Chapter 1: Introduction

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Background and Purpose of This Science Synthesis

We live in an era of information. Although this brings many benefits to society, it creates challenges for those responsible for understanding and applying new and older information to their day-to-day work. How does one keep up with the volume of relevant information that is published daily?

People who manage the 24 million ac (9.7 million ha) of public land within the area of the Northwest Forest Plan (NWFP, or Plan) depend on sound scientific knowledge about ecological systems and about how they function and how they respond to change. The Plan area stretches from Washington's northern border to a significant portion of northern California, encompassing diverse geography, ecological systems, and human communities. The authors of the NWFP understood that scientific knowledge would be critical to the efficacy of the plan, both in preparation of plan guidance and in learning how affected forests and communities (i.e., socio-ecological systems) would change over time, with and without active management. Current direction to national forests that are undertaking forest plan revisions also specifically calls for sound scientific information to guide plan preparation and to make selected changes to how forests might be managed in the future. Land managers responsible for updating forest plans find it challenging to remain current with all the new scientific knowledge. For a geographic region as large, diverse, and complex as the Plan area, this presents one of the greatest challenges to plan preparation and execution.

The majority of public lands within the NWFP area are managed by the U.S. Forest Service. This includes roughly 19.2 million ac (7.68 million ha) on 17 national forests (the Deschutes, Fremont-Winema, Gifford Pinchot, Klamath, Lassen, Mendocino, Modoc, Mount Baker–Snoqualmie, Mount Hood, Okanogan-Wenatchee, Olympic, Rogue River–Siskiyou, Shasta-Trinity, Siuslaw, Six Rivers, Umpqua, and Willamette National Forests). There are also roughly 2.5 million ac (1 million ha) of U.S. Department of the Interior Bureau of Land Management (BLM) lands and roughly 2.3 million ac (0 .92 million ha) of National Park Service lands within the Plan area. This synthesis is intended to support upcoming management work on all public lands, but is expected to serve primarily Forest Service lands and their impending forest plan revisions. In 2016, the BLM revised its resource management plans for its lands in western Oregon. Although the BLM and Forest Service are using distinct and separate planning processes to revise land use plans within the Plan area, the two agencies share common goals for long-term monitoring of the impacts of the implementation of their land use plans.

To help meet the challenge of forest plan revision, this science synthesis provides a comprehensive overview of the full body of relevant science accumulated in the 24 years since the NWFP was initiated. The synthesis was developed at the behest of the Pacific Southwest and Pacific Northwest Regions (Forest Service Regions 5 and 6). To accomplish this task, the Pacific Northwest (PNW) Research Station and the Pacific Southwest (PSW) Research Station assembled a team of scientists who are experts in a variety of biological, ecological, and socioeconomic disciplines.

The term "synthesis" can have many different meanings. For our purposes, it is a compilation of relevant scientific findings that pertain to key issues around the NWFP. Such a compilation not only summarizes science by topic areas but also makes connections across scientific themes and addresses multilayered and interacting natural and socioeconomic resource issues. This report has been prepared to assist land managers in updating existing forest management plans and on-the-ground projects. Our hope is that it will serve as a reference that provides a condensed and integrated understanding of the current state of knowledge regarding the NWFP, as well as an extensive list of published sources, where readers can find further information.

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This synthesis is not a bibliography or an interpretation of all available science; and is not intended to direct management through recommendations or analysis of management alternatives. In contrast, the charge given to the scientists who served as members of the Forest Ecosystem Management Assessment Team (FEMAT) under the original NWFP (FEMAT 1993) requested that scientists assess the science and use their expert knowledge to develop a set of plan alternatives and corresponding management recommendations. President Bill Clinton selected and adapted one of these plan alternatives, which formed the basis of the standards and guides for the NWFP. This science synthesis provides a summary and interpretation of relevant science findings to support subsequent planning efforts under Forest Service regulations.

Our approach largely follows the role of "science arbiters," one of the four roles that scientists can play in policy arenas (Pielke 2003). Science arbiters answer questions from managers from a scientific perspective (e.g., What are the ecological differences between dry forests and moist forests, or what is known about the ecological effects of different restoration strategies?). But they do not develop or evaluate policy alternatives. We do not play an alternative role of "honest brokers of policy alternatives" who develop a wide range of policy alternatives and characterize their possible consequences using scientific findings and expert opinion. That was the role that the scientists in FEMAT played. Although this synthesis does not develop plan alternatives or evaluate them, it does characterize what is known about the ecological effects of various management practices (e.g., salvage logging or prescribed fire), and it identifies ecological and socioeconomic tradeoffs associated with different management goals (e.g., ecosystem integrity vs. single species) and practices. We also characterize how well the NWFP has met some of its original goals by using information from the monitoring programs and peer-reviewed published sources.

The synthesis builds upon the 10-, 15-, and 20-year NWFP monitoring reports and it considered well over 4,000 peer-reviewed publications. The authors of individual chapters have extensive knowledge of the scientific literature, and much of what was reviewed comes from their knowledge of the most relevant work. As part of this review process, we also established a Web portal to enable members of the public to offer appropriate literature that they wanted to ensure would be included in the review. We provided a comprehensive summary of the scientific literature that we considered salient to the key issues to be addressed by land managers as they begin considering forest plan revision.

The breadth of topics and number of scientific papers that could be covered in this synthesis is enormous. At the direction of Regions 5 and 6, we focused on topics that had a direct bearing on activities that resulted from the NWFP and subsequent forest plan revision. Focal topics were distinguished from a large set of management questions identified by Forest Service management staff in the two regions. The core author team worked with Forest Service managers to condense the initial set of questions to 73 (see app. 1). The final list was established by removing questions that were outside the scope of this effort (including those that could not be addressed by published scientific information or were not relevant to the NWFP), then identifying only those topics that could be addressed by reviewing the evidence contained in the scientific literature (i.e., at least some scientific information exists that would enable some insight on the question). The final questions were grouped into four main categories (Vegetation/Forest Management, Terrestrial Species/Habitat Management, Aquatic/Riparian Management, and Social/Economic, including Timber Production), which formed the basis for the organization of the synthesis. Lead authors used these questions to build chapter outlines and provide useful information to support subsequent management planning efforts.

The authors of the chapters address the management questions using a range of approaches. In some cases, there is ample scientific evidence from the Plan area to address the questions; however, in many cases, few research studies exist from the NWFP area. In such cases, studies from other regions or current scientific theory are used to address the questions to the extent possible. In many cases, major uncertainties are identified, while in others much uncertainty remains. The following chapters provide comprehensive reviews of the relevant scientific literature within their topic areas, but the authors do not evaluate tradeoffs among different resource management and planning objectives. Chapter 12, however, addresses the most significant integration issues as well as potential tradeoffs to identify where additional evaluation or more monitoring/research will be necessary in subsequent assessments and planning efforts to resolve potential or existing conflicts.

Northwest Forest Plan History and Context

The NWFP is rooted in the environmental history of the region and followed a series of ecological and socioeconomic triggers in the 1980s and early 1990s (Johnson and Swanson 2009). Historically, the ecosystems of this region have been influenced by many tribes of native people for millennia (see chapter 11). More than two centuries ago, their civilizations and stewardship of the ecosystems of the region were greatly affected by visitors and settlers from the Eastern United States or from European countries, and the United States gradually seized or acquired lands from tribes, converting much of the forested area into farmlands, industrial timberlands, and other new land uses. By the beginning of the 20th century, large tracts of forest lands in the Western United States were put into "forest reserves" and managed by the U.S. Forest Service to protect watersheds and ensure a continuous supply of timber. The initial reserve era gave way to the era of sustained-yield forestry to support economic growth (Steen 2004). These practices continued into the 1970s, when three significant federal laws were passed: the National Environmental Policy Act (NEPA) of 1970, the Endangered Species Act (ESA) of 1973, and the National Forest Management Act (NFMA) of 1976. Collectively, these laws engendered an era of increasing environmental awareness and concern. During the next two decades, the stage was set for conflict between timber-focused policies and the emerging public concern over the environmental impacts of forest management practices in the Northwest. By 1990, conservation of biodiversity had ascended to become a new priority for federal forests, and numerous organizations stepped in to initiate litigation, which ultimately led to establishment of the NWFP in 1994 (Johnson and Swanson 2009).

The NWFP was a product of many social and ecological drivers, but the focal point of the deliberations was the protection of the old-forest ecosystems that provide habitat for northern spotted owls (*Strix occidentalis caurina*). The Plan also addressed the needs of the marbled murrelet (*Brachyrampus marmoratus*), anadromous fish, and other species associated with older forests, as well as stressing the importance of sustaining rural communities and economies through continued timber harvest (Charnley 2006). There are many alternative views and definitions of "old growth" (chapter 3) (Haynes et al. 2006). For the sake of simplicity, we use only the term "old-growth forests" in this introduction.

The 1980s were part of a transformative period for the Pacific Northwest and northern California (Johnson and Swanson 2009). For many years, timber harvest was extensive across the region, and concerns about the effects that the logging of old growth had on wildlife and riparian areas grew steadily into the early 1990s. The 1990 listing of the northern spotted owl as a threatened species precipitated numerous legal challenges regarding the cumulative impacts of federal timber management in the Pacific Northwest and northern California. When a federal court issued an injunction in 1991 on all timber sales on federal lands within the range of the northern spotted owl, the political and environmental landscape shifted substantially. The ensuing political crisis set the stage for the emergence of the NWFP.

These dramatic events and emerging science precipitated federal government engagement, up to and including the White House, to seek a workable solution. Over the next 2 years, beginning in earnest with the Northwest Forest Summit in 1993, the federal government forged a plan. The extensive involvement of the White House and principal land management agencies (i.e., the Forest Service and BLM) led to the 1994 adoption of the NWFP by the Clinton Administration (Pipkin 1998).

