 0.108 | 99% | 13.8 | 36.6 | 166% |
| | Mature | 0.03 | 0.25 | 715% | 0.003 | 0.013 | 363% | 8.7 | 33.9 | 288% |

**Appendix B: Historical and current percentage area, patch density and patch area of vegetation types on National Forest land in river basins of eastern Oregon and Washington. Historical years for assessment ranged from 193259; current ears ran ed from 1985-90. Area is ex ressed as the percentage of total basin area.**

| | | Percent area | | | Patch density (n/km²) | | | Mean patch area (ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **River basin & overstory cover** | **Structure[a]** | **H[b]** | **C** | **%D** | **H** | **C** | **%D** | **H** | **C** | **%D** |
| **YAKIMA** | | | | | | | | | | |
| Agric/urban | | 0.20 | 0.58 | 191% | 0.036 | 0.037 | 1% | 29.4 | 77.8 | 165% |
| Bare round | | 4.90 | 7.88 | 61% | 0.134 | 0.248 | 85% | 38.5 | 31.0 | -20% |
| Water | | 1.39 | 1.27 | -8% | 0.048 | 0.040 | -17% | 72.6 | 52.0 | -28% |
| Grass/forb | | 3.97 | 3.43 | -14% | 0.076 | 0.118 | 55% | 31.3 | 32.3 | 3% |
| Shrub | | 0.18 | 0.23 | 24% | 0.017 | 0.023 | 39% | 14.1 | 12.3 | -13% |
| Hardwood | | 0.06 | 0.00 | -100% | 0.017 | 0.000 | -100% | 11.2 | 0.0 | -100% |
| PIPO | SSP | 0.24 | 0.30 | 24% | 0.006 | 0.035 | 453% | 18.1 | 14.6 | -19% |
| | Young | 5.51 | 6.89 | 25% | 0.115 | 0.146 | 27% | 34.5 | 49.6 | 44% |
| | Mature | 7.22 | 7.19 | -0% | 0.265 | 0.252 | -5% | 57.6 | 47.1 | -18% |
| | Old forest | 1.38 | 0.30 | -78% | 0.093 | 0.020 | -79% | 30.5 | 29.5 | -3% |
| | Park-like | 0.21 | 0.24 | 12% | 0.010 | 0.014 | 33% | 18.5 | 16.7 | -9% |
| PIMO/PILA | SSP | 0.03 | 0.17 | 522% | 0.006 | 0.013 | 121% | 9.0 | 21.7 | 142% |
| | Young | 0.57 | 0.48 | -16% | 0.055 | 0.045 | -18% | 8.7 | 25.8 | 195% |
| | Mature | 0.06 | 0.07 | 26% | 0.012 | 0.012 | -0% | 36.0 | 45.2 | 26% |
| LAOC | SSP | 0.00 | 0.00 | na | 0.000 | 0.009 | na | 0.0 | 2,9 | na |
| | Young | 0.67 | 0.35 | -49% | 0.032 | 0.029 | -11% | 33.2 | 11.9 | -64% |
| | Park-like | 0.01 | 0.00 | -100% | 0.012 | 0.000 | -100% | 9.5 | 0.0 | -100% |
| | Mature | 0.80 | 1.04 | 30% | 0.046 | 0.059 | 30% | 24.1 | 51.6 | 114% |
| PICO | SSP | 0.17 | 0.40 | 140% | 0.008 | 0.015 | 85% | 17.3 | 35.3 | 104% |
| | Young | 0.91 | 0.51 | -45% | 0.042 | 0.036 | -13% | 28.4 | 24.9 | -12% |
| | Mature | 0.11 | 0.05 | -58% | 0.004 | 0.004 | -3% | 34.3 | 17.0 | -50% |
| PSME/ABGR | SSP | 1.34 | 3.24 | 143% | 0.032 | 0.123 | 279% | 27.5 | 26.9 | -2% |
| | Young | 8.04 | 17.52 | 118% | 0.197 | 0.397 | 102% | 39.7 | 39.4 | -1% |
| | Mature | 24.72 | 17.24 | -30% | 0.307 | 0.291 | -5% | 68.8 | 54.7 | -20% |
| | Park-like | 1.37 | 0.76 | -45% | 0.034 | 0.043 | 26% | 37.5 | 20.0 | -47% |
| | Old forest | 3.89 | 0.91 | -77% | 0.051 | 0.025 | -50% | 58.7 | 30.2 | -49% |
| ABLA/PIEN | SSP | 1.51 | 0.18 | -88% | 0.061 | 0.013 | -78% | 45.9 | 10.8 | -76% |
| | Young | 6.64 | 2.80 | -58% | 0.228 | 0.108 | -53% | 30.1 | 22.4 | -26% |
| | Mature | 2.36 | 2.16 | -9% | 0.066 | 0.066 | 1% | 36.1 | 31.8 | -12% |
| | Park-like | 0.91 | 0.04 | -95% | 0.028 | 0.009 | -67% | 78.9 | 10.6 | -87% |
| ABAM/TSHE | SSP | 2.14 | 3.59 | 68% | 0.047 | 0.176 | 278% | 15.2 | 28.2 | 86% |
| | Young | 3.85 | 8.20 | 113% | 0.096 | 0.284 | 196% | 37.8 | 34.5 | -9% |
| | Mature | 5.13 | 4.33 | -16% | 0.125 | 0.164 | 31% | 41.8 | 48.1 | 15% |
| | Park-like | 0.85 | 2.40 | 183% | 0.075 | 0.183 | 143% | 20.6 | 96.1 | 368% |
| | Old forest | 6.15 | 0.51 | -92% | 0.143 | 0.028 | -80% | 169.1 | 40.3 | -76% |
| TSME | SSP | 0.15 | 0.01 | -90% | 0.010 | 0.004 | -61% | 37.8 | 3.0 | -92% |
| | Young | 0.45 | 0.37 | -18% | 0.032 | 0.026 | -21% | 18.8 | 33.0 | 75% |
| | Mature | 1.25 | 1.55 | 24% | 0.051 | 0.041 | -20 | 85.3 | 70.9 | -17% |
| | Park-like | 0.00 | 0.03 | na | 0.000 | 0.019 | na | 0.0 | 14.4 | na |
| | Old forest | 0.37 | 0.27 | -29% | 0.024 | 0.020 | -16% | 35.5 | 45.5 | 28% |
| PIAL/LALY | SSP | 0.00 | 0.65 | na | 0.000 | 0.044 | na | 0.0 | 56.6 | na |
| | Young | 0.23 | 1.88 | 707% | 0.021 | 0.038 | 78% | 7.9 | 84.5 | 973% |
| | Mature | 0.06 | 0.00 | -100% | 0.009 | 0.000 | -100% | 39.6 | 0.0 | -100% |

