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Synthesis of Science to Inform Land Management Within the Northwest Forest Plan Area

Executive Summary







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Technical Coordinators

Thomas A. Spies is a senior scientist emeritus, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331; **Peter A. Stine** is research program manager and biogeographer (retired), U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, and is a research associate, John Muir Institute for the Environment, University of California–Davis, 1 Shields Avenue, Davis, CA 95616; **Rebecca Gravenmier** is a science coordinator, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1220 SW 3rd Avenue, Portland, OR 97204; **Jonathan W. Long** is an ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1731 Research Park Dr., Davis, CA 95618; **Matthew J. Reilly** is a postdoctoral researcher, Humboldt State University, Department of Biological Sciences, 1 Harpst Street, Arcata, CA 95521; **Rhonda Mazza** is a science writer, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1220 SW 3rd Avenue, Portland, OR 97204.

Cover photos: Upper left: coho spawning on the Salmon River; photo by Bureau of Land Management. Upper middle: a typical stream in the Cispus River watershed, Washington; photo by Alanna Wong. Upper right: a northern spotted owl in the McKenzie River Basin in Oregon; photo by John and Karen Hollingsworth, U.S. Fish and Wildlife Service. Middle left: prescribed burn operations on the Wallowa-Whitman National Forest, Oregon. Lower middle: backcountry skiing on the Willamette National Forest; photo by Emily Jane Davis. Lower right: orange coral fungus, Olympic National Forest. Lower left: an adult captive red tree vole mechanically removing one of two unpalatable resin ducts in a Douglas-fir needle before eating the rest of the needle; photo by Michael Durham.

Synthesis of Science to Inform Land Management Within the Northwest Forest Plan Area: Executive Summary

Thomas A. Spies, Peter A. Stine, Rebecca Gravenmier,
Jonathan W. Long, Matthew J. Reilly, and Rhonda Mazza

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Abstract

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This is the executive summary of a three-volume science synthesis that addresses various ecological and social concerns regarding management of federal forests encompassed by the Northwest Forest Plan (NWFP). Land managers with the U.S. Forest Service provided questions that helped guide preparation of the synthesis. It builds on the 10-, 15-, and 20-year NWFP monitoring reports and synthesizes the vast body of relevant scientific literature that has accumulated in the 24 years since the NWFP was initiated. Here we summarize scientific findings and considerations for management that were identified in the full science synthesis.

We find that the NWFP has protected dense old-growth forests and has maintained habitat for northern spotted owls (*Strix occidentalis caurina*), marbled murrelets (*Brachyramphus marmoratus*), aquatic organisms, and other species despite losses from wildfire and low levels of timber harvest on federal lands. Other goals have not been met, including producing a sustainable supply of timber and the broad use of adaptive management. New concerns include the impact of nonnative barred owls (*Strix varia*) on northern spotted owl populations, effects of fire suppression on forest succession, fire behavior in dry forests, and the effects of climate change and invasive species on native biodiversity.

A growing body of scientific evidence supports the importance of active management or restoration inside and outside NWFP reserves to promote a full complement of biodiversity and ecological resilience. Active management to promote heterogeneity of vegetation conditions is important to sustaining tribal ecocultural resources. Declines in agency capacity, lack of markets for small-diameter wood, lack of wood processing infrastructure in some areas, and lack of social agreement have limited the amount of active management for restoration on federal lands. All management choices involve social and ecological tradeoffs related to the goals of the NWFP. Collaboration, risk management, adaptive management, and monitoring are considered elemental approaches in dealing with complex social and ecological systems with futures that are difficult to predict and affect through policy and land management actions.

Keywords: Northwest Forest Plan, science, management, restoration, northern spotted owl, marbled murrelet, climate change, socioeconomic, environmental justice.

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Koosah Falls, Willamette National Forest.
USDA Forest Service photo.

Chapter 1: Context and Purpose for the Northwest Forest Plan Science Synthesis

Peter A. Stine and Thomas A. Spies[1]

Main Points

- The 1994 Northwest Forest Plan (NWFP, or Plan) drew from science available at the time and included mechanisms for subsequent learning—anticipating that updates would be needed as subsequent research revealed how the affected forests and communities (i.e., socioecological systems) were changing over time, with or without active management.
- The 2018 NWFP science synthesis (Gen. Tech. Rep. PNW-GTR-966) provides a comprehensive overview of the relevant science accumulated in the 24 years since the Plan was implemented.
- The science synthesis was prepared by request to inform the revision of land and resource management plans for 17 national forests within the footprint of the NWFP in Washington, Oregon, and northern California.

Introduction

We live in an era of massive amounts of information. E.O. Wilson, renowned ecologist and author, summarized this situation well:

> "We are drowning in information, while starving for wisdom. The world henceforth will be run by synthesizers, people able to put together the right information at the right time, think critically about it, and make important choices wisely."
>
> — E.O. Wilson, *Consilience: The Unity of Knowledge* (1988)

Access to information brings many benefits to society. It also creates challenges for those who are responsible for understanding and applying considerable new as well as older-but-still-relevant information to their day-to-day work. How does one keep up with the volume of information that is published daily? Placed in the context of land management, this challenge is particularly daunting. The biology of a single species, the dynamics of ecosystems shaped by disturbance, and societal values and human behavior all carry weight in land management. Understanding

[1] **Peter A. Stine** is a research program manager and biogeographer (retired), U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, and is a research associate, John Muir Institute for the Environment, University of California–Davis, 1 Shields Avenue, Davis, CA 95616; **Thomas A. Spies** is a senior scientist emeritus, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331.

both deeply and broadly is no small order. Each year, new studies illuminate various new and sometimes unexpected facets of these intertwined connections.

With the Northwest Forest Plan science synthesis, we take up this challenge. The NWFP footprint stretches from the Washington/Canada border to the Bay Area in northern California and encompasses diverse geography, ecological systems, and human communities. We have compiled the most current information relevant to these ecosystems and their intersections with human communities. Federal land managers within the Plan area depend on sound scientific knowledge about ecological systems—how they function and respond to change—and how people view forest resources and management choices. Our goal with this synthesis, which was prepared by request of the USDA Forest Service Pacific Northwest and Pacific Southwest Regions, is to support science-based resource management choices in coming years (fig. 1-1).