The Forest Ecosystem Management Assessment Team

President Clinton established three interagency working groups to build a foundation for what would ultimately become the NWFP. One of these groups was FEMAT, a team of scientists, resource managers, and technicians from many different universities and public agencies, charged with identifying management alternatives that could attain the greatest economic and social contribution from forests, while meeting all applicable laws and regulations (FEMAT 1993). Specifically, FEMAT was asked to consider and develop conservation approaches, restoration actions, and adaptive management strategies to meet the following biological diversity goals: (1) habitat for the northern spotted owl and marbled murrelet, (2) habitat for other species associated with old growth, (3) spawning and rearing habitat for anadromous fish, and (4) maintenance of a connected old-growth forest reserve system on federal lands.

FEMAT issued an extensive report (FEMAT 1993) that analyzed the ecological, social, and economic implications of 10 management options for the federal forests within the range of the northern spotted owl. The team used expert opinion to assess biophysical processes and disturbances, community capacity, and economic factors, and it estimated tradeoffs and risk to species associated with different levels of protection for biodiversity and timber production. This was, and may still be, the most extensive regional forest biodiversity and management assessment of its kind. Many of today's persistent policy challenges were raised and considered 24 years ago in this report. The FEMAT report identified risk and uncertainties associated with the different conservation and management issues and recognized that monitoring and adaptive management would be needed to maintain a long-term, scientifically based and adaptive plan. This synthesis summarizes published research, monitoring and knowledge of plan implementation over the past 24 years, providing a current scientific foundation for forest planning.

Principal Elements of the NWFP

Conservation and management of old-growth forests are central to the NWFP and the past 24 years of its implementation. As readers consider the various chapters in this synthesis, they will see that old-growth forests have both an ecological and a social dimension. These dimensions can be linked, but also can emerge in quite different contexts. We address and discuss these facets in the following chapters.

The principal tasks of the NWFP were to conserve and restore habitats for animals and plant species associated with old-growth forests and maintain and restore habitat for anadromous fish within the confines of existing laws and regulations (e.g., NFMA and ESA). Management of the affected 24 million ac (9.7 million ha) of land was altered significantly to meet these new biological diversity goals. At the time, relatively little was known about most species associated with late-successional and old-growth forests, and this is still the case. Although the biology and ecology of the northern spotted owl were relatively well understood, there were many gaps in our understanding of this long-lifespan species with a low reproductive rate. The major shift in federal forest management was part of a larger global trend toward increasing protection for the forest biodiversity through a process called "ecosystem management" (Grumbine 1994). As Chuck Meslow, then leader of the Oregon Cooperative Wildlife Research Unit at Oregon State University, explained, the NWFP originated at a time when many scientists were beginning to advocate for a more ecological approach to managing remaining old-growth forests (FEMAT 1993).

The intent of ecosystem management, as it was initially envisioned at the time, was to sustain ecosystems by maintaining (1) viable populations of native species, (2) native ecosystem types, and (3) evolutionary and ecological processes over long time horizons (Grumbine 1994). In doing so, it was posited that such a management regime would accommodate human use and occupancy within the capacities of ecosystems. The NWFP changed federal management by giving priority to ecological sustainability; the team was directed to plan for social and economic values **after** meeting ecological objectives. The hope was that the Plan could find common ground through the right balance of biodiversity and timber management objectives (Charnley 2006).

The NWFP evolved out of three preceding efforts in the early 1990s to find a solution to the conflicts over federal forest management (Thomas et al. 2005): (1) a conservation strategy for the northern spotted owl (Thomas et al. 1990), (2) "Gang of Four" report on alternatives for management of Pacific Northwest late-successional forests for multiple species (Johnson 1997, Johnson et al. 1991), and (3) the Scientific Analysis Team (known as the SAT) report, which conducted a scientific analysis that added riparian protection and more species to the assessment. (Thomas et al. 1993). These efforts laid the foundation for much of the NWFP. FEMAT, established by the president, used this and other sources of information to develop options that would (1) consider human and economic dimensions of the problem; (2) protect the long-term health of forests, wildlife, and waterways; (3) be scientifically sound, ecologically credible, and legally responsible; (4) produce a predictable and sustainable level of timber sales and nontimber resources that would not degrade the environment; and (5) emphasize collaboration among the federal agencies responsible for management of these lands (Thomas et al. 2005).

FEMAT developed 10 options for the president and agency heads to consider. They selected option 9, which was based on both ecosystem- and species-level conservation and restoration strategies. This option was subsequently modified to meet viability requirements under NFMA during the final environmental impact statement process, and the final plan was set forth in the record of decision (ROD), with the following key elements:

- Adoption of a yet-to-be-defined **ecosystem management approach**
- **Seven land allocations** (see fig. 1-1) to address key conservation/management concerns, including:
    - Congressionally reserved areas (7.3 million ac/2.95 million ha)
    - New late-successional reserves (7.4 million ac/2.99 million ha)
    - New adaptive management areas (1.5 million ac/607 000 ha)
    - New managed late-successional areas
    - Administratively withdrawn areas
    - New riparian reserves (2.6 million ac/1 million ha)
    - Matrix (for ecologically sensitive timber production) (nearly 4 million ac/1.6 million ha)
- An emphasis on **effective consultation with more than 70 federally recognized tribes** to avert conflicts with American Indian trust resources on public lands and exercise of tribal treaty rights.
- **Standards and guidelines** that provided detailed requirements describing how land managers would treat forest lands within the range of the northern spotted owl.
- A **new monitoring program** consisting of implementation monitoring (are the standards and guidelines being followed?) and effectiveness monitoring (is the plan having the desired effect?).
- **"Survey and manage" measures to provide for other late-successional species** that may not be covered under the conservation strategies for the spotted owl and marbled murrelet, and for aquatic ecosystems and old-growth forests.

Reserves are a key component of the terrestrial and aquatic components of the NWFP and are discussed at length in chapters 3, 4, 5, 7, and 12. Reserves were intended to provide immediate and wide-ranging benefits for target species (e.g., spotted owls) and target ecosystems (old-growth forests, streams). Reserves were carefully delineated across the Plan area with the intention of improving ecological conditions for key Plan elements such as spotted owls or anadromous fish. We use monitoring results to evaluate how those conditions have changed and how well the underlying goals of the Plan have been met.

The ROD for the NWFP amended the planning documents for 19 national forests.[2] It is important to recognize that, over the past 24 years, implementation of the Plan across the entire area has varied from location to location. This can be attributed to geography and variation in how planning standards and guidelines have been interpreted by different forests, districts, and personnel over time. This is inevitable given the challenges of implementing a complex land management plan across a broad and diverse geography. The monitoring data we used to evaluate

[2] The Northwest Forest Plan area currently includes 17 national forests; in 2000, the Okanogan and Wenatchee National Forests administratively merged as the Okanogan-Wenatchee National Forest, and in 2002 the Fremont and Winema National Forests administratively merged as the Fremont-Winema National Forest. The Plan area also includes five Bureau of Land Management districts and one resource area (formerly six districts and one resource area), with extensive standards and guidelines that comprised a comprehensive ecosystem management strategy.