## Appendix B. Definitions for table

a —

*SSP* — 1 canopy layer, seedling, sapling or pole trees (<23 cm diameter at breast height [dbh]);

*Young* — 2 canopy layers, overstory pole or young trees (13-41 cm dbh), understory saplings or poles (<23 cm dbh);

*Mature* — 2+ canopy layers, overstory mature trees (40-64 cm dbh), understory trees young or smaller (<40 cm dbh);

*Mature park-like* — 1 or 2 canopy layers, mature to old overstory trees (>40 cm dbh), understory trees absent or saplings (<13 cm dbh);

*Old forest* — 2+ canopy layers, overstory trees larger than mature (>64 cm dbh), pole to mature understory (13-64 cm dbh).

b — H = historic, C = current, and %D is percent change from historic.

c — Species codes:

PIPO — ponderosa pine

PIMO/PILA — white pine and sugar pine

LAOC — western larch

PICO — lodgepole pine

PSME/ABGR — Douglas-fir, grand fir, or white fir

ABLA/PIEN — subalpine fir and Engelmann spruce

ABAM/TSHE — Pacific silver fir, western hemlock, noble fir, Shasta red fir, or western red cedar

TSME — mountain hemlock

PIAL/LALY — whitebark pine and alpine larch.

d — percentage change from historic not available because historic value was zero.