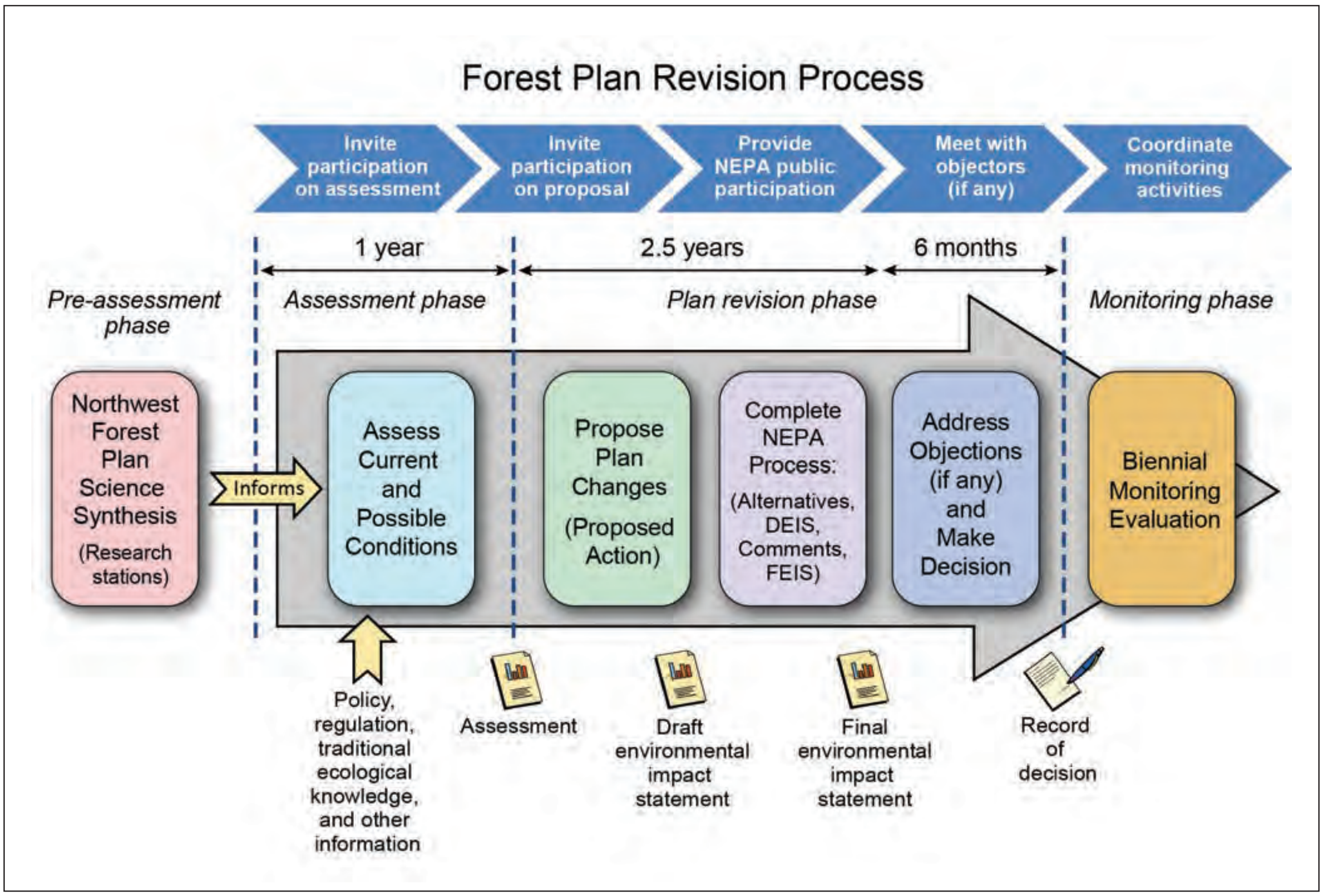

Figure 1-1—A diagram of the forest plan revision process. The Northwest Forest Plan science synthesis was prepared for the pre-assessment phase but can be used throughout the planning process and during plan implementation. NEPA = National Environmental Policy Act; DEIS = draft environmental impact statement; FEIS = final environmental impact statement.

Most public lands within the NWFP area are managed by the Forest Service. This includes roughly 19.2 million ac (7.68 million ha) on 17 national forests (Deschutes, Fremont-Winema, Gifford Pinchot, Klamath, Lassen, Mendocino, Modoc, Mount Hood, Mount Baker–Snoqualmie, Okanogan-Wenatchee, Olympic, Rogue River–Siskiyou, Shasta-Trinity, Siuslaw, Six Rivers, Umpqua, and Willamette). The Plan area also includes roughly 2.5 million ac (1 million ha) of Bureau of Land Management (BLM) lands and about 2.3 million ac (0.92 million ha) of National Park Service lands.

This synthesis is intended to support upcoming management planning and forest management on all federal lands in the NWFP area, but is expected primarily to serve impending revisions of forest and resource management plans that apply to land managed by the Forest Service. In 2016, the BLM completed revising 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 their land use plans, the two agencies share common goals for long-term monitoring of the impacts of their land use plans following implementation.

History and Elements of the Northwest Forest Plan

The 1980s were part of a transformative period for the Pacific Northwest and northern California. For many years, timber harvest was extensive across the region, and concerns about the effects that the logging of old-growth forest had on wildlife and riparian areas grew steadily into the early 1990s. The 1990 listing of the northern spotted owl (*Strix occidentalis caurina*) as a threatened species under the Endangered Species Act precipitated numerous legal challenges regarding the cumulative impacts of federal timber harvests in the region. 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 NWFP.

Under President Clinton's direction, the Forest Service, BLM, and other federal agencies set out to develop a scientifically defensible path forward. Deliberations focused on protecting old-forest ecosystems for spotted owls while sustaining rural communities and economies through sustained timber harvest. Also considered were the needs of marbled murrelets (*Brachyramphus marmoratus)*, anadromous fish, and other species associated with older forest.

The authors of the NWFP understood that scientific knowledge would be crucial to the success of the Plan. They drew on available science and included mechanisms for testing the Plan's assumptions and anticipated that changes would be needed as new science revealed how and why the affected forests and communities (i.e., socioecological systems) change over time, with and without active management. Extensive involvement of the White House, Forest Service, and BLM led to adoption of the NWFP in 1994.

The Plan was based on both ecosystem- and species-level conservation and restoration strategies. Its principal tasks were to conserve and restore habitats for animals and plant species associated with old-growth forests and to maintain and restore habitat for anadromous fish within the confines of existing laws and regulations (e.g., the National Forest Management Act and Endangered Species Act). The final plan was set forth in the record of decision with the following key elements:

- Adoption of an ecosystem management approach.
- Designation of seven land use allocations (fig. 1-2) 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 (102,000 ac [41 000 ha])
    - Administratively withdrawn areas (1.48 million ac [597 000 ha])
    - New riparian reserves (2.2 million ac [890 000 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 specific management direction for forests and riparian areas 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 better understand and provide for other late-successional species that may not be covered under the conservation strategies for the spotted owl, marbled murrelet, aquatic ecosystems, and old-growth forests and may be at risk from further logging of old-growth forests in the matrix.

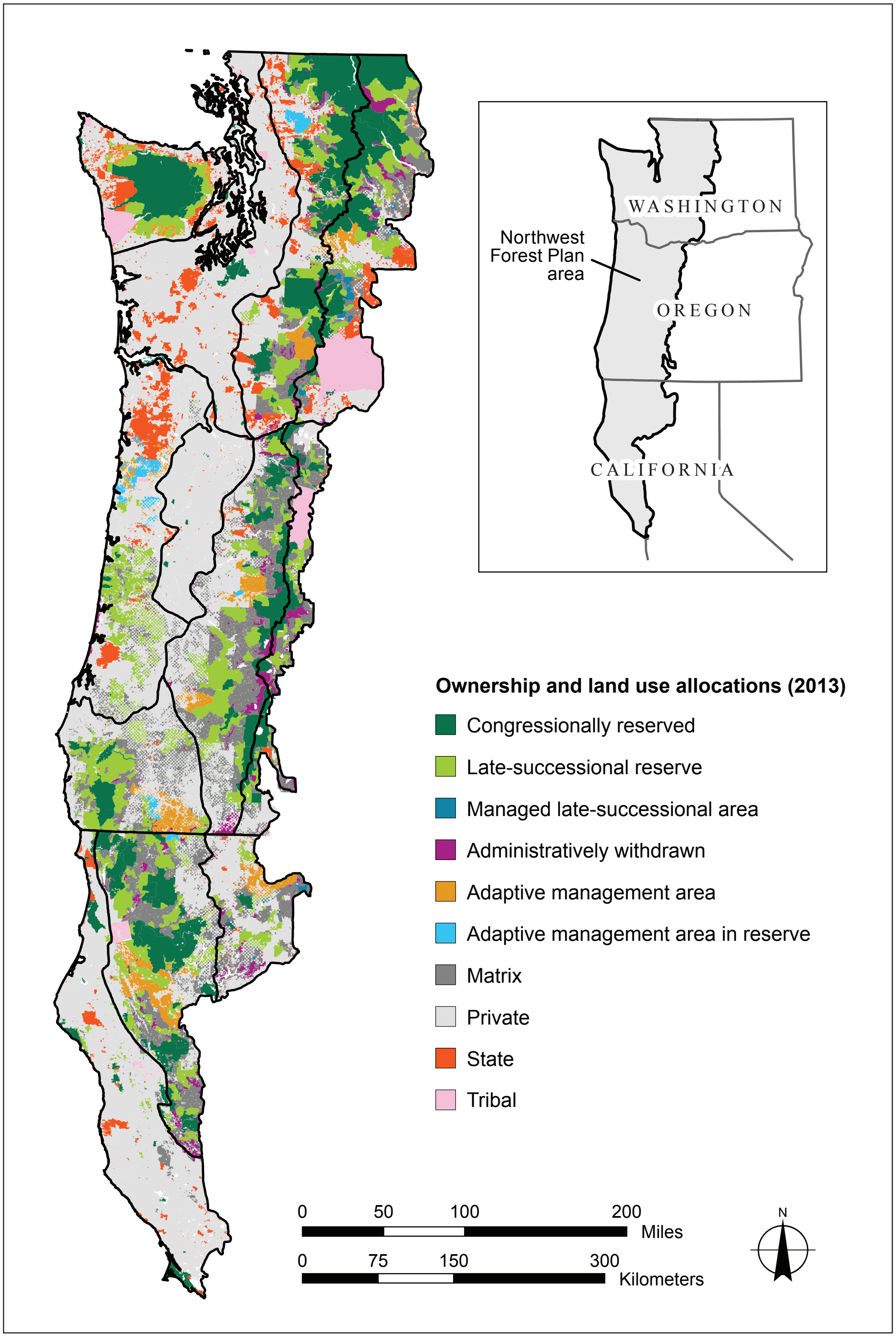

Figure 1-2—Ownership and land use allocation within the Northwest Forest Plan area. Management of the affected 24 million ac of land was altered significantly to meet the new biological diversity goals set forth by the Plan in 1994.