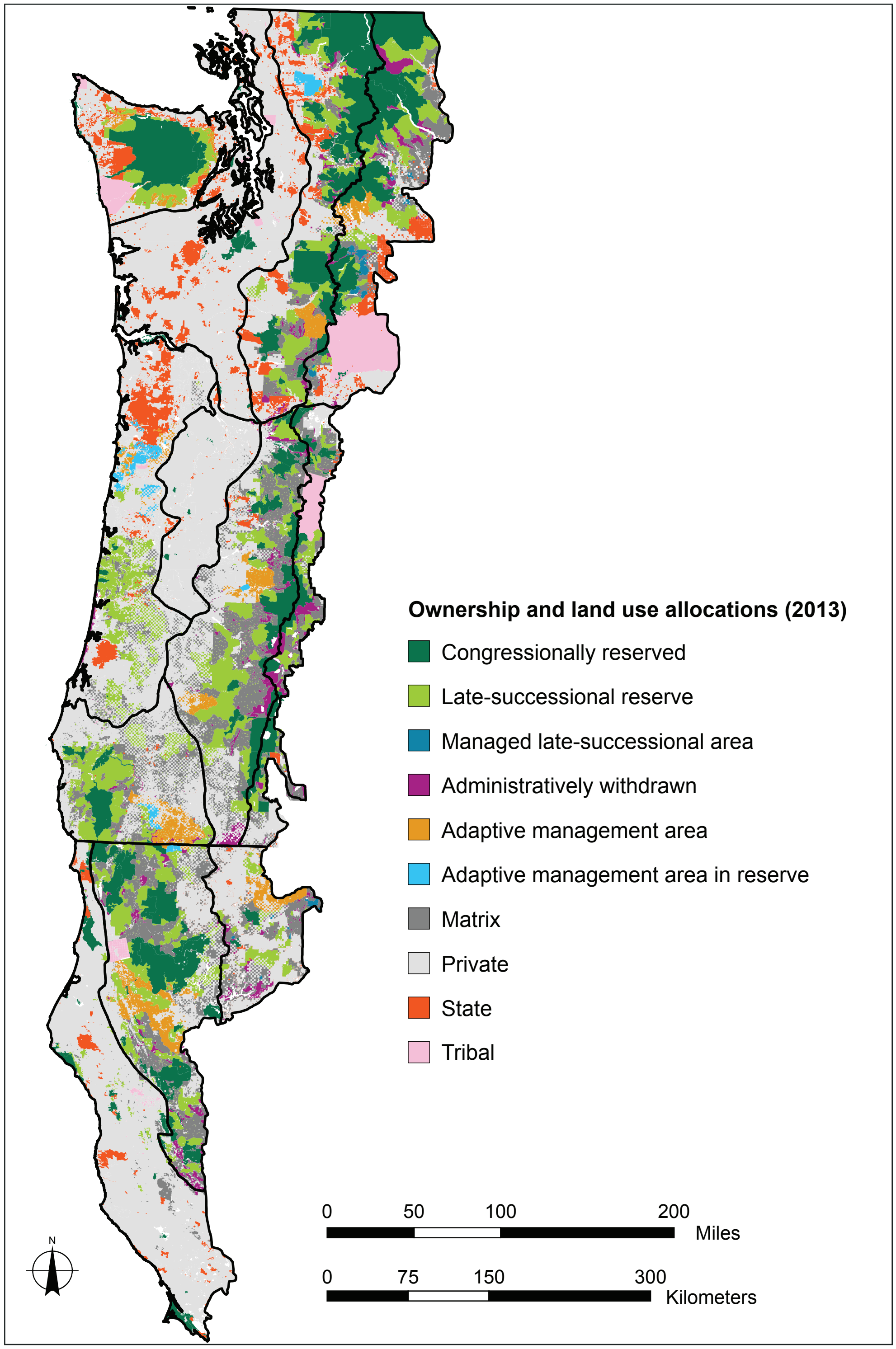

Figure 1-1—Land allocation categories and original 12 physiographic provinces (outlined in black) for the Northwest Forest Plan area. Note that "matrix" includes riparian reserves and other unmapped buffers (e.g., Survey and Manage).

the NWFP are regional in scale and may not capture variability in Plan effects. In addition, unlike the effectiveness monitoring program, the implementation monitoring program has not been continued, making it difficult in some cases to determine what has actually occurred. The limits of the monitoring programs mean that some of our characterization of the Plan may not be correct.

Decisionmakers considered monitoring to be an essential component of the selected alternative. Monitoring was intended to provide information to determine if standards and guidelines were being followed (implementation monitoring) and to verify if they were achieving desired results (effectiveness monitoring). In addition, a third type of monitoring, validation monitoring, was identified as a way to determine if underlying assumptions of the Plan were sound (this monitoring program was never formally established). The monitoring plan was subsequently cited by U.S. District Court Judge William Dwyer in his ruling upholding the Plan after challenges from the timber industry. The judge ruled that monitoring was a key element of the Plan and was essential to its success. Information obtained through monitoring, together with new research and experience gained through implementation, would provide the basis for adapting the Plan in the future (USDA 1994).

History of Reporting on the Research and Monitoring Within the NWFP Area

The NWFP involved the scientific community, through research and monitoring, in ways and to lengths not used before in Forest Service planning and management. The NWFP was driven, in large part, by a requirement to meet certain standards under the ESA and the viability clause of the NFMA, as well as by changes in land management related to three other federal laws (Thomas et al. 2006). These circumstances quickly triggered the need to engage scientists from the beginning, to provide both the planning and implementation process with robust, reliable scientific information.

The record of decision included the requirement of a detailed monitoring plan to ensure that management actions meet the prescribed standards and guidelines, and that actions complied with applicable laws and policies. Information obtained through monitoring, together with new research and information from adaptive management areas and studies, were intended to provide a basis for changes to the Plan, including changes to the standards and guidelines. Although a formal validation monitoring program was never established, research activities were conducted to help testing of hypotheses related to NWFP goals.

10-, 15-, and 20-Year Monitoring Reports

The NWFP was designed to include an adaptive management approach to enable "learning from doing." The record of decision called for gathering information through an extensive monitoring effort, together with targeted new research and other new sources of information, to provide a basis for adaptive management and updating the selected alternative with new scientific knowledge. This set lofty aspirations for the scientific rigor of the Plan; however, there has been little adaptive management work done (i.e., actual designed experiments to test management strategies and assumptions in designated AMAs) since the Plan was initiated.

Monitoring was designed for data collection at multiple scales, ranging from site-specific projects to the regional-scale planning area, to allow localized information to be compiled and considered in a regional context. Many but not all of the data sources used in the 20-year reports were initially developed and used for the 10- and 15-year monitoring reports. During each 5-year monitoring cycle, previously used data sources are updated to incorporate new research findings and other information, or to correct errors or previous misconceptions. So, to the extent possible, results are comparable between the two major reporting periods, but caution is suggested when examining topics that relate findings from one time period to the next because of minor analytical or reporting differences between monitoring reports.

Monitoring results have been evaluated and reported in 1- and 5-year intervals since the inception of the NWFP. The first comprehensive analysis of 10 years of NWFP monitoring data was published in a series of general technical reports (GTRs) summarizing what had been learned over that time. This was an important first step in adaptive management. The 10-year report synthesized the status and trends of five major elements of the plan: old-growth forests, old-growth forest species at risk, aquatic systems, socio-economics, and adaptive management (Haynes et al. 2006). It also synthesized the new science that resulted from 10 years of research related to the Plan. At this time, the cadre of researchers and managers also addressed four additional interconnected questions:

1. Has the NWFP resulted in changes that are consistent with objectives identified by President Clinton?
2. Are major assumptions behind the Plan still valid?
3. Have we advanced learning through monitoring and adaptive management?
4. Does the Plan provide robust direction for the future (Haynes et al. 2006)?

Based on the first 10 years of data collection, findings were ambiguous and conclusions hard to reach—perhaps unsurprisingly for a plan that was expected to take 100 years to achieve its goals. It was clear that the complexity of ecosystem interactions and the effects of new drivers (e.g., encroachment of barred owls, climate change, and changes in social values) were far greater than had been envisioned 10 years earlier. Nonetheless, insights into ecosystem response began to emerge, including circumstances and ecological interactions not contemplated at the time the Plan began. Rapp (2008) provided some highlights of the first decade of monitoring and research as follows:

- Nearly all existing old-growth forest on federal land was protected from timber harvest (although 100-percent protection was not part of the original plan).
- Old-growth forest on federal land had an estimated net increase of roughly 1.2 million ac (~480 000 ha), increasing from 7.87 million ac (3.15 million ha) to 9.12 million ac (3.65 million ha) in the first 10 years as a result of accretion by growth.
- Despite protection of northern spotted owl habitat on federal land, spotted owl populations declined at a greater rate than expected in the northern half of their range, likely because of barred owl competition, and losses of habitat to wildfires.
- Watershed condition improved slightly because of reduced harvest in riparian areas, tree growth, and increased emphasis on restoration.
- Federal timber harvest in the NWFP area was only 54 percent of the level set by the Plan’s goals.
- In spite of mitigation measures, most local communities near federal lands suffered significant job losses and other adverse effects.
- State, federal, and tribal governments worked together on forest management issues more effectively than in the past.
- Increased collaboration with communities changed how the agencies get work done.

Recently, reports analyzing a full 20 years of monitoring data under the NWFP were released by the Regional Interagency Executive Committee and published as GTRs (Davis et al. 2015, 2016; Falxa and Raphael 2016; Grinspoon et al. 2016; Miller et al. 2017). These reports summarize the latest periodic monitoring data gathered since 1994, with a focus on the past 5 years. Some of the key findings contained in these new reports include:

- Overall late-successional and old-growth habitat area has decreased 3 percent on federal lands, with the biggest losses resulting from wildfires. However, this rate of loss was in line with expectations outlined in the FEMAT report during the design of option 9.
- Nesting habitat of the marbled murrelet showed a net decrease of about 2 percent on federal lands and 27 percent on nonfederal lands.
- In Washington, there was an annual rate of decline of 4.6 percent in the population of marbled murrelets between 2001 and 2013; a cumulative decline over 10 years of 37.6 percent. Populations had no detectable trends in Oregon and California.
- The forest types suitable for nesting and roosting for northern spotted owls on federal lands decreased by 1.5 percent since inception of the NWFP. Forest succession is resulting in habitat recruitment that has compensated for losses resulting from wildfire, timber harvest, and insects and disease. However, suitable habitat (i.e., the full range of conditions necessary for a species to survive, persist, and reproduce) has declined more because of the influx of barred owls into forests with otherwise suitable forest vegetation throughout much of the range of

spotted owls. Recent northern spotted owl research indicates that populations are declining throughout the range of the subspecies, and that annual rates of decline are accelerating in many areas. Dugger et al. (2016) observed strong evidence that barred owls negatively affected spotted owl populations, primarily by decreasing apparent survival and increasing local territory extinction rates. The amount of suitable owl habitat, local weather, and regional climatic patterns also appear to be related to demographic parameters, including survival, occupancy (via colonization rate), recruitment, and, to a lesser extent, fecundity (Dugger et al. 2016).

- The attributes of watershed conditions (in-channel physical habitat, macroinvertebrates, and water temperature) showed slight improvements, but uncertainties in the trends of overall conditions remain. Upslope and riparian areas showed moderate, broad-scale improvements in vegetation structure and larger score increases from road decommissioning in a number of watersheds. In the regional average, these increases were largely offset by declines in scores because of fires, particularly on congressionally reserved lands.
- Timber volume harvested has fluctuated over the past 20 years. The volume of timber offered has been on a general upward trend since 2000, with volume offered in 2012 at about 80 percent of probable sale quantity (PSQ) identified in the NWFP (based on revisions to the original PSQ of 1.1 billion board feet, as stated in the ROD, to a PSQ in 2012 of about 805 million board feet).
- Rural communities are not all alike, forest management policies affect different communities differently, and the social and economic bases of many traditionally forest-dependent communities changed in the years since the start of the NWFP.
- Federal-tribal relations are more effective and meaningful when there is common understanding of consultation, tribal rights, federal trust responsibilities, and compatibility of tribal and federal land management.