## Appendix C: List of common and scientific names and abbreviations

| Common Name-Abbreviation | Scientific name |
|---|---|
| Annosum root disease | *Heterobasidion annosum* (Fr.) Bref. |
| Armillaria root disease | *Armillaria ostoyae* (Romag.) Herink |
| Douglas-fir—PSME | *Pseudotsuga menziesii* (Mirb.) Franco |
| Douglas-fir tussock moth—DFTM | *Orgyia pseudotsugata* (McDunnough) |
| Douglas-fir beetle—DF13 | *Dendroctonus pseudotsugae* Hopkins |
| Douglas-fir dwarf mistletoe—DFDM | *Arceuthobium douglasii* Engelm. |
| Engelmann spruce—PIEN | *Picea engelmannii* Parry ex Engelm. |
| Fir engraver—FE | *Scolytus ventralis* LeConte |
| Goshawk | *Accipter gentilis* |
| Grand fir—ABGR | *Abies grandis* (Dougl. ex D. Don) Lindl. |
| Laminated root rot | *Phellinus weirii* (Murr.) Gilb. |
| Lodgepole pine dwarf mistletoe—LPDM | *Arceuthobium americanum* Nutt. ex Engelm. |
| Lodgepole pine—PICO | *Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm |
| Mountain hemlock—TSME | *Tsuga mertensiana* (Bong.) Carr. |
| Mountain pine beetle—MP13 | *Dendroctonus ponderosae* Hopkins |
| Noble fir—ABPR | *Abies procera* Rehd. |
| Pacific silver fir—ABAM | *Abies amabilis* Dougl. ex Forbes |
| Pandora moth | *Coloradia pandora* Blake |
| Pine butterfly | *Neophasia menapia* (Felder and Felder) |
| Pine marten | *Martes americana* |
| Ponderosa pine—PIPO | *Pinus ponderosa* Dougl. ex Laws. |
| Shasta red fir—ABMA | *Abies magnifica* A. Murr. |
| Spruce beetle | *Dendroctonus rufipennis* Kirby |
| Subalpine fir—ABLA | *Abies lasiocarpa* (Hook.) Nutt. |
| Subalpine larch—LALY | *Larix lyallii* Parl. |
| Western spruce budworm—WSB | *Choristoneura occidentalis* Freeman |
| Western redcedar—THPL | *Thuja plicata* Donn ex D. Don |
| Western hemlock—TSHE | *Tsuga heterophylla* (Raf.) Sarg. |
| Western larch—LAOC | *Larix occidentalis* Nutt. |
| Western larch dwarf mistletoe—WLDM | *Arceuthobium laricis* (Piper) St. John |
| Western dwarf mistletoe—PPDM | *Arceuthobium campylopodum* Engelm. |
| Western pine beetle—WPB | *Dendroctonus brevicomis* LeConte |
| Western white pine—PIMO | *Pinus monticola* Dougl. ex D. Don |
| Whitebark pine—PIAL | *Pinus albicaulis* Engelm. |
| White fir—ABCO | *Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr. |

## GLOSSARY

**Aspect**—The direction a slope faces.

**Bark beetles**—Beetles (Coleoptera/Scolytidae) that attach tree stems and produce their young in galleries located between the outer wood and inner bark.

**Basin (river drainage area; catchmerit)**—The area of land that drains water, sediment and dissolved materials to a common point along a stream channel.

**Biodiversity (biological diversity)**—The variety of living organisms and their processes.

**Brooms or witches-brooms**—Abnormally dense clusters of shoots or branches on conifers caused by infection by dwarf mistletoes and certain needlecast or rust fungi.

**Butt rot**—Internal wood decay caused by fungi in the base (butt) of a tree.

**Canopy**—The part of any stand of trees represented by the tree crowns; canopies may occur in layers.

**Clearcut**—An area of forest from which all merchantable trees have been removed by harvesting.

**Clearcutting**—A regeneration harvest method whereby all trees (with the exception of advance regeneration) are removed from an area of the forest.