Ensuing management on the affected 24 million ac (9.7 million ha) of land was directed 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 largely 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 threatened species. The major shift in federal forest management in the 1990s was part of a larger global trend toward protecting biodiversity through a process called "ecosystem management."

Research and Monitoring Within the NWFP Area

The NWFP involves the scientific community, through research and monitoring, in ways and to lengths not used before in Forest Service planning and management. The record of decision required a detailed monitoring plan to ensure that management actions would meet the prescribed standards and guidelines and that these actions would comply with applicable laws and policies.

Information obtained through monitoring, together with new research and information from adaptive management areas, were intended to provide a basis for changes to the NWFP as needed, including changes to the standards and guidelines. Although a formal validation monitoring program was never established, research activities were conducted to help test hypotheses related to NWFP goals.

Monitoring results have been evaluated and reported in 1- and 5-year intervals since the Plan's inception. A series of comprehensive reports summarizing the first 10 years of NWFP monitoring data was published by the Forest Service Pacific Northwest Research Station in 2006. This was an important first step in adaptive management. The 10-year reports synthesized the status and trends of five major elements of the Plan: old-growth forests, old-growth forest species at risk, aquatic systems, socioeconomics, and adaptive management.

The 10-year reports found the following:

- Nearly all old-growth forest on federal land was protected from timber harvest and had increased an estimated 1.2 million ac (~480 000 ha) in the first 10 years as a result of accretion by growth.
- Northern spotted owls were declining at greater rate than expected in their northern range, likely because of competition from barred owls and habitat loss from wildfire.
- Watershed condition improved slightly because of tree growth, reduced harvest in riparian areas, and increased emphasis on restoration.

- Federal timber harvest in the Plan 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.

Reports analyzing 20 years of monitoring data under the NWFP were published between 2015 and 2017. These reports summarized the latest periodic monitoring data gathered since 1994, with a focus on the previous 5 years. Key findings from the 20-year reports include:

- Overall late-successional and old-growth habitat area decreased 3 percent on federal lands, with the biggest losses resulting from wildfires.
- In Washington, the marbled murrelet population declined by 4.6 percent annually from 2001 to 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 the Plan was implemented. Although forest succession resulted in recruitment of suitable vegetation, the influx of barred owls negatively affected population viability.
- 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.
- Timber volume harvested 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 identified in the NWFP.
- 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 has changed since 1994.
- 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.

Changing Context

The NWFP and the 2012 Planning Rule

The 2012 National Forest System Land Management Planning Rule (hereafter, planning rule) brings many changes to the forest planning process. The agency's goal with the new planning rule was to promote an adaptive land management planning process that was inclusive, efficient, collaborative, and science-based to ensure healthy, resilient, diverse, and productive national forests and grasslands. It emphasizes adaptive planning and engagement of science in Forest Service land management. The 2012 planning rule increases the emphasis on coarse filter (ecosystem) approaches to conservation and reduces emphasis on species (population viability) approaches compared to its predecessor, the 1982 planning rule.

The 2012 planning rule could be seen as evolving from the 1982 rule based in part on lessons learned from administration of the NWFP. That is, the 2012 planning rule aims to reduce the administrative burden of managing for hundreds of individual species. Science and the concept of adapting practices in light of new information are central to the NWFP, although formal adaptive management approaches were discontinued. Although the Plan emphasized fine-filter (meeting needs of a particular species) approaches to conservation for the spotted owl, marbled murrelet, and hundreds of other species, it recognized that both coarse-filter and fine-filter conservation strategies are needed to more thoroughly meet biological diversity goals. However, as the science synthesis documents, the NWFP's emphasis on maintaining or increasing dense older forests in dry, fire-frequent forests does not mesh with the objective of the 2012 planning rule to manage for resilience to climate change.

The 2012 planning rule calls for a three-phase process for revising forest plans: assessment, plan revision, and monitoring. The science synthesis is intended to support the assessment phase for national forests within the Plan area. It will also provide a foundation of information to support the monitoring phase.

Other Emergent Issues

Although the 2012 planning rule changed the policy context for the NWFP, over the past 24 years the ecological, social, and scientific contexts of the NWFP have changed as well. New threats and concerns have emerged. Three significant ones are invasive species, such as the barred owl and its impact on the northern spotted owl; wildfire, which has increased in frequency; and climate change, which may already be affecting rates of mortality in old trees in the region.

Socioeconomic changes have also occurred, including the growth of amenity-based economies in many communities, shifts of the timber industry from large- to small-diameter logs, and increasing efforts to use collaboration in the management of Forest Service lands.

The agency's capacity and workforce for conducting management activities, including restoration, have both declined. These new issues add additional challenges for land managers as they engage in future on-the-ground management and plan revision.

Scope and Approach of the NWFP Science Synthesis

The NWFP science synthesis is a joint effort by the Forest Service's Pacific Northwest and Pacific Southwest Research Stations. The synthesis will inform the development of revised land and resource management plans (forest plans) for 17 national forests. Its structure stems from an array of questions received from land managers. We ultimately grouped 73 questions into these major headings:

- Vegetation conditions
- Terrestrial species
- Aquatic and riparian management
- Social and economic well-being
- Integrated topics

To help meet the challenge of revising forest plans, the synthesis provides a comprehensive overview of the full body of relevant science accumulated in the 24 years since the NWFP was initiated. It builds on the 10-, 15-, and 20-year NWFP monitoring reports. Chapter authors drew upon their extensive knowledge of scientific literature that applies to the Plan area; more than 4,000 peer-reviewed publications were considered during the writing process. The synthesis does not provide management recommendations, nor does it assess likely outcomes of different approaches to revising forest plans in the NWFP area.

This synthesis has been classified as "highly influential," according to the Office of Management and Budget's 2004 *Final Information Quality Bulletin for Peer Review*, because of perceptions that differing scientific information from various sources may be controversial and that there would be significant interagency interest in the science. Accordingly, we employed a rigorous review process. We established a Web portal to enable the public to suggest appropriate literature to be reviewed. We employed an external peer-review process that included multiple reviewers with relevant expertise for each chapter and public input for the reviewers' consideration. The Ecological Society of America managed the independent reviews for each chapter and the synthesis as a whole.

This executive summary follows the format of the full synthesis (Spies et al. 2018). The following 10 chapters synthesize the state of knowledge for the particular topic and highlight key findings and management considerations. The final chapter examines integrated themes that bind the individual chapter topics together and examines how this synthesized knowledge can inform vital forest management activities.

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

Chapter 2: Climate Change, Disturbance, and Vulnerability to Vegetation Change in the Northwest Forest Plan Area

Matthew J. Reilly, Thomas A. Spies, Jeremy Littell, Ramona Butz, and John B. Kim[1]

Main Points

- Climate change was not explicitly considered during development of the Northwest Forest Plan (NWFP, or Plan) in 1994. Over the past two decades, however, climate change has emerged as an overarching theme in natural resource science and management.
- The NWFP area is projected to enter a novel climate regime during the next century. Conditions are projected to exceed the 20th century range of variability around the 2050s in some portions of the region, particularly in the Klamath Mountains and southern Cascade Range.
- Most models project that the region will experience warmer, drier summers and potentially warmer, wetter winters.
- The effects of climate change will occur through a variety of mechanisms at a range of spatial scales and levels of biological organization. These effects will be seen in the physiological responses of individual plants as well as in the composition and structure of stands and landscapes.
- Considering a variety of approaches may be helpful when managing in the face of uncertainty. "Bet hedging" strategies and multiple courses of action may help to minimize risk and enable further learning.