Scope and Approach of This Science Synthesis

The PNW Research Station partnered with the PSW Research Station to prepare this synthesis, which was initiated at the request of Forest Service land managers. The two station directors guided this effort, and the day-to-day activities were led by Thomas Spies and Peter Stine. Other core team members included Matthew Reilly, Jonathan Long, and Becky Gravenmier. The core team, in consultation with the station directors, identified a group of experienced, knowledgeable scientists to serve as lead chapter authors. This put the responsibility for each chapter in one place and ensured that we would draw upon highly qualified sources.

The public has expressed interest in this synthesis, given the importance of the NWFP in the management of Northwest forests and its influence on forest management approaches around the world. During listening sessions held in spring 2015 to gather feedback from the public about forest plan revisions, attendees provided suggestions relevant to the development and publication of this science synthesis. We heard many participants express a desire for continuous communication about the science, more access to scientific information, and participation in a greater variety of information-sharing venues. A number of steps were taken to enhance public input into this process, including a Web portal for submitting literature for consideration in the synthesis, and a public forum to accept oral and written public input to the peer review team.

Rationale for Topics Covered

Questions from managers guided the focus of the synthesis. The set of 73 management questions were grouped into the following major headings:

- **Vegetation conditions**, including forest management/climate change/ecological disturbance effects on old growth and other vegetation types.
- **Terrestrial species**, including habitat management for the northern spotted owl; marbled murrelet; and other plant, plant-ally, invertebrate, and vertebrate species, and conservation of the biodiversity associated with old-growth forests.

- **Aquatic/riparian management**, including aquatic and riparian species and ecosystems.
- **Socioeconomic well-being**, including timber production, collaborator and stakeholder attitudes, and tribal values and resources.
- **Integrated topics:** themes that cross over between chapters or separate management activities.

This synthesis is organized into 12 chapters, in three volumes, that include an introduction, 10 chapters addressing the primary topics of concern, and a final "integration" chapter that ties together what has been learned and reported in the various chapters and conveys how this synthesized knowledge bears on vital forest management activities. Each chapter provides a summary of the relevant scientific literature, lessons learned over the past 20 years, and the relevance of these findings to management. The synthesis does not provide management recommendations, nor does it conduct assessments of likely outcomes of different approaches to plan revisions.

Sources of Information Considered

This science synthesis considered science published by peer-reviewed scientific or professional journals, or reviewed through an agency-sponsored, third-party process that meets the general criteria for competent and credible peer review. This process collected material from many sources, including an extensive body of original research and monitoring activities). In addition, academic theses, government reports, symposium proceedings, and the like may have been used to support certain topics that were not adequately covered in the peer-reviewed literature. Most of the literature considered was compiled by the authors based on their experience with the subject matter. In some cases, especially in chapter 3 ("Old Growth, Disturbance, Forest Succession, and Management in the Area of the Northwest Forest Plan"**),** some simple analyses of existing data were conducted to illustrate key ideas. Through a Web portal developed specifically for this purpose, we also provided opportunities for the public to suggest literature sources that we may not have already considered. A "Science Synthesis Literature Database" (https://www.fs.fed.us/pnw/research/science-synthesis/literature-database.shtml) for the NWFP area lists all publications reviewed in this report, including many recommended by the public.

Dealing With Scientific Uncertainty

There is always some degree of uncertainty embedded in scientific findings, especially related to our understanding of large and complex socio-ecological systems. The scientific literature in the fields covered by this synthesis does not necessarily address specific questions that land managers posed. Accordingly, chapter authors selected from a wider range of published research in an effort to reduce this uncertainty. To do so, we made judgments based on scientific consensus about how the findings of different scientific reports related to management questions, what the uncertainties are within published reports, and what the uncertainties are related to our interpretation of multiple reports. We report what is known about these topics with high confidence whenever possible, and describe what issues remain uncertain.

In the FEMAT report, an expert evaluation process was used to address gaps in the scientific literature, as well as limits to our understanding, to better estimate the likely outcomes and risks to biodiversity associated with different conservation and management options and practices. FEMAT convened panels of scientific experts to rate the probabilities of viability outcomes for components of the Plan (such as northern spotted owls and aquatic functions) for the different Plan options. Although the FEMAT results and recommendations represented a consensus of scientific knowledge at the time, they contained considerable uncertainties, thus monitoring and adaptive management were regarded as being critical to the Plan's scientific basis. This synthesis does not rely on an expert judgment process to fill large information gaps related to management questions or Plan trends. For example, we do not rate the probability of the long-term viability of the northern spotted owl in light of threats from barred owls or climate change. Although we use expert knowledge to interpret existing science, we avoid speculation about outcomes related to management effects, climate change, or other drivers or threats for which there is no published science. In this sense, the synthesis is more limited in scope than FEMAT was in the interface between science and policy. The process of assessing Plan alternatives, developing revisions to the standards and guidelines, or choosing actions in the face of uncertainties will be handled by federal land managers in subsequent steps of the upcoming planning precess. We report what is known to apprise managers of the best available scientific information and allow them to apply that information to their management concerns.

Role of Peer Review in This Document

Unlike FEMAT, the science synthesis has been subject to external peer review and revision based on those reviews. The Office of Management and Budget (OMB) explained the importance of peer review in its *Information Quality Bulletin for Peer Review*[3] as follows:

> Peer review is one of the important procedures used to ensure that the quality of published information meets the standards of the scientific and technical community. It is a form of deliberation involving an exchange of judgments about the appropriateness of methods and the strength of the author's inferences. Peer review involves the review of a draft product for quality by specialists in the field who were not involved in producing the draft.

The OMB guidelines require that influential scientific information developed by a federal agency be subjected to formal, independent, external peer review to ensure its objectivity. Scientific knowledge is cumulative, building upon previous findings; therefore, safeguarding this trust is essential. Peer-reviewed science does not guarantee that what is presented is true or factual, because new information may overturn, refute, or refine previous findings. Peer-reviewed science is also not necessarily definitive because of the limitations of knowledge, current perspectives, and available studies. However, peer review is the standard within the scientific community for determining which findings meet and exceed adequate thresholds of scientific scrutiny. For these reasons, this science synthesis focused on material that has been peer reviewed and published in print or online.

Peer-reviewed published literature, however, is limited for some topics. For example, some social, economic, health, cultural, or highly specialized ecological topics tend to have less coverage in the peer-reviewed literature. To address such gaps, authors were given latitude to incorporate relevant scientific information from academic theses and other research subjected to some form of committee review. In some cases, analyses were done using existing data and with data sources identified and methods of analysis provided. For example, in chapter 3, we developed a new classification and map of NWFP fire regimes by synthesizing existing data on climate, lightning ignitions, potential vegetation types, and fire-history studies. In contrast, forest management strategies and plans such as the NWFP are generally not peer reviewed or based only on peer-reviewed information. National forest managers consider a host of other sources of information to inform their plan revisions and involve the public in forest plan development.

In general, the authors focused on peer-reviewed research that occurred in the synthesis area or in forest ecosystems with highly similar ecological or social conditions. Ecological and social research is always context-specific, thus we attempted to guard against use of overgeneralizations applied to areas apart from where the research was conducted. This can be especially true of the ecologically and socially diverse region of the NWFP. Scientific studies are often published with caveats about their spatial and temporal scale. However, many basic ecological processes are universal, thus we can apply some findings to other locations. Obviously, basic research cannot be conducted everywhere, so it is important to make prudent application of scientific findings from a given location to other areas. To address this challenge, the synthesis notes the extent and limitations of available information, especially by highlighting various research gaps.

This science synthesis has been identified as a "highly influential scientific assessment," in accordance with the OMB's 2004 peer-review bulletin (see footnote 3), which means that the information contained therein could have a large impact on the public or private sector, or be of

[3] https://www.gpo.gov/fdsys/granule/FR-2005-01-14/05-769.

significant interest to multiple agencies, or be controversial. For this report, we have employed an external peer-review process that includes multiple reviewers with relevant expertise and experience assigned to each of the chapters, and three reviewers who reviewed the entire document. The review was managed by the Ecological Society of America, which selected the review team from scientists with extensive experience and strong credentials, and managed the review process independently.

The peer-review team, led by the Ecological Society of America's director of scientific programs, Clifford Duke, was given basic instructions for conducting peer review in accordance with OMB direction for peer review of highly influential scientific assessments developed by federal agencies (USOMB 2002). Peer-review comments were delivered to the author team in March 2017, and authors used them to develop the final document. Authors also prepared reconciliation documents for each chapter explaining how all comments were used.

The NWFP Area

The establishment and implementation of the NWFP was unprecedented in many ways. Its geographic scope, breadth of topic areas, and long-term investment in monitoring and research all combined to set a new standard for large-scale land management.

The NWFP area covers 24 million ac (9.7 million ha) of federally managed land, extending from the Mendocino National Forest and Ukiah District of the BLM near the coast of northern California to the northern boundaries of the Mount Baker–Snoqualmie and Okanogan-Wenatchee National Forests on the Canadian border. The area spans almost 10 degrees of latitude and ranges from coastal rain forest landscapes to dry east-side pine forests. This expansive and diverse footprint created significant challenges for establishing management guidance and the scientific foundation needed to support it. By recognizing and embracing the variability of this landscape, NWFP managers intended for management efforts to be more nuanced and thus more effective at addressing particular features in any given area.

Ecogeographic Variability of NWFP Area

Efforts to classify and partition the natural world into component parts have been directed at many different levels of biological or ecological organization, from genes and species to communities and ecosystems (Grossman et al. 1998). The NWFP area spans many biological community and ecosystem types and disturbance regimes, and the Plan goals include conservation strategies that focus on ecosystems as well as individual species. It is vital that the application of scientific findings within the Plan area recognize this broad geographic and ecological diversity. This concern is addressed in several chapters in which ecogeographic variation is central to careful treatment of management challenges (e.g., chapter 2 on climate, chapter 3 on old-growth forest, and chapter 5 on northern spotted owls).