**Climatic climax**—A climax condition that is maintained by climatic factors such as temperature and precipitation regimes, and length of growing season; compare with edaphic climax.

**Climax**—The terminal, theoretically stable, self-perpetuating condition in a series of plant communities that culminates plant succession on any given site in the absence of any major disturbance.

**Climax species (or series)**—The tree species predominating on a site at climax especially in the absence of major disturbances. Sites are often described in terms of the major forest series they belong to (example-grand fir climax series, which includes plant associations where grand fir is the dominant overstory species at climax).

**Climax vegetation**—The pattern or complex of climax plant communities on a landscape corresponding to the pattern of environmental gradients or habitats.

**Clumpiness**—The distribution of tree cover within a patch of vegetation. Low clumpiness occurs where tree cover is evenly distributed across the patch; whereas high clumpiness indicates an uneven or patchy distribution of tree cover within a stand.

**Coarse-filter management**—Conservation of land areas and representative habitats under the working hypothesis that the needs of all associated species, communities, environments, and ecological processes will be met; compare with Fine Filter Management.

**Connectivity (of habitats)**—The linkage of similar but spatially separated vegetation stands (such as mature forests) by patches, corridors, or "stepping stones" of like vegetation across the landscape; also, the degree to which similar habitats are so linked.

**Contagion**—A measure of landscape complexity at a small scale. Low contagion indices occur in landscapes with very large patches in regular patterns; high indices indicates a complex mosaic of small patches. The contagion index ranges from 0 to 1.

**Cover**—Any feature that provides protective concealment for fish and wildlife. Cover may consist of live or dead vegetation, or geomorphic features such as boulders and undercut banks. Cover may be used for the purposes of escape from predators, feeding, or resting.

**Crown**—The part of any tree containing live foliage.

**Crown differentiation**—The relative differences in tree crown sizes within a patch of vegetation. Low differentiation occurs where trees within a patch have similar crown diameters, and high differentiation occurs where a wide variety of crown diameters occur.

**Cumulative effects**—Effects on the environment resulting from individual events that become collectively-significant over a period of time.

**Defoliating insects**—Insects which feed on leaves or needles of living trees.

**Disturbance**—Any event which alters the structure, composition, or function of terrestrial or aquatic habitats.

**Dominance**—An index related to diversity indices that measures the relative dominance of vegetation types across the landscape. High dominance values indicate landscape area dominated by few vegetation types; whereas, low values occur where landscapes have diverse vegetation. Dominance does not measure the pattern of distribution, however.

**Dominant**—A group of plants that by their collective size, mass, or number exert a primary influence on other ecosystem components.

**Ecosystem**—A complete interacting system of organisms considered together with their environments. A biotic community and its abiotic environments.

**Ecosystem management**—Conservation and use of natural resources to maintain biological diversity, long-term site productivity, and sustainable resource production and use; the new management paradigm on National Forests.

**Ecoregion**—Regions of relative homogeneity in ecological systems or in relationships between organisms and environments based on patterns of terrestrial vegetation and environment.

**Edaphic climax**—A climax that is the result of unique soil conditions usually differing from those of the surrounding area.

**Edge**—See Habitat Edge.

**Extent**—The dimensions of a mapped area. For example, the map of a 1000-ha area is of smaller extent than a map of 10,000 ha.

**Fine-filter management**—Management that focuses on the welfare of a single or few species rather than broad management of a habitat or ecosystem (see Coarse-filter management).

**Fire cycle**—The average time between fires in a given area.

**Fire frequency**—The return interval of fire.

**Fire regime**—The frequency, predictability, intensity, seasonality, and extent characteristics of fires in an ecosystem.

**Fire severity**—The effect of fire on plant communities. For trees, it is often measured as the percentage of basal area killed by fire.

**Forb**—An herbaceous plant that is not a sedge, grass, or other plant with grass-like foliage.

**Forest health**—A measure of the robustness of forests in terms of their biological diversity, soil, air, and water productivity, disturbance ecology, and capacity to supply a sustainable flow of goods and services for humans.