Introduction

Climate change is expected to alter the structure, composition, and function of forested ecosystems across the globe. Increases in atmospheric concentrations of greenhouse gases (e.g., carbon dioxide [CO_2]) and temperature, as well as altered precipitation and disturbance regimes (e.g., fire, insects, pathogens, and windstorms), are likely to have profound effects on biodiversity and the delivery of

[1] **Matthew J. Reilly** is a postdoctoral researcher, Humboldt State University, Department of Biological Sciences, 1 Harpst Street, Arcata, CA 95521; **Thomas A. Spies** is a senior scientist emeritus and **John B. Kim** is a biological scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331; **Jeremy Littell** is a research scientist, U.S. Department of the Interior, Geological Survey, Alaska Climate Science Center, 2160 Koyukuk Drive, Anchorage, AK 99775; **Ramona Butz** is an ecologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, 1330 Bayshore Way, Eureka, CA 95501.

ecosystem services within the Plan area over the next century. The effects of climate change will occur through a variety of mechanisms at a range of spatial scales and levels of biological organization. These effects will be seen in the physiological responses of individual plants and in the composition and structure of stands and landscapes. It is difficult to generalize about the effects of climate change. The region's environmental and climatic setting is extremely diverse (fig. 2-1) and its ecological interactions are complex. Understanding how climate change projections and the potential ecological effects and uncertainties differ across the region is essential for developing adaptation and mitigation strategies.

Climate change was not explicitly considered during development of the NWFP in 1994. In the past two decades, however, it has emerged as an overarching theme in natural resource science and management. It sets the context for any discussion about future conditions—both in terms of likely changes it will trigger and the uncertainty associated with managing forests when the past is not necessarily a reliable reference point.

Chapter 2 of the NWFP science synthesis lays the foundation for understanding the physical basis of climate change for the remaining chapters and reviews what is known about possible direct (e.g., growth, mortality) and indirect (disturbance) effects of climate change on forests. We summarize key findings below. Other chapters of the synthesis explore how climate change might affect specific terrestrial and aquatic species and additional adaptation considerations associated with those species and ecosystems.

Key Findings

The Region's Climate Has Always Been Dynamic but May Be Entering a Novel Regime

The climate and vegetation of the NWFP area went through continuous change over the past 11,700 years during the Holocene. During this period, complex interactions between a fluctuating climate and fire drove vegetation change at millennial scales. Species ranges expanded and contracted over time in response to climate and disturbance. Some species persisted in refugia in regions where climate was otherwise generally unsuitable. Refugia played an important role in the persistence of populations of plants and animals through the multiple climatic transitions that occurred in the region since the last glacial maximum.

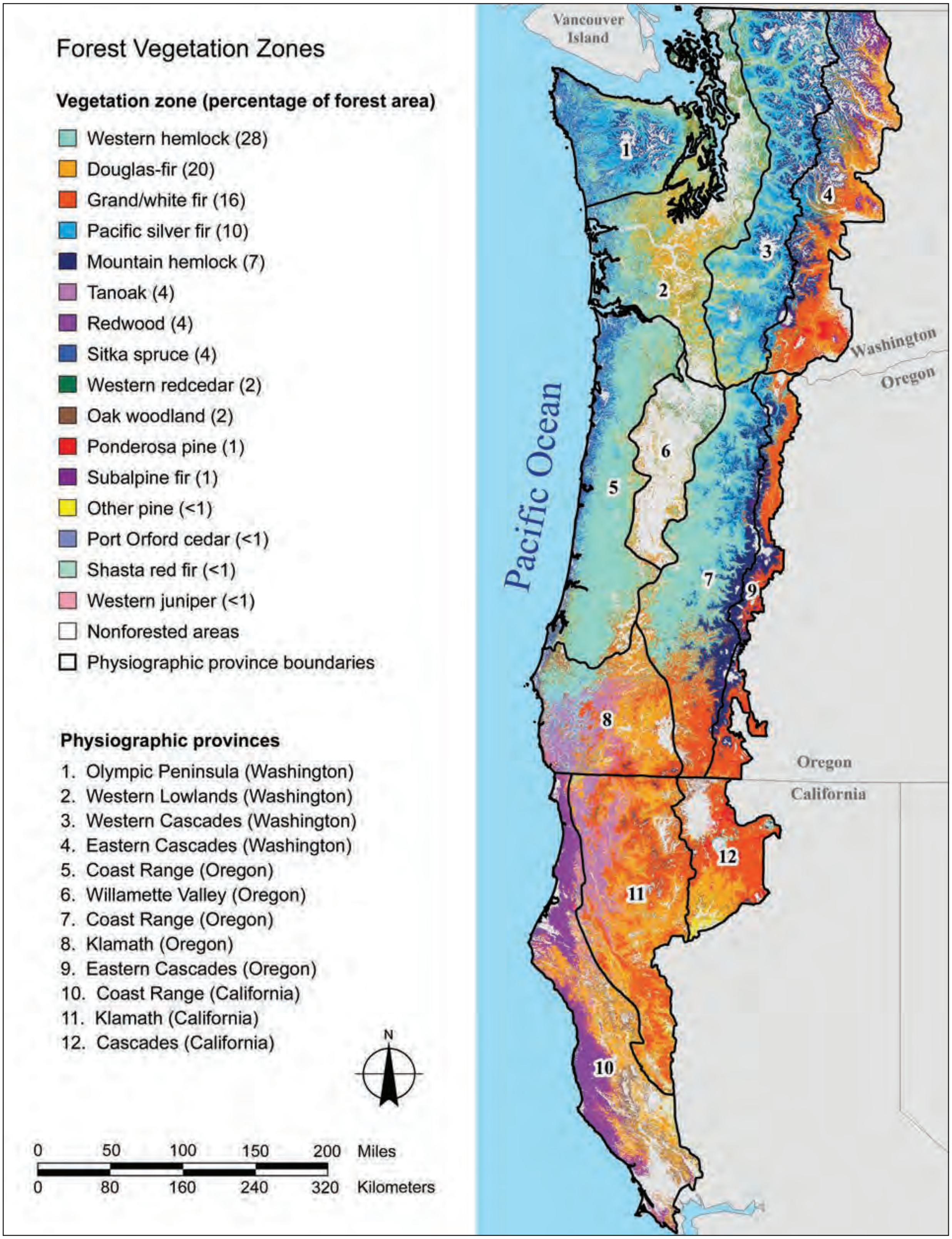

Figure 2-1—Geographic distribution of vegetation zones (Simpson 2013) and ecoregions (physiographic provinces) within the Northwest Forest Plan area. The environmental and climatic setting of the region is extremely diverse.

Historical fluctuations in climate and fire episodes-—
During the past 1,000 years, climate and fire fluctuated at centennial scales. The warmest temperatures occurred during the Medieval Climate Anomaly (~900–1250 CE), and the coldest temperatures occurred during the Little Ice Age (~1450–1850 CE). Precipitation also varied during this time, but there is less consensus about this in the literature. Although there is some evidence that a relatively dry period occurred during the Medieval Climate Anomaly, more recent evidence suggests that this period was wet and the Little Ice Age was dry. The synchronous occurrence of fires in the Plan area over the past 400 years was related to regional drought driven by teleconnections with sea surface temperature anomalies (e.g., El Niño/Southern Oscillation, Pacific Decadal Oscillation). Fire was generally infrequent in most moist vegetation zones but fire return intervals ranged from about 50 years to >200 years, with synchronous, regional fire episodes occurring across the region from the 1400s to the mid-1600s, and again from the early 1800s to around 1925. Fire was far more frequent in dry vegetation zones, where return intervals were shorter and generally varied from 10 to 50 years until the late 19th and early 20th centuries.