Climate, geology, disturbance, and topography all play important roles in controlling forest community patterns at regional scales in the Pacific Northwest (Barbour et al. 2007, Franklin and Dyrness 1973, Ohmann and Spies 1998). The relationships among environment, the biota, and disturbance differ across the region, making it precarious to extrapolate findings from one ecoregion to another. Kennedy et al. (2012) highlighted the importance of understanding the finer grain patterns of forest ecosystems within the NWFP area and their response to disturbances. This understanding is critical for delivering effective management insights across the many, sometimes subtly different, forest conditions distributed within the Plan area. The authors made a concerted effort to address this subject, as in chapter 12, "Integrating Ecological and Social Science to Inform Land Management in the Area of the Northwest Forest Plan."

The NWFP area was originally partitioned into 12 physiographic provinces (see fig. 1-1) based on recognized landscape subdivisions exhibiting different physical and environmental features (Thomas et al. 1993). The resulting breakdown of provinces reflected the regional distribution of major forest types (and state boundaries for management purposes).

A number of qualitative approaches to classifying geographic variation have been used, including Ecoregions of the United States (Bailey 2009) and the Holdridge life zones, as discussed in Lugo et al. (1999). Quantitative ecoregionalization approaches are also available (e.g., Hargrove and Hoffman 2004, Hessburg et al. 2000), but are less often adopted by land managers because of the long-standing habit of using the more qualitative schemes. It is noteworthy that the quantitative schemes show highly intuitive, spatially disjunct patterns of ecoregions, which are largely absent in the qualitative approaches, suggesting that early delineations of ecoregional boundaries are inadequate. The various qualitative methods for identifying ecological regions use macroclimatic conditions (climate unaffected by landform), and prevailing plant formations as the means for classification (Bailey 2009).

Vegetation classifications are a critical part of regional ecological characterizations. Vegetation can be classified based on successional potential (e.g., the late-successional vegetation that would develop in the absence of disturbance for a particular environment), or on current vegetation structure and composition. Both types of vegetation classifications are needed. The two Forest Service regions use different vegetation classification schemes (Region 6 uses potential vegetation, and Region 5 uses actual or current vegetation [cover types]) (chapter 3), which makes it challenging to conduct a seamless ecological assessment across the entire Plan area. For this synthesis, we used the Region 6 potential vegetation classification and developed a crosswalk for linking the two types of classifications.

We also now have access to ecological delineations that are more data-driven, using data models based on machine learning. An example is the habitat modeling developed for the northern spotted owl and contained within the recent recovery plan for this taxon (USFWS 2011). The effort, aimed at partitioning habitat in the range of the spotted owl (essentially the same as the NWFP area), used machine learning via MaxEnt (Phillips et al. 2006) to predict relative existing habitat suitability. Results of this data-driven effort provide a delineation of 11 "modeling" regions as oppossed to the 12 ecoregions originally described for the NWFP area. It is unclear how accurate these habitat suitability models are for predicting actual habitat suitability of different vegetation conditions for northern spotted owls. Barred owls, a significant component of current northern spotted owl habitat through much of its range, drastically complicate our ability to assess habitat suitability. Further work will be needed to understand spotted owl response in the different habitat regions delineated by this modeling work.

Regardless of how this large Plan area is dissected, it is increasingly clear from recent scientific work that geography matters. The diversity of the NWFP landscape is both stark and subtle. We draw more specific attention to this issue throughout the following chapters.

Other Syntheses Reports Relevant to the NWFP Area

The effectiveness of the NWFP was originally evaluated through a set of reports produced 10 years after its initiation (Haynes et al. 2006). This set included a series of status and trends reports, a synthesis of all regional monitoring and research results, a report on interagency information management, and a summary report. Although some existing science was synthesized in the 2006 report, it was not a comprehensive characterization of the literature and did not address a special set of questions posed by managers. Updated monitoring reports were produced in 2009 and 2015 that evaluated the first 15 and 20 years of monitoring data developed under the NWFP (Davis et al. 2015, and others). Each of these monitoring reports included key summaries of the results for each monitoring module, methods, and a set of recommendations for monitoring into the future. These monitoring reports did not include a broader evaluation of the scientific literature.

Other efforts have been made in recent years to consolidate relevant scientific information within the Plan area. Notably, the Forest Service published *The Ecology and Management of Moist Mixed-Conifer Forests in Eastern Oregon and Washington: a Synthesis of the Relevant Biophysical Science and Implications for Future Land Management* (Stine et al. 2014). This synthesis overlapped with the NWFP area along the east Cascades of both Oregon and Washington and addressed some similar land management issues.

Role of Science in Supporting Land Management

This synthesis will inform the development of revised land and resource management plans for 17 national forests by synthesizing relevant information on key topics and management questions across the NWFP area. The synthesis will directly support land managers' ability to make decisions grounded in the best available science, and will provide managers with the needed foundation for assessments as required under the 2012 planning rule (USDA FS 2012).

Context of the NWFP and Forest Plan Revision Under the New Planning Rule

The 2012 National Forest System Land Management Planning Rule brought forth a wide range of changes to the forest planning process through the most collaborative rulemaking effort in agency history. The agency's goal was to implement an adaptive land management planning process that was inclusive, efficient, collaborative, and science-based, and that would promote healthy, resilient, diverse, and productive national forests and grasslands. This new rule is currently being used by national forests to revise forest plans that, in many cases, are 30 or more years old.

The 2012 planning rule, like the 1982 planning rule, sets a broader goal framework and direction for the NWFP revision. The National Forest Management Act requires the Forest Service to "provide for a diversity of plant and animal communities…to meet overall-multiple-use objectives" (Schulz et al. 2013). The 1982 rule required that this regulation be met by "maintaining viable populations of existing native and desired nonnative species in the planning area." As a result, the 1994 NWFP emphasized viability of all species as a goal. This requirement imposed an administrative burden on the agency and proved quite difficult to accomplish and provided controversial results. (Schultz et al. 2013). Consequently, the 2012 rule does not use viability of all species as a basis for conservation of biological diversity, but instead directs that maintenance of species be met through "coarse filter" (ecosystem) approaches that maintain ecological integrity, ecological functions, and habitat connectivity. The 2012 rule acknowledges that ecosystem-scale strategies do not necessarily provide for all species, and that a few species may require special attention as "species of special concern." We do not make recommendations on how to revise the NWFP, given the changes in planning rule direction since the Plan was developed. However, the NWFP contained specific objectives pertaining to conservation strategies for both ecosystems (coarse filter) and particular species (fine filter) and how these were intended to meet biological diversity goals. In several places in this synthesis, we discuss the published scientific findings that convey the advantages and shortcomings of employing these different conservation tactics.

Another change in the 2012 planning rule, compared to the 1982 rule, is its emphasis on using planning that is adaptive, as well as to more fully base Forest Service land management on scientific findings. The rule acknowledges that the body of science that can inform land management planning in such areas as conservation biology and ecology has advanced considerably since the 1982 planning rule was drafted. The new 2012 rule thus calls for planning to include three phases: assessment, plan development/amendment/revision, and monitoring (fig. 1-2). The assessment phase prepares the staff on a national forest for subsequent efforts to consider a full range of options for plan revision, including evaluation of existing information about relevant ecological, economic, and social conditions, trends, and sustainability, and their relationship to the land management plan within the context of the broader landscape. Assessment, including landscape assessments and other supporting science, can include local or traditional sources of information in addition to peer-reviewed science. This framework is intended to support an integrated approach to the management of resources and uses, incorporates the landscape-scale context for management, and ideally will help the Forest Service adapt to changing conditions, while improving management based on new information and monitoring.

The assessment process is conducted and managed by a responsible official, usually the forest supervisor, who has the discretion to determine the scope, scale, and timing of an assessment. Importantly, this synthesis is intended to be available to responsible officials in time to support their plan revision process. It also will support subsequent monitoring efforts, which are also required under the new planning rule. Monitoring information is intended to enable planners to change plan components or other content as needed.