**Fractal**—A simple index of edge complexity that ranges from 0 to 1. There are several measures of the fractal dimension, but the perimeter/area fractal used in this paper measures the complexity of patch shape as measured by the perimeter length relative to area. Low indices indicate regular rectangular or circular shapes, whereas high indices indicate complex patch shapes and high edge.

**Fragmentation**—See Habitat Fragmentation.

**Fuel**—Dry, dead tree parts which can readily burn.

**Habitat**—The area where a plant or animal lives and grows under natural conditions. Habitat consists of living and non-living attributes, and provides all requirements for food and shelter.

**Habitat edge**—The margin where two or more vegetation patches meet, such as the boundary of a clearcut next to a mature forest stand; also see Habitat Fragmentation.

**Habitat fragmentation**—The splitting or isolating of patches of similar habitat, typically forest cover (but could also apply to grass fields, shrub patches, and other habitats); habitat can be fragmented from natural conditions, such as thin or variable soils, or from forest management activities, such as clearcut logging.

**Habitat interior species**—See Unitype Species.

**Habitat type**—The land area capable of supporting a single plant association.

**Harvest**—Felling and removal of tree stems from the forest for the manufacture of forest products.

**Harvest systems**—Patterns of tree removal that mimic aspects of partial or complete stand-replacing disturbances.

**Heart rot**—Wood decay that is apparently restricted to heartwood.

**Heartwood**—The interior wood in living trees that provides strength and rigidity to stems, has ceased conducting water and nutrients, contains no living cells, and is generally darker in color than wood to the exterior.

**Heat capacities**—The amount of heat required to raise the temperature of one gram of soil one degree.

**Herb**—Non-woody vegetation that includes both grasses and broad-leaf plants of low profile, known as forbs.

**Infection center**—A population of trees that are infected to varying degrees by a particular forest pathogen, usually a root disease pathogen or dwarf mistletoe species.

**Low grade pathogens**—Weak pathogens that are easily resisted by vigorous plants; low vigor plants are host to low-grade pathogens.

**Matrix**—The least fragmented, most continuous pattern element of a landscape; the vegetation type that is most contiguous.

**Metapopulation**—A term for a population that consists of several to many sub-populations.

**Mid-seral forest**—See Seral Stage.

**Mixed stand**—A stand consisting of two or more tree species.

**Natural fire rotation**—A fire return interval calculated as the quotient of a time period and the proportion of a study area burned in that time period.

**Old growth**—Old forest often containing several canopy layers, variety in tree sizes and species, decadent old trees, standing and down dead woody material.

**Overstory**—The upper canopy layer; the plants below comprise the understory.

**P-group annosum**—Isolates of the root pathogen, Heterobasidium annosum are divided into two host specialized groups. The S-group principally attacks Spruces, hemlocks, and true firs. The P-group principally attacks Pine species.

**Park-like stands**—Stand having scattered, large, seral overstory trees and open growing conditions usually maintained by frequent ground fires.

**Patch**—An area of vegetation with homogeneous composition and structure as viewed from aerial photography.

**Pathogen**—An entity such as a fungus, bacterium, or virus that has the capacity to incite disease in another, organism (host).

**Pathogenesis**—The action of infecting and causing disease.

**Pattern**—The arrangement of vegetation types or other features across landscapes.

**Plant association**—The distinctive combination of trees, shrubs, grasses, and herbs occurring in a theoretical terminal or climax community of a series of communities.

**Plant series**—Aggregations of plant associations having the same overstory dominant.

**Polygon**—The map representation of a vegetation patch. The delineation of vegetation patches by computer with geographic information systems results in a polygon formed by the lines that define the boundaries of the patch. The term polygon is generally synonymous with patch in this report; polygon generally is used when describing data analysis procedures that involve manipulation of patch data.