Temperature and precipitation changes in the 20th century—
Increases in temperature and precipitation across the NWFP area during the 20th century exceeded average global increases and vary across the region as well as among seasons. There is evidence supporting both strong human-caused climate change and temperature increases associated with ocean/atmospheric variability, but natural factors alone cannot explain warming in the region. Average annual temperature in western Oregon and Washington increased by 1.6 °F (0.91 °C) during the 20th century, with the greatest increase of 3.3 °F (1.83 °C) occurring during the winter. Likewise, precipitation during the same period also increased by 13 percent with the greatest increase of 37 percent during spring. Northern California also experienced accelerated warming since 1970. Mean annual temperature increased by 0.3 °F (0.18 °C), and northern California recently experienced the hottest and the driest period in the observational record, and potentially in the past 1,200 years. Twentieth century trends in precipitation varied in northern California with evidence of overall increases as well as slight decreases in some parts of the Plan area.

Climate trends across the region indicate changes in several characteristics of weather associated with climate change relevant to forest and vegetation dynamics. Spring (March to May) temperature increased approximately 1.8 °F (1 °C) from 1950 to 1998, and snowpack declined during the latter half of the 20th century.

Decreases in the proportion of annual precipitation falling as snow, the amount of water contained in spring snowpack (i.e., the depth of water if the snow were to melt), and increased evapotranspiration from longer growing seasons increased soil water deficits since the 1970s. A longer freeze-free season, an increase in the temperature of the coldest night of the year, and increased potential evapotranspiration during the growing season also occurred during this period. Fog frequency along the coast of northern California declined by 33 percent during the 20th century, as has low summertime cloudiness. Most recently, northern California has undergone a dramatic shift from extreme drought conditions in 2012 to 2016 followed by extreme precipitation events and severe flooding.

A warmer future with potentially wetter winters and drier summers—
Climate change projections for Washington, Oregon, and northern California depict a future with significant warming by the end of the 21st century, though the magnitude of warming differs across the region. Projected increases in annual average temperature for Oregon and Washington range from 4.3 to 5.8 °F (2.4 to 3.2 °C) by the middle of the century (2041 to 2070), and 5.9 to 17.5 °F (3.3 to 9.7 °C) by the end of the century (2070 to 2099).

Warming is projected to occur across all seasons, with the greatest temperature increases occurring during summer months. Projected changes in precipitation are more uncertain, with some models projecting a 10-percent decrease in annual precipitation by the end of the century (2070 to 2099) and others projecting as much as an 18 percent increase in precipitation. Most projections depict wetter winters and drier summers. Temperature conditions projected by 2100 across much of the western Cascade Range and Klamath Mountains do not resemble conditions experienced during the 20th century. A more extreme scenario projects that most of Oregon and Washington will depart from their historical climate regime by 2050 when the mean annual temperature of a given location will exceed the 20th century range of variability.

In northern California, projections for increases in annual temperature range from 2.7 to 8.1 °F (1.5 to 4.5 °C) by 2100. Projections depict drier futures, with total annual precipitation decreasing by 18 percent in a more extreme scenario. Increases in temperature are projected for all seasons across northern California, with the greatest increases occurring during the summer months. Projected decreases in summer precipitation range from 4 to 68 percent, whereas projected changes in precipitation during winter months range from a 9 percent decrease to a 4 percent increase. Interannual variability is expected to increase with the occurrence of greater wet and dry extremes during the wet season (October to March). Most of northern California is projected to depart from its 20th century climate by 2040, and the projected future climate of the Klamath Mountains by 2100 represents conditions of temperature and precipitation not experienced in the recent past.

Changes in the magnitude and seasonality of temperature and precipitation patterns will most likely affect vegetation by altering the availability of water in the soil. Cumulatively, these will be experienced ecologically through hotter droughts and greater deficits in water balance. Water balance deficit for vegetation is defined as the difference between potential evaporation and actual evapotranspiration. Ecologically, water-balance deficit equates to the difference between the atmospheric demand for water from vegetation and the amount of water that is actually available to use. Even if precipitation remains similar to 20th century levels, projected increases in temperatures could reduce the amount of soil moisture available for plants.

Projections for changes in water-balance deficit differ among models and across the region (fig. 2-2). Most of the region is projected to experience increased summer (June through September) water-balance deficits during the middle part of the 21st century. The eastern Cascades, Klamath Mountains, and southern portion of the western Cascades in Oregon will likely experience the greatest increases in water-balance deficit, as well as the southeastern

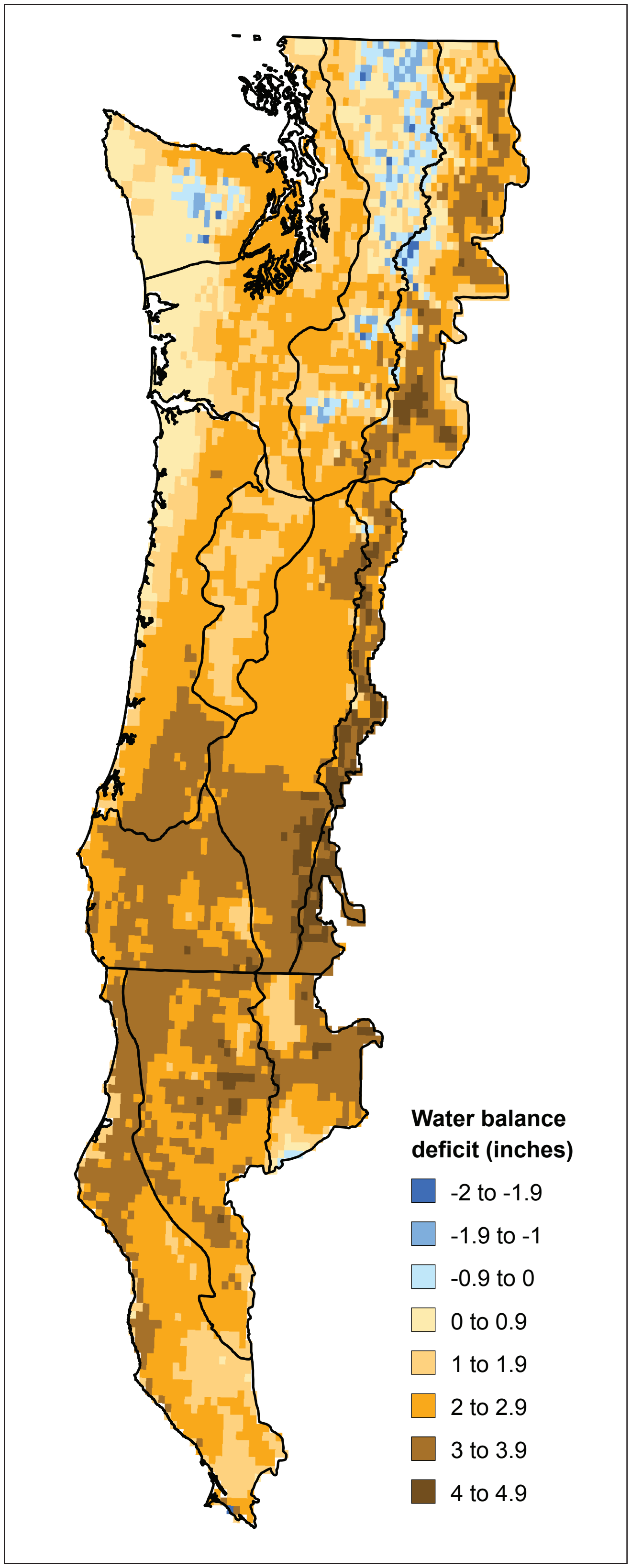

Figure 2-2—Projected changes in summer water balance deficit across the Northwest Forest Plan area for 2030–2059 (June through September), compared to water-balance deficit from 1916 to 2006. Higher water balance deficit (browns) means decreased water available for plant uptake. Map boundaries correspond with the ecoregions in figure 2-1.

portion of the Oregon Coast Range and the northern portion of the California Coast Range. The least amount of change is projected in the northern portions of the Coast Range along the Pacific Ocean. Higher elevations of the Olympic Peninsula and the northern portion of the western Cascades in Washington are projected to experience less summer water balance deficit in the future.