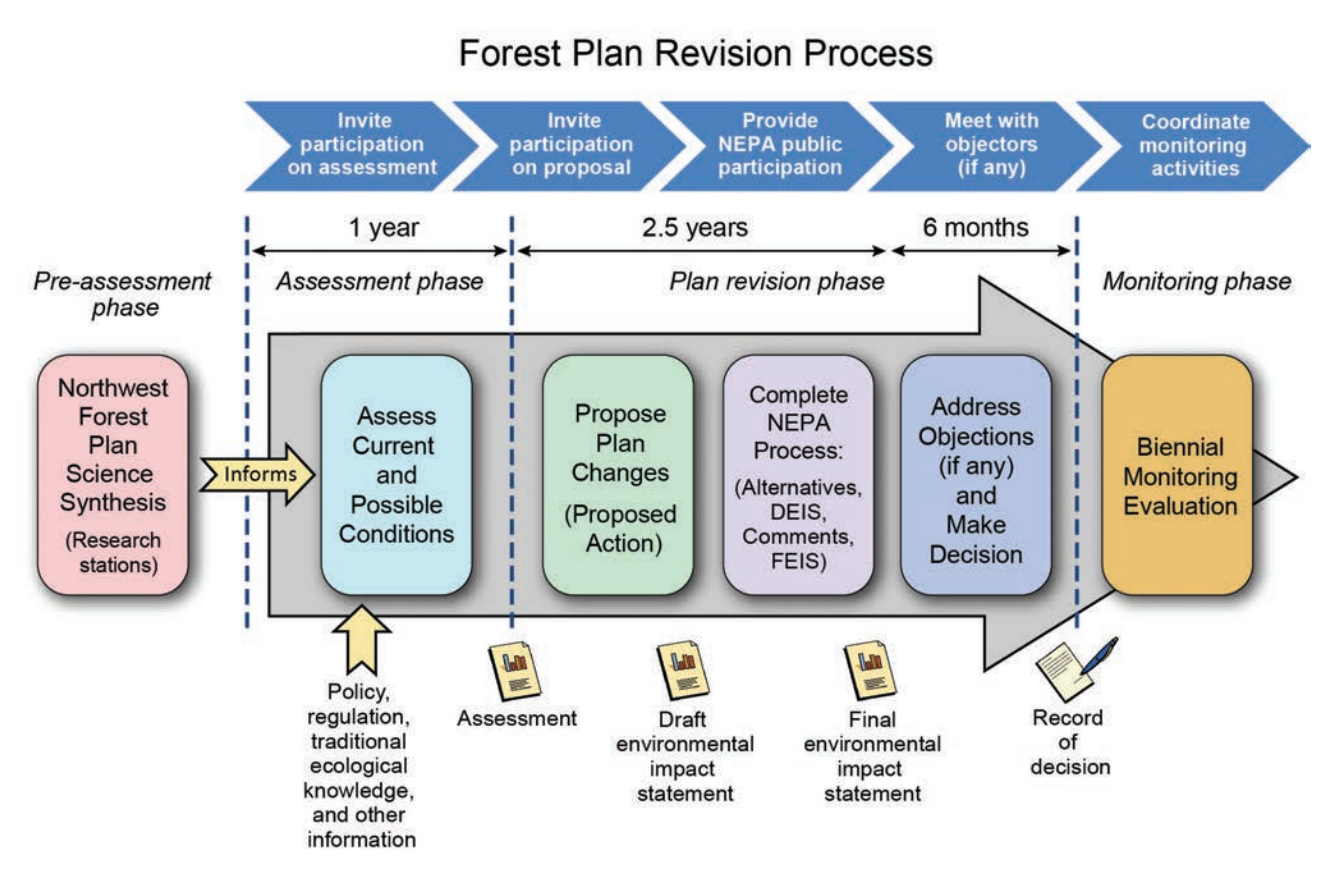

Figure 1-2—The science synthesis is part of the preassessment phase in forest plan revision and will inform the assessment phase of the planning process. NEPA = National Environmental Policy Act.

Given the pivotal role of science in the new planning rule, and the breadth and complexity of potential decisions in the NWFP area, development of this science synthesis was deemed essential to the entire plan revision process. The 17 national forests within the NWFP's footprint are expected to revise their land and resource management plans in the near future under the guidance of the new rule. The regional foresters in Regions 5 and 6 have been charged with following the new rule's detailed requirements, including the enhanced role of science in forest plan revisions. The new rule requires that:

> [the] responsible official shall determine what information is the most accurate, reliable, and relevant to the issues being considered. The responsible official shall document how the best available scientific information was used to inform the assessment, the plan decision, and the monitoring program as required in §§ 219.6(a) (3) and 219.14(a) (4). Such documentation must: Identify what information was determined to be the best available scientific information, explain the basis for that determination, and explain how the information was applied to the issues considered.

Accordingly, the Regions 5 and 6 regional foresters have asked that this science synthesis provide a thorough, up-to-date review of the relevant scientific literature pertaining to key resource management topics within the NWFP area.

Emergent Issues

Much has changed in the arenas of land management and science in the past 20-plus years. New issues have arisen that those designing or implementing the NWFP did not face at its inception. Going forward, some of these issues are particularly relevant to the fate of land management decisions within the NWFP area. The major considerations are summarized here briefly and amplified in subsequent chapters, particularly chapter 12, which explores various crosscutting themes and important implications for future forest plan revision.

Changing climate—

We devote an entire chapter (chapter 2) to the significance of climate change and the many ramifications it has on environmental conditions and on options that land managers have to achieve natural resource objectives. This issue has precipitated many shifts in conservation science and land management. Today, land managers are confronting difficult challenges and an uncertain future as they endeavor to mitigate climate effects through innovative management of forested landscapes. This development will continue to have a major impact on land management decisions throughout the NWFP area. Chapter 2 of this report is intended to lay a foundation for more indepth discussions of the realized and potential impacts of climate change on the other topics discussed in this synthesis. Although some core issues related to climate change are considered in chapter 2, additional chapters more specifically characterize climate change effects and concerns.

Single-species and multispecies conservation strategies—

The NWFP revolved around a select number of species at risk within the overall Plan area. Conservation of the northern spotted owl and the marbled murrelet were principal objectives for the Plan, and much NWFP management direction revolved around their species-specific needs. Additional focus was placed on conservation of aquatic ecosystems that support the many taxa of anadromous fish throughout the planning area. These include 15 species of salmon and steelhead formally listed as threatened, and one listed as endangered, since the Plan was initiated.

Although these particular taxa remain a vitally important focus in the Plan area, there has been much discussion and contemplation in the scientific literature about land management strategies aimed at single species, as reflected in changes in the 2012 planning rule described above. Management strategies aimed at individual endangered species may not always be in alignment with strategies to conserve ecosystem function. There is no single path to resolve this dilemma; it is a matter of much scientific debate and a subject we explore in more detail in chapter 12.

Successional and disturbance dynamics—

Succession, disturbance, and other ecosystem processes create a wide array of structural and compositional conditions within any given vegetation type. A primary focus of the NWFP was to manage for the continued existence of "old-growth forests" and their associated species. Succession and disturbance are continuously operating to shape forests, both independently and in concert. These topics are addressed in great detail in chapter 3.

The concept of ecological succession has been considered by ecologists for almost 200 years. More recently, however, the specific role of periodic disturbances (e.g., fire, windstorms, flooding) has been recognized as a critical element in shaping forests and promoting biological diversity by maintaining a variety of seral stages on landscapes. Disturbance ecology, especially fire ecology and the historical and contemporary role of fire within the NWFP area, has emerged in the past 30 years as a foundational science around which ecosystem management can be based. In many dry forests, simple models of successional change that were developed for moist forests do not apply because frequent fire regulated vegetation change in dry forests. Even within wetter forest areas, the effects of different historical disturbances, including fire, are important to consider in the conservation of important values (see chapters 3 and 11). This means that strategies to conserve and restore biological diversity across the diverse NWFP area may differ strongly between forest types, especially between dry and moist forests. After 150 years of Euro-American land use, the effects of anthropogenic disturbances, both obvious and subtle, have altered forest ecosystems and plant and animal communities. Knowledge of human influences on disturbance regimes is fundamental to sustaining biological diversity and ecosystem resilience.

Historical range of variability—
In the early developmental stages of the NWFP, the concept of historical range of variability (HRV) and its use in ecosystem management was just emerging in the scientific literature for the Pacific Northwest (Cissel et al. 1994). In the original discussions, this concept was useful for developing management goals for ecosystems that were based on inherent dynamics and processes rather than static structure targets. Although HRV is not explicitly referenced in the 2012 planning rule, the idea is addressed in directives for the rule in terms of "natural range of variability," which is essentially equivalent (Wiens et al. 2002). The rule does require forest plans "… to maintain or restore the ecological integrity of terrestrial and aquatic ecosystems and watersheds in the plan area," where ecological integrity depends in part on the functioning of natural disturbance regimes, which typically occur within some natural range of variation for a given climatic period. This is especially relevant in considering the significant role of fire in many different forest types throughout the NWFP area. For example, managing for ecological integrity in forest types subject to moderate- to high-frequency fire is quite different than in forest types where fire occurs infrequently. The complexity of land management becomes more apparent as we consider not just a simple dichotomy of wet and dry forests, but instead a spectrum of precipitation and fire regimes as well as the importance of fine-scale heterogeneity.

Research on changing climates has also emerged in the past 20 years, with a profound impact on our view of the HRV and its implications for management. We now face new scientific challenges in the restoration of degraded ecosystems, while managing for ecosystem resilience to climate change during the "Anthropocene," a proposed term for the geological and ecological epoch in which human activity has been the dominant influence on landscapes, invasive species, and climate change. These new impacts make maintaining some historical ecological patterns and processes difficult or impossible to reestablish (Corlett 2015). In chapters 3, 4, and 12, we assess this dilemma by describing scientific findings about the resilience of a variety of forest types to climate change, and consider what the implications are for maximizing suitable habitat for northern spotted owls. The notion of HRV and its potential consequences on other topics is also considered in other chapters.

Invasion of the barred owl and use of the term "habitat"—
The term "habitat" is widely used in natural resources publications and popular literature to describe the environmental area inhabited by a particular species of plant or animal. However, the many variations on the precise meaning of this term can lead to confusion. In common usage, "habitat" typically focuses primarily on the forest cover type chosen to depict the age and structure of a forest, or, more generally, the vegetation type that typifies the structure and composition of vegetation preferred by a given species. We note this because such definitions of habitat typically miss features believed to be important in conveying the full array of conditions suitable for a species. In particular, we identify the influence of an array of ecological factors, especially the role of nonnative species. Their impact has prompted much discussion as to what people generally consider to be habitat for any given indigenous species. In this report, we define habitat as follows:

> An area with the environmental conditions and resources (e.g., vegetation structure, food/prey, water, etc.) necessary for individuals of that species to survive and reproduce.

This definition specifically intends to draw attention to the phrase "environmental conditions," which includes potential effects of competitors or predators, including those that may be nonnative species. Clearly, competition between spotted owls and invasive barred owls represents a profound impact on the suitability of habitat for spotted owls.