**Population viability**—The likelihood of continued existence of well-distributed populations of a species.

**Raster**—Representation of map data in geographic information systems by cells in a grid. Each cell is assigned a single value of a map attribute, such as vegetation type, slope, aspect, distance to streams, etc.

**Rate of spread (ROS)**—The rate at which a fire moves across a landscape, usually measured in m $sec^{-1}$.

**Riparian**—Pertaining to land that is next to water, where plants dependent on a perpetual source of water reside.

**Root disease center**—An infection center in the forest having infected, dead, and dying trees, where the causative agent is a pathogenic root—infecting fungus. Root diseases typically spread underground via fungal growth from diseased to healthy host roots.

**S-group annosum**—Isolates of the root pathogen, Heterobasidium annosum are divided into two host specialized groups. The S-group principally attacks Spruces, hemlocks, and true firs. The P-group principally attacks Pine species.

**Seral**—1. Successional; 2. A species or a community which will be replaced by another in succession.

**Seral stage**—Any of a predictable sequence of transitional plant communities that leads to the terminal or climax community.

**Series**—An aggregation of taxonomically related associations that takes the name of the climax species that dominates the principal layer. A taxonomic unit in a classification.

**Snag**—A standing dead tree.

**Stand**—Vegetation occupying a specific area and sufficiently uniform in composition, size, arrangement, structure, and condition as to be distinguished from the vegetation in adjoining areas.

**Stratified random sampling**—A system of sampling in which the study area is first stratified, or divided, into subunits, then samples are selected randomly within the strata or subunits. This method of sampling ensures a more evenly distributed samples across a study are than usually occurs with simple random sampling.

**Structure**—The physical organization and arrangement of vegetation; the size and arrangement (both vertical and horizontal) of trees and tree parts.

**Surface fire**—A fire burning along the surface without significant movement into the understory or overstory, usually below 1 m flame length.

**Transition frequency**—The frequency at which vegetation types occur together across a landscape. Landscape maps are girded into individual cells of a specified area, often 1 ha, then the immediate neighborhood bordering each cell is examined and the number of neighborhood cells in different vegetation types are tallied. This procedure occurs for each cell to form a matrix of transition frequencies.

**Underburn**—Burn by a surface fire.

**Understory**—Collectively, those plants that are beneath the overstory. See Overstory.

**Understory fire**—A fire that burns in the understory, more intense than a surface fire with flame lengths of 1-3 m.

**Unitype species**—A wildlife species that presumably requires one kind of habitat or successional stage. Unitype species typically prefer interior, more secluded portions of their habitat.

**Vector**—Representation of map data in geographic information systems by lines, polygons, and points. Lines, polygons, and points can be assigned multiple attributes in a database associated with a single map.

**Vegetative composition**—The plant species present in a plant community.

**Watershed (also catchment area; basin; drainage area)**—Total land area draining to any point in a stream, as measured on a map, aerial photo, or other horizontal, two-dimensional projection.

**Wildfire**—A human or naturally-caused fire that does not meet land management objectives.

**Lehmkuhl, J.F.; Hessburg, P.F.; Everett, R.L.; Huff, M.H.; Ottmar, R.D. 1994.** Historical and current forest landscapes of eastern Oregon and Washington. Part I: vegetation pattern and insect and disease hazard. PNW-GTR-328. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 88 p. (Everett, Richard L., team leader; Eastside forest ecosystem health assessment; Hessburg, Paul F., science team leader and tech. ed., Volume III: assessment).

We analyzed historical and current vegetation composition and structure in 49 sample watersheds, primarily on National Forests, within six river basins in eastern Oregon and Washington. Vegetation patterns were mapped from aerial photographs taken from 1932 to 1959, and from 1985 to 1992. We described vegetation attributes, landscape patterns, the range of historical variability, scales of change, and disturbance hazards. The distribution of forest age classes and structure has changed, with smaller area in early-seral and old forest stages and greater area in multiple-canopy young and mature stands.

Keywords: Historical vegetation, landscape pattern, insect and disease hazard, range of variation, scale forest health, disturbance, fire suppression, Oregon, Washington, Cascades, Blue Mountains.



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