Climate refugia—

When considering the coarse resolution of climate projections, it is important to recognize the potential variability in future climate and vegetation change at finer scales. Differences in vegetation structure and topography can drive fine-scale variation in temperature extremes, with differences in maximum and minimum temperatures of similar magnitude to those projected at a broader scale. Complex topography and cold air pooling may decouple climate conditions in mountain valleys from surrounding landscape, and snow may persist later in the season in canopy gaps and topographic depressions. Recent findings also indicate that dense old-growth forests in moist vegetation zones of the region may provide local cooling effects.

The potential for relatively stable climatic conditions at finer scales in some landscapes suggests these areas may serve as climatic refugia and contribute to the future persistence of some species. Refugia will most likely be found in topographically-complex landscapes in which microclimates differ because of differences in aspect, shading and insolation, and cold air drainages. Such refugia may enable species persistence during unfavorable climatic conditions and serve as sources for future recolonization, provided that suitable conditions return in the future.

Disturbance and Tree Mortality as Agents of Regional Forest Change

Climate change is expected to alter vegetation through direct effects (e.g., of CO_2 and climate on vegetation processes) and indirect effects (e.g., disturbance processes). The direct effects of climate change and increasing CO_2 on vegetation will be expressed through changes in tree growth and mortality, both of which may be sensitive to altered phenology and biotic interactions within and among species. The indirect effects of climate change are expected to be expressed through increases in the frequency, severity, and extent of disturbances, particularly drought, fire, insects, and pathogens. These have the potential for rapid ecological change at landscape scales, and are predicted to be a greater driver of ecological change than direct effects, at least in the near term. The relative importance of these drivers, however, is likely to vary geographically across the region among species, seral stages, physiographic provinces, and disturbance regimes.

Water availability will determine tree growth—

The potential response of tree growth to climate change varies substantially among species depending on the factors that limit growth, including water availability and length of growing season. Growth in Douglas-fir is predicted to decrease under climate change where it is currently water limited, but may increase where this species is limited by growing-season length or by lower than optimal temperatures. In species of high-elevation forests where growth is limited by temperature and growing-season length, growth increased during the 20th century owing to warmer winter temperatures and longer growing seasons. Warmer winters and earlier snowmelt may also increase potential for drought and water stress in higher elevation forests, especially toward the southern portion of their range, but these effects are not yet well documented. The effects of climate change on ponderosa pine is uncertain as wetter fall seasons may increase growth while drier summers decrease growth. These effects may vary across the landscape as ponderosa pine may be more sensitive to drought at lower elevations. The response of ponderosa pine also depends on the potential for CO_2 to enhance growth by increasing water-use efficiency. However, some evidence suggests that any benefits of CO_2 fertilization in the future will be outweighed as the climate warms and water becomes more limiting.

Tree mortality will likely vary geographically and by species—

Tree mortality from higher temperatures and drought stress has already occurred in many forests of the region, and is expected to increase in the 21st century. Warmer temperatures and increased frequency and duration of droughts are likely to increase climate-induced physiological stress on plants and potentially exacerbate the effects of biotic disturbance agents (e.g., insects and pathogens). However, the magnitude of these effects are likely to be variable and differ geographically as well as among species. Pathogen activity is likely to increase where such organisms typically infect drought-stressed host species, but climate change effects on pathogens that occur under moist conditions may be more variable and difficult to predict. Warmer winters and hotter droughts are expected to enable insects to move into previously unsuitable habitat. Recent increases in tree mortality rates in old-growth forests are associated with pathogen and insect activity and resulted in cumulative losses in basal area and density. However, a better understanding of the trends and ecological consequences of mortality and how these vary among seral stages in terms of community-level change (i.e., structure and composition) is needed.

Longer fire seasons and drought point to increased future fire activity in drier forests—
Increases in the frequency and extent of fire are related to longer fire seasons associated with earlier snowmelt and warmer spring and summer temperatures as well as drought. Annual area burned increased since the mid-1980s, but there is growing consensus that dry vegetation zones experienced less fire during this period than they would have during presettlement times due to fire suppression. The effects of recent fires, however, have been extremely variable across the region, and several large fires have occurred in the Klamath Mountains, eastern Cascades, and western Cascades of Oregon (fig. 2-3). Fire severity has been related to climate and drought at broad spatial scales, and there is little evidence that the proportion burning at high severity has increased across the region since the mid-1980s. There is evidence, however, that fires are getting bigger and that larger patches of high-severity fire occur during drought years when more area is burned.

A number of studies using different techniques project increases in a variety of metrics of fire activity (i.e., area burned, fire size, severity, fire interval) during the 21st century, although projections vary considerably across the NWFP area. Drier forests in the Klamath Mountains, western Cascades, and eastern Cascades are projected to experience more fire activity over the next century, while most studies project little increase in fire activity in moist maritime forests (i.e., Sitka spruce, redwood, western hemlock).

Key Vulnerabilities

Several vulnerabilities triggered by climate change have been identified either explicitly in the literature or may be inferred based on knowledge of long-term vegetation change in the region, the distribution and dynamics of current vegetation, and projected changes across the region. Increases in temperature, as well as altered precipitation and disturbance regimes, are expected to affect vegetation across the region.

General vulnerabilities include:

- Increased wildfire and insect activity driven by drought and extreme weather events.
- Ongoing and new invasions of nonnative species.
- Loss of some high-elevation tree species (e.g., whitebark pine).
- Loss of climate-suitable habitat for fragmented populations at the margins of their range (e.g., Alaska yellow-cedar), narrowly distributed species, and species with poor dispersal, especially where topography does not foster the potential for long-term persistence in relatively climate stable refugia.