Landscape ecology and management—
For many decades, forest management was conducted at the stand scale. The stand was traditionally an operational unit used by forest managers to target local forest management objectives, largely around local timber production goals. However, social and scientific trends over the past 25 years have led to broader scale silvicultural objectives and appreciation of more complex forest structures and nested scales for understanding forest dynamics.

Landscape ecology has emerged as a discipline that embraces the inherent spatial variation in landscapes, expressed at a variety of scales. We now more thoroughly appreciate the relationship between pattern and process in landscapes; the relationship of human activity to landscape pattern, process, and change; and the effects of scale and disturbance on the landscape. Above all, we now understand and intentionally incorporate the biophysical and societal causes and consequences of landscape heterogeneity as part of a landscape management philosophy. Several chapters in this report give consideration to the emergence of a landscape point of view.

Changes in agency capacity and workforce—

Federal agency budgets, number of employees, and number of field offices in the NWFP area have dropped substantially since the Plan was implemented, in large part because of shrinking timber programs and related budget allocations. These reductions have been most pronounced in Forest Service Region 6, and least pronounced on BLM lands. Declines in budgets and staffing have decreased the capacity of agencies to accomplish forest management goals, including forest restoration. Community-based organizations, local business partners, environmental and recreation organizations, and other groups have helped fill critical gaps by raising money and providing labor to accomplish forest management goals on federal lands in the face of declining agency capacity. But communities must have means to play this role. Title II funding from the Secure Rural Schools and Community Self-Determination Act has also played a vital role in helping pay for ecosystem management and forest restoration work on federal forests. However, the future of this law is uncertain given that this law expired in 2015 and it requires Congressional reauthorization. Thus, the issue of how to accomplish ecosystem management and forest restoration amidst reductions in agency capacity will continue to be a challenge.

Changes in wood processing infrastructure—

Wood processing infrastructure in Plan-area communities began declining in the 1980s. This decline has continued into the 2000s because of reduced demand for wood products from the Pacific Northwest, and in the supply available from federal forests, as well as because of changes in wood processing technology. Supply and demand of wood products is also influenced by a complex set of international market forces. Local supply is affected by changes in timber management resulting from policies and regulations that constrain available volume. Supply available to local markets is also significantly affected by international timber markets, which are entirely independent of federal forest policy. However, a decline in locally provided supply has had a profound impact on the local timber-processing industry, and its capacity to maintain its infrastructure.

This current lack of infrastructure makes the sale of timber, small-diameter wood, and biomass less economical, owing to longer haul distances and reduced demand for wood products, factors that reduce stumpage prices. Not only does this create a financial barrier to accomplishing forest management goals on federal forests; it also poses financial challenges for private forest owners who face declining markets for their wood products. For mills to stay in business, or for investments in new infrastructure development to occur, a reliable supply of raw material is needed. Private lands may be unable to increase wood product production and still ensure sustainable harvest levels. Thus federal lands have an important role to play in providing a sustainable supply of wood products to keep existing wood processing infrastructure operating, and to expand it if desired through new investments. To date, federal forests in the NWFP area have not met the goal of ensuring a predictable supply of timber, nor have they met the probable sale quantity established by the Plan. This topic is treated in detail in chapter 8.

Evolving public values and public policies around natural resources—

Social scientists and policy analysts studying environmental values and attitudes in the United States documented a shift away from the predominantly commodity-oriented view of forest management, common prior to the 1980s, to a more mixed or balanced perspective that includes commodity and noncommodity uses. This shift in public values followed a series of policies initiated in the 1960s that placed greater attention on protection of wildlife, wilderness, air, and water, as well as a desire for improved relationships with tribal governments, to name a few concerns.

Longitudinal studies conducted both on a national scale and in subregions of the United States indicate a gradual shift in public attitudes. Since the 1990s, attitudes about public lands have shifted from a sole focus on economic values, outputs, and commodities toward a greater diversity of values that includes noneconomic values, especially protection of ecosystems and aesthetic values. Sometimes this transition is described as a shift from an exclusively anthropocentric perspective to a balance of anthropocentric and biocentric perspectives. Residents of the NWFP area echoed this national trend.

In reflection of this value shift, the Forest Service was one of the first public land management agencies to adopt an ecosystem management approach in the 1990s, one that aimed to conserve ecological services and restore resources while meeting the needs of current and future generations. In more recent years, public recognition of the dual focus of producing goods and services while protecting resources has gained ground, and the challenges in achieving this balance in a complex ecological system appear to be more widely understood.

Ecosystem services—

The concept of ecosystem services was originally characterized by economist E.F. Schumacher as "natural capital" in 1973. Only recently has the concept become widely recognized as relevant to land and resource management. The 2005 Millennium Ecosystem Assessment (MEA 2005) provided a simple definition of ecosystem services as "the benefits people obtain from ecosystems." Historically, management efforts focused on the provision of such resources as water and timber. Currently, policy and management efforts have increased the appreciation and importance of the full suite of services derived from ecosystems, including nonprovisioning services such as spiritual and cultural heritage values. Our understanding of the full scope of ecosystem services and attendant societal values associated with Northwest forests is still emerging. Our aptitude for quantifying these values, particularly in monetary terms, will continue to evolve as methods improve.

Attitudes toward land management agencies—

Public lands management is an important element of public discourse in the national environmental policy arena. Some recent issues have been controversial in the public eye. The number of appeals and litigation of forest decisions provides clear evidence that social views about forest management are often polarized. Effective public engagement can help provide accessible processes for public deliberation. Studies have shown that public dissatisfaction with opportunities to participate has led to more appeals of agency decisions, and that participants desire public processes that are more collaborative.

An important factor shaping natural resource management outcomes is the degree of trust between land management agencies and the public. A lack of public trust in government is cited as a primary barrier in natural resource planning (see chapter 9) that potentially can lead to litigation or noncompliance, and, ultimately, to managerial impasse. Furthermore, trust has been shown to be correlated with social acceptability of forest management actions, although the actual causes of social acceptability are likely far more nuanced. There are two basic kinds of trust: institutional trust (trust in agencies to represent and serve the public), and interpersonal trust (trust cultivated based on personal relationships). When social trust is improved, there is greater support for land management policies. The assumption held by many is that trust can be built (and conflict reduced) through fair participation processes or transparent decision-making. Trust building occurs when stakeholders engage in meaningful dialogue in a context of shared power and high levels of substantive knowledge. Collaborative processes represent opportunities to build iterative experiences and develop relationships among multilateral stakeholders and between stakeholders and public land management agencies. Examples of how collaborations between the Forest Service and tribal governments and communities are facilitating cross-boundary management and pursuit of integrated social and ecological objectives are featured in chapter 11. These examples illustrate how local units and communities are working to fulfill the many goals for public lands management as reflected in the NWFP and the new planning rule, as well as the many challenges in that pursuit.

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Appendix: Priority Management Questions to Guide the Northwest Forest Plan Science Synthesis As Defined by Pacific Northwest and Pacific Southwest Forest and Regional Staff and Edited by the Science Synthesis Team

The Northwest Forest Plan (NWFP) science synthesis was constructed based on a set of questions submitted by Forest Service land managers. The questions addressed concerns that developed from 24 years of experience in implementing the Plan, as well as new issues that have emerged since the Plan was initiated. The Science Synthesis Team reviewed an initial list of 190 questions submitted by Forest Service land managers and suggested additional questions that they believed were relevant and could be addressed in the synthesis. The team then removed redundant questions and grouped others to arrive at the final list of 73 questions delineated below. This list is sorted into four general topical areas that are covered in one or more of the 12 synthesis chapters. Based on available information, the synthesis attempted to fully or partially address all the questions. Although the chapters do not necessarily address these questions directly, they were organized to be consistent with the scientific understanding of the issues that these questions address. In each chapter, the management considerations section endeavored to more directly link the science to management issues related to these questions. To the extent possible, the synthesis addressed how the science differs by physiographic province, vegetation type, and disturbance regime.

Priority Questions

Vegetation/forest management/climate change/ecological disturbance (old-growth and other vegetation types)—

1. What is the latest science on active management, including "ecological forestry," to protect and restore late-successional forests and maintain ecological diversity?
2. How do the effects differ by treatment (mechanical and prescribed fire) in terms of key ecosystem components (structure, composition, connectivity, and function)? What are the associated costs and commodity outputs?
3. What is the latest science on the dynamic landscape approach versus a fixed reserve system in terms of providing sustainable amounts and adequate distribution and connectivity of late-successional forest across the landscape?
4. How does each approach allow us to adapt in response to large-scale disturbances?
5. What is the relationship between amount and configuration of old growth and potential to sustain a variety of disturbance regimes and late-successional-dependent species?
6. How might management and conditions on other ownerships affect the above relationship with the understanding that old growth is likely to persist only on federal lands?
7. What is the latest science on treatments in stands greater than 80 years of age when the objective is to accelerate the development of late-successional habitat?
8. Similarly, what is the latest science on limiting harvest of large trees (usually >21 inches diameter at breast height when conducting restoration activities?
9. What are the latest estimates for historical/natural range of variation (HRV/NRV)? What is the proportional mix of seral stages and special habitats (e.g., hardwoods, meadows, etc.)?
10. What are estimates of patch and gap size, connectivity, disturbance (fire, insect and disease, drought), habitat, and within-patch heterogeneity?
11. What are important differences between "dry forests" vs. "wet forests" and how can these distinctions be used to prioritize restoration activities?
12. What does the latest science tell us about the concept about using HRV/NRV to inform ecological restoration, in terms of the mix of structural conditions, species composition, patch size, etc.? Does HRV/NRV help inform landscape-level patch dynamics and within-stand heterogeneity?
13. What are the effects, if any, on invasive species on old-growth forests and succession following disturbance?