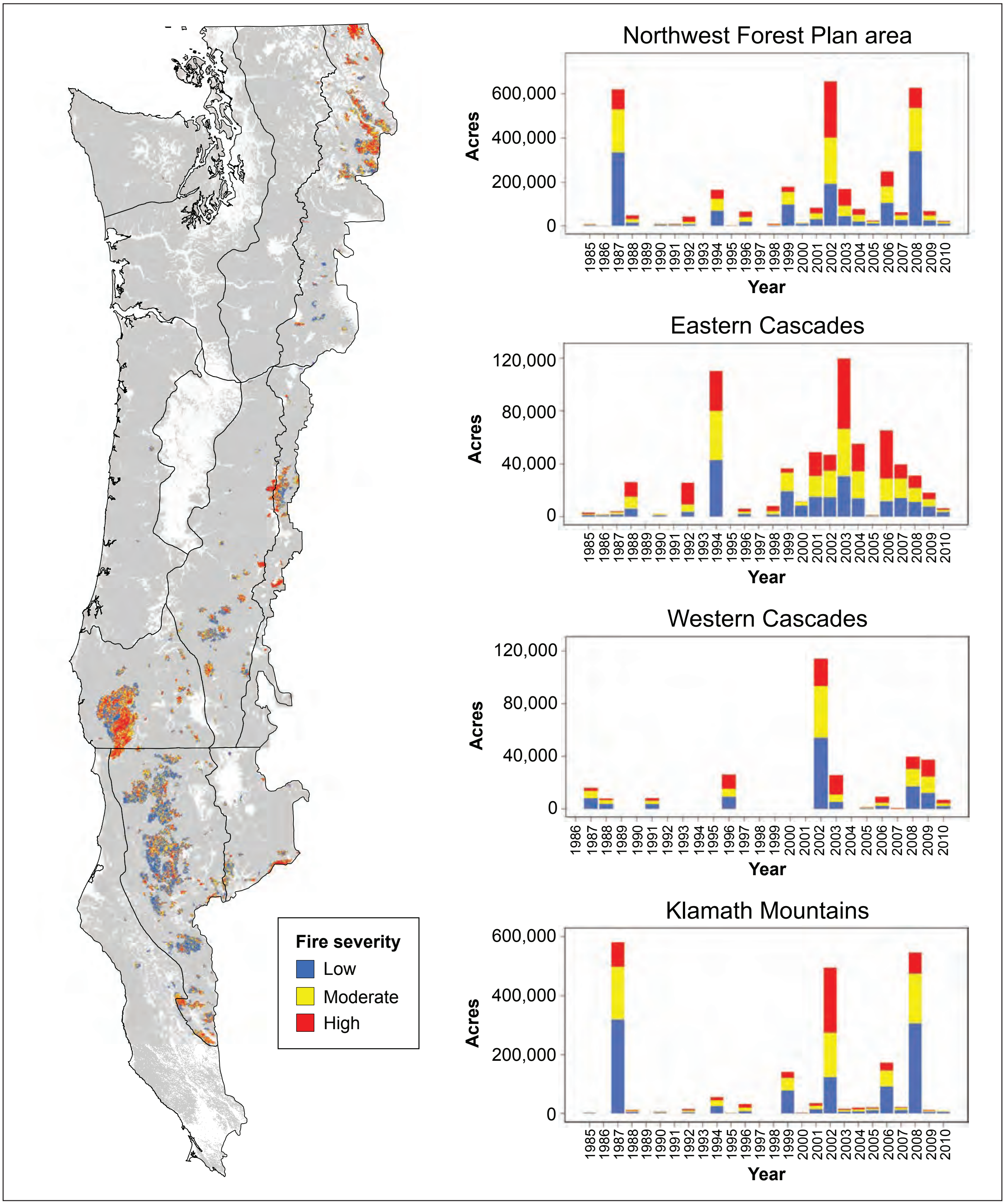

Figure 2-3—Geographic patterns of burn severity from 1985 to 2010 in the Northwest Forest Plan area. The effects of recent fires have been extremely variable across the region. Map boundaries correspond with the ecoregions in figure 2-1 (adapted from Reilly et al. 2017).

The greatest vulnerability to climate change exists in the drier and colder portions of the Plan area: the eastern Cascades, southern portion of the western Cascades of Oregon, coastal and inland areas of the Klamath Mountains, and the California Coast Range.

- In dry vegetation zones of these ecoregions, increases in area burned during drought conditions are likely to result in larger patches of high-severity fire and drive landscape-scale change.
- In general, there is good model agreement that subalpine forests will decline everywhere except in the northern portion of the eastern Cascades.
- Several tree species in both wet and dry vegetation zones are vulnerable to nonnative pathogens whose effects may be exacerbated by climate change.
  - These include whitebark pine, subalpine fir, sugar pine, western white pine, Port Orford cedar, tanoak, and several species of oak. Old-growth forests will also be vulnerable to periods of elevated mortality rates associated with insects and pathogens during drought.
- Along the coast, decreases in summer fog may substantially reduce suitable climate for redwood and other coastal species that depend on it to mitigate summer drought.

Strategies for Adaptation and Mitigation to Climate Change

Adaptation and mitigation are essential components of strategic planning to address the effects of climate change. Adaptation options include management actions at stand and landscape scales to reduce vulnerabilities to climate change. Mitigation includes efforts to increase carbon sequestration in forest ecosystems and provide new energy-efficient products and technologies for society.

Several adaptation options to reduce climate change vulnerability are available (table 2-1). These range from manipulating stand and landscape structure to foster resistance and resilience to future disturbance, to protecting intact areas and potential climate change refugia that provide connectivity that facilitates migration by species to more favorable habitats.

Table 2-1—Summary of adaptation options to climate change vulnerabilities in the Northwest Forest Plan area

Vulnerability	Strategy	Tactics
Increased drought stress	Increase resilience	Thinning Favor drought-resistant species/genotypes
	Foster genetic and phenotypic diversity	Protect trees adapted to water stress Collect seeds for future Maintain connectivity for natural species migration
Increasing area affected by fire, insects, and pathogens	Increase stand resilience	Thinning and prescribed fire Increase stand heterogeneity Favor fire-tolerant species
	Increase landscape resilience	Increase landscape heterogeneity Increase diversity of patch sizes Use topography to guide treatments
Loss of forest cover	Monitoring of change	Use existing data and add more where needed Planting/assisted migration Maintain connectivity for natural species migration
Exotic species	Increase control efforts	Early detection/rapid response/frequent inventory Interagency coordination

Source: Halofsky et al. 2017.

Adaptation Through Stand Manipulation

Manipulation of stand and landscape structure with management tools (i.e., thinning or prescribed fire) is thought to increase resistance and resilience to future vulnerabilities associated with drought and disturbance (e.g., fire, insects) in drier forests that may be subject to moisture stress and fire. Findings from dry forests in other regions support the use of thinning as an option to increase soil water availability, reduce growing-season moisture stress, and improve vigor in older trees, but the NWFP area is lacking specific studies on this topic.

Prescribed fire can also increase resistance to drought in dry forests of the Sierra Nevada of California. Thinning has been used effectively to reduce fire severity in dry Douglas-fir of Washington's eastern Cascades and other regions in the Western United States. Fuel treatments may be effective at reducing fire behavior and burn severity during moderate burning conditions; however, treatments may not be effective during large weather-driven fires.

Mitigation by Increasing Carbon Sequestration

Activities that can mitigate the effects of changing climates include efforts to increase carbon sequestration in forest ecosystems. Forests in the Plan area have great potential to store large amounts of carbon in both live and dead biomass. Total carbon storage varies among physiographic provinces as a result of productivity and disturbance. Recent findings suggest that forests on Forest Service lands in Oregon and Washington currently store about 63 percent of their potential maximum carbon. At current rates, harvest and disturbance have little overall impact on carbon sequestration on federal lands in Oregon and Washington as a whole. This differs at smaller scales among geographic areas, however, particularly in areas where dry forests have experienced substantial landscape change after recent fires.

- In the Oregon Coast Range, projected increases in productivity are associated with projections of increased carbon storage, but gains could be offset by losses, depending on harvest intensity.
- Projections suggest future decreases in carbon storage from increases in fire activity in the eastern and western Cascades of Washington.
- In forests west of the Cascades where fire is less frequent, decreasing harvesting, increasing rotation age, and maintaining and increasing the extent of late-successional and old-growth forests are strategies to increase carbon storage toward theoretical maximum limits.
    - Maintaining and increasing the area of dense old-growth forests with high biomass also has the potential to mitigate temperature changes in topographically complex mountainous environments.
- Carbon stores in the drier, more fire-prone parts of the eastern and southwestern NWFP area are more unstable and less predictable owing to future projections of increased fire activity.

Some studies from other regions in the Western United States (i.e., Southwest, Sierra Nevada) suggest that thinning and fuel reduction can mitigate carbon loss from fire. Fuel reduction may reduce losses of carbon at stand levels compared with the consequences of high-severity wildfire burning in stands with high fuel loads. However, because the probability of treated areas burning is generally low, and most live and dead biomass is not consumed by fire, fuel reduction is not generally considered a viable mitigation strategy because cumulative carbon losses from fuel-reduction treatments are greater than losses from combustion. That said, thinning and prescribed fire (common fuel-reduction methods) can be viable climate adaptation tactics (table 2-1) for increasing stand heterogeneity and resilience to insects and pathogens, particularly in the dry and mesic forests of the Klamath and southern Cascade Range regions of California and southern Oregon. As the amount of fire on the landscape increases, the difference in carbon sequestration between untreated and treated landscapes declines, and the likelihood increases that thinning will pay off in respect to the overall carbon balance.

Management Considerations

Considering the Range of Likely Variation in Change for Different Areas

Projections for climate and vegetation change represent a range of outcomes that can be used to estimate the potential magnitude of effects across the region, but they do not predict specific outcomes in terms of climate or vegetation conditions. When planning management activities, it is important to consider the variability in projections among ecoregions, as well as among landscapes and topographic settings **within** an ecoregion.

Bet hedging—
Considering a variety of management approaches may be the best strategy when faced with a range of possible outcomes. "Bet hedging" strategies and multiple courses of action may help minimize risk and enable further learning. One strategy for dealing with this uncertainty in a planning context is to use scenarios and risk analysis.

Dense, moist older forests may help buffer effects of warming at finer scales—
Maintaining dense late-successional forests may help mitigate effects of climate change and buffer warming at finer scales in moist vegetation zones where fires are infrequent. In addition to storing large amounts of carbon, late-successional forests also may provide refugia for species that depend on cooler, moist habitats.