14. What is the competing science on restoration of Pacific Northwest forest systems? For example, we need to have an upfront discussion of differing viewpoints in the science on the need for restoration of late-successional/old growth (LSOG) in dry forests.
15. What is the relationship between retention of dead wood, including dead and damaged trees, and potential for disturbance in dry forests with a frequent fire regime?
16. How does dead wood affect our ability to maintain LSOG?
17. What is the relationship between retention of green trees in harvest units and ecological diversity and species viability?
18. What is the relationship between green tree retention potential and insect and disease epidemics (especially dwarf mistletoe) in post-harvest or post-wildfire situations?
19. How does each approach allow us to adapt in response to large-scale disturbances?
20. How do green tree retention effects differ by physiographic province and vegetation type?
21. What is the latest science on the connectivity of late-successional and other key habitats (fixed corridors versus landscape permeability)?
22. What does the current body of science suggest about postfire recovery options, including the social license and economics associated with salvage?
23. What are the ecological features associated with early-successional vegetation, and what is the role of early-successional vegetation in ecosystem function and biodiversity?
24. What are the potential conservation and restoration needs related to early-successional vegetation?
25. What are our most vulnerable ecosystems, species, and resources due to climate change?
26. What are the key adaptation strategies that could mitigate these vulnerabilities?
27. What different management strategies might be needed for forests and terrestrial and aquatic ecosystems?
28. How do we deal with uncertainty in our restoration efforts, models, and predictions?
29. What are the anticipated changes in climate within the NWFP area, and what are the potential impacts to disturbance processes (insect, disease pattern, drought, fire, etc.), vegetation, species habitats, aquatic ecosystems, and the provision of goods and services (timber, values, etc.) within the area?
30. What resources and components of a regional planning framework require analysis and consideration at the regional scale?

Terrestrial species/habitat management (northern spotted owl, marbled murrelet, other species associated with older forests)—

1. What is the latest science surrounding the effects of various treatments (silviculture, fuels) and wildfire on LSOG and plantations and what are the effects on terrestrial wildlife species, with particular attention on northern spotted owl (NSO), barred owl (BAOW), marbled murrelet (MAMU), and survey and manage (S&M) species?
2. How or do these species use these treated habitats post-treatment, and are there ways to modify treatment to benefit these terrestrial species?
3. How do these treated habitats compare to untreated habitat in terms of habitat use and reproductive success?
4. How does use of treated and untreated areas compare to use of postfire habitats, including salvage?
5. How do the risks of fire compare in treated and untreated habitats, and are the impacts of treatments by the risk of habitat loss due to fire?
6. What is the latest science on the interaction of barred owls and spotted owls and the impact to recovery of the spotted owl?
7. What is the relationship of fires to barred owl encroachment?
8. What is the current scientific understanding about the rarity of survey and manage species, and how effective are the management recommendations for habitat buffers in retaining these species across treated landscapes?

9. Is forest management under the NWFP providing habitat for rare and uncommon species as planned?
10. Are rare and uncommon species maintaining populations under NWFP management?
11. Have we accumulated enough information to change status of these species? Are there species originally ranked as having low potential for persistence that are now of less concern, particularly with the reduction in harvest levels of old growth we've seen under the NWFP?
12. Has the Interagency Special Status/Sensitive Species (ISSSP) program benefitted these species?
13. What is the effect of prescribed fire and wildfire on rare and uncommon species (S&M)?
14. Are known site buffers as effective as landscape scale habitat management in ensuring species persistence, dispersal and habitat connectivity?
15. Does the current S&M species list truly represent currently rare species with population persistence questions dependent upon LSOG habitat?
16. Does the current NSO critical habitat better represent late-successional forest and provide for a higher level of assurance of persistence for NSO, MAMU, and S&M species when compared to the current NWFP late-successional reserve (LSR) network?
17. Is there a difference in persistence in treated vs. untreated LSRs or LSOG habitat in the face of wildfire, insects and disease, and climate change?
18. What role and importance are riparian reserves and various buffer widths as terrestrial species (including mollusks) habitat, including dispersal and connectivity, and how does riparian reserve management impact the terrestrial species that utilize them?
19. How can we manage a riparian area for the variety of habitats needed?
20. What is the status of other species of concern (not included as survey and manage species) within the footprint of the NWFP?
21. What is the effect of pesticide use associated with cannabis cultivation or species viability (i.e. fisher)?
22. How can we manage for viable populations of snag-dependent species when snags are not present long-term on the landscape?
23. How can we identify important biological refugia? What are they and where are they?

Aquatic/riparian management (aquatic and riparian species and ecosystems)—

1. What is the current thinking/science on riparian thinning/management? Has it produced the desired results, including contributions toward recovery of listed fish species, impaired waters, and reduction of fire risk?
2. What are the effects of common silvicultural treatments/prescriptions with respect to Aquatic Conservation Strategy (ACS) goals and objectives (especially riparian microclimate and stream temperature, wood recruitment, diversity in riparian species structure and composition, fish populations, terrestrial processes)?
3. What are the effects of not managing previously harvested stands in riparian reserves (RRs)? What is the risk of severe wildfire in untreated riparian corridors, and do/how do various types of treatment reduce this risk?
4. What does the current science indicate regarding the value of woody material in second-growth riparian reserves? When and where should the creation of large wood be a purpose and need driving silvicultural treatment in riparian reserves?
5. What does the current science indicate about the role of vegetation management in affecting ground water flows and temperatures, and how do those changes affect surface water?
6. Does current science indicate that the ACS is needed to achieve Plan goals of maintaining and restoring the ecological health of watersheds and aquatic ecosystems on public lands?
7. Are all components (riparian reserves, key watersheds, watershed restoration, watershed analysis, ACS objectives, standards and guidelines, monitoring and evaluation) necessary to achieve these goals?

8. Does the current science indicate that refinements to the ACS may be needed to increase its efficacy?
9. Does ACS provide appropriate levels of connectivity or does it need to be refined?
10. What are the effects of interbasin water transfers and water diversions?
11. What does the current science indicate about where in the NWFP area the greatest potential for conflicts exist over water supply and demand for additional storage based on the current water supply and demand situation, projected changes in supply due to climate change, and projected changes in demand due to climate change and population growth.
12. How well have RRs met their intended objectives?
13. Does current science support or refine Forest Ecosystem Management Assessment Team (FEMAT) conclusions regarding the role and function of RRs? If so, how?
14. What have we learned since FEMAT that should be incorporated into RR designation and management in plan revisions?
15. What is the latest science on the effectiveness of treatments within riparian reserves, and implementation of varying riparian reserve widths?
16. Is the type, scope and scale of watershed restoration that has occurred over the life of the NWFP consistent with FEMAT and Plan assumptions?
17. How effective are instream restoration treatments (e.g., large woody debris [LWD] augmentation, channel reconstruction) in achieving ACS objectives at multiple spatial and temporal scales? Fish passage restoration? Road decommissioning and improvements? Riparian restoration treatments (e.g., reforestation, thinning, gaps)?
18. What does the current science indicate about potential short-term impacts to aquatic and riparian ecosystems when managing for long-term restoration of aquatic and ecosystem processes and functions (e.g., short-term stream temperature increases to achieve long-term large wood recruitment and normal disturbance processes)?
19. What are the consequences of the current road management regime on water and aquatic resources? Consider (a) the status and trends in the size of the road system on NFS and other federal lands, (b) the amount of the current system that poses a high risk to aquatic resource, and (c) the amount of the system that is being maintained or improved.

Social/economic (including timber production) (socioeconomic well-being, timber harvest; collaboration and stakeholder attitudes; tribal values and resources)—

1. What does social science tell us about how stakeholders' attitudes, beliefs, and values (ABV) have changed over the past 20 years, and how those ABV are associated with resource management (including recreational experience, resource use or protection)?
2. How have stakeholders' relationships to landscapes and natural resources changed in the Northwest Forest Plan area?
3. What value do people place on cultural ecosystem services from public lands, including outdoor recreation?
4. What are the general conditions of and influences upon values of special concern to tribes (including first foods such as salmon, elk, huckleberry, camass root) in the NWFP area?
5. What management strategies does science suggest would enhance these values of special concern to tribes?
6. What does the body of science indicate are important factors contributing to successful collaboration in forest management?
7. Where are our most successful examples of such collaboration?
8. What are the most important factors in successful collaboration?
9. What strategies are suggested by science for engaging communities in forest plan revision in the NWFP area?
10. What are implications for forest management from trends in the size and socioeconomic status of low-income, minority, and tribal populations (i.e., environmental justice populations) in the NWFP area?

11. Are these populations growing?
12. What are the drivers of change related to socioeconomic well-being in rural communities?
13. What are the implications for forest management of trends in socioeconomic well-being in rural communities in the NWFP area?
14. How does the body of science inform sustainable recreation and social interest in valuing place (as required under the 2012 planning rule)?
15. What does the science infer about the contribution of outdoor recreation across the region to social and economic sustainability?
16. What are the trends in outdoor recreation use and visitor satisfaction on public lands?
17. What are the drivers for change related to recreation?
18. What are the implications for forest management of changes in land use and ownership in the past 20 years?

Other Topics to Be Considered in the Integration Section of the Synthesis (Pulled From Region 5 and Region 6 Long List)

1. Influence of illegal marijuana cultivation on federal lands on resources (this was noted under terrestrial biological resources question #15, but effects on resources other than fisher will also be considered).
2. Effects of invasive species on forest succession and habitats (this topic is noted under vegetation question #10 in the context of old growth)
3. Salvage logging
4. Conservation of nonfederally listed species (noted under terrestrial biology question #5)

Prescribed burn operations on the Wallowa-Whitman National Forest, Oregon.
Photo by USDA Forest Service.