Topography can help guide landscape-scale treatment to increase resilience in older, dry forests—
In dry forest landscapes, maintaining large areas of dense, multilayered older forests is inconsistent with a strategy for increasing resilience to drought and fire. Landscape-scale treatments to reduce fuels by selectively thinning forest stands and using prescribed fire and managed wildfire may promote resilience in dry forests where historical fire regimes were interrupted during the 20th century. These activities can reduce vulnerability to high-severity fire during moderate weather conditions, and potentially reduce extensive outbreaks of pathogens and insects. Topography can provide a physical template to consider when designing and implementing landscape-scale treatments (e.g., thinning on dry ridges and around topographically sheltered refugia).

Habitat connectivity may help some species but not all as the climate changes—
Maintaining and increasing habitat connectivity may facilitate migration of species experiencing unsuitable climatic conditions. However, connectivity needs

are likely to differ among species, and generic connectivity measures may not be adequate for focal species. Where climate envelopes within the range of a given species are changing more rapidly than the species can migrate, assisted migration can promote genetic and phenotypic diversity and may help maintain forest cover, although the net benefits of this practice are uncertain and controversial in the scientific literature.

Monitoring is essential to informed decisions and to help prioritize adaptive management objectives—
Monitoring of populations, species distributions, forest conditions, and contemporary disturbance regimes is essential to inform management decisions and help prioritize objectives for adaptive management in response to changes. Most species are expected to respond individually to projected changes in climate and disturbance regimes, and future forest communities may not have contemporary analogs. Understanding the responses of individual species, and how responses differ across their range, will be essential for developing strategies to promote species persistence and prioritize management efforts. However, little research on climate change effects exists for most species, with the exception of some of the major tree species.

Conclusions

Despite the range of projections for future climate, vegetation, and disturbance change around the region, several key vulnerabilities are well supported by the body of scientific evidence. Most models agree that the region will experience warmer, drier summers and potentially warmer and wetter winters. Conditions are projected to exceed the 20th century range of variability around the 2050s, particularly in the Klamath Mountains and southern Cascade Range. Potential impacts in lower elevation, moist vegetation zones (i.e., western hemlock) include decreased growth and productivity, especially where species are already water limited during the growing season. Higher elevation forests, specifically the subalpine vegetation zone, will be most vulnerable to the effects of climate change. These forests types are likely to experience large decreases in area and may potentially be limited to refugia in the northern Cascades. Although there is a great deal of uncertainty surrounding future vegetation change in dry forests, most models consistently agree on an increased role of fire in the 21st century, which is likely to include more area burned and larger patches of high-severity fire. Foremost among possible adaptation and mitigation strategies are "bet hedging" strategies that use multiple courses of action and enable further learning through monitoring and adaptive management.

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Old-growth forest, Oswald West State Park, Oregon. Photo by David Patte, U.S. Fish and Wildlife Service.

Chapter 3: Old Growth, Disturbance, Forest Succession, and Management Within the Northwest Forest Plan Area

Thomas A. Spies, Paul F. Hessburg, Carl N. Skinner, Klaus J. Puettmann, Matthew J. Reilly, Raymond J. Davis, Jane A. Kertis, Jonathan W. Long, and David C. Shaw[1]

Main Points

- Moist old-growth forests and dry old-growth forests have key differences in their structure, function, and disturbance regimes.
- Conserving biodiversity is about more than protecting old-growth forests; it is also about maintaining processes, other successional stages, and forest dynamics at multiple scales.
- Differences in disturbances regimes—particularly fire regimes—mean that different management techniques are needed to restore or conserve moist and dry old-growth forests and other successional stages.
- Although ecological differences between moist and dry forest regions were recognized in the Northwest Forest Plan (NWPF, or Plan), the focus in dry forests was on protecting dense, multilayered old growth rather than restoring and promoting resilience of forests to fire and climate change.
- Active management within and outside of reserves in moist and dry forests is important for meeting many of the ecological goals of the Plan and for fostering ecological integrity, as emphasized by the 2012 planning rule.

[1] **Thomas A. Spies** is a senior scientist emeritus, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331; **Paul F. Hessburg** is a research landscape ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1133 N Western Avenue., Wenatchee, WA 98801; **Carl N. Skinner** is a geographer (retired), U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Redding, CA 96002; **Klaus J. Puettmann** is a professor, Oregon State University, College of Forestry, Corvallis, OR 97331; **Matthew J. Reilly** is a postdoctoral researcher, Humboldt State University, Department of Biological Sciences, 1 Harpst Street, Arcata, CA 95521; **Raymond J. Davis** is a wildlife biologist and **Jane A. Kertis** is an ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, 3200 SW Jefferson Way, Corvallis, OR 97331; **Jonathan W. Long** is an ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1731 Research Park Drive, Davis, CA 95618; **David C. Shaw** is a professor, Oregon State University, Corvallis, OR 97331.

Introduction

The scientific basis of conserving and restoring old-growth forest biodiversity rests on understanding how forest succession and disturbances differ across the NWFP area. The historical dynamics of moist and dry forest zones were very different, and forest dynamics also vary within these broad zones. Over the past 150 years, timber harvest and fire exclusion—including suppression of natural ignitions and curtailment of traditional burning practices by tribes in the region—and grazing have profoundly changed the forests of the Plan area.

The NWFP was borne from threats to biodiversity and controversy in moist forests—specifically clearcutting of old growth and associated loss of nesting and roosting habitat for northern spotted owls (*Strix occidentalis caurina*). However, human activity has led to more pervasive ecological changes in dry forests, which occupy about 43 percent of the Plan area. Dry forests have lost large, fire-resistant trees to logging; surface and canopy fuels, and their connectivity, have increased; and patch size and distribution of all seral stages have changed. These changes have affected all species and ecosystem processes in these forests. Habitat for some dense forest species has increased, for example, while open, old-growth forest and ecological resilience to fire and drought have decreased.

Changes in moist forests are also significant, but the effects of logging and fire exclusion have been less extensive than in dry forests. In moist forests, intensive timber harvest has had the greatest impact on biodiversity because it dramatically reduced the amount of closed-canopy old-growth forests and fragmented the habitats of old-forest species. Fire exclusion in moist forests has also had an important but less obvious effect than in dry forests. Historically, fires created a patchwork of diverse seral stages across many moist forest landscapes, especially in drier parts of this zone. This patchwork is now highly altered.

The 2012 planning rule added a new policy context for national forests in the NWFP area. The planning rule calls for managing for ecological integrity[2] and species conservation by using a coarse-filter (ecosystem) approach. Fine-filter approaches (single species) may be used for a limited number of species when coarse-filter approaches are insufficient. Ecosystem approaches have the potential to rebuild ecosystem functions that promote resilience to fire and climate change. In doing so, threats to native species may be reduced, possibly minimizing the need to list more species under the Endangered Species Act. Approaches based on restoring or increas-

[2] Ecological integrity is the condition of an ecosystem that occurs when its natural disturbance and successional processes operate and are within their natural range of variation and it can withstand or recover from most disturbances and stressors imposed by nature or humans.

ing resilience to fire and climate change are also more likely to be socially acceptable and contribute to the socioeconomic well-being of forest-based communities.

Chapter 3 of the NWFP science synthesis explains the current scientific understanding of old-growth forest conditions and successional dynamics in the Plan area, especially as they apply to conservation and restoration of forest ecosystems and landscapes. Below is a summary of the current state of knowledge.

Key Findings

"Old Growth" Differs in Moist and Dry Forests

Differences between moist and dry older forests—
Tree density, spatial heterogeneity, and species composition of older forest differ in moist and dry forest zones. Older forests also differ geographically across disturbance regimes. Dense, multilayered old forests were typical of infrequent/high-severity fire regimes in the moist forests of the region (fig. 3-1), whereas relatively open, clumpy forests of pine, Douglas-fir, and other conifers were typical of very frequent/low- and mixed-severity regimes in the dry forest landscapes (fig. 3-2). Dense, multilayered older forest in dry forest landscapes occurred in fire refugia (areas sheltered from frequent fire by features such as topography). Old-growth forest structure and composition was most diverse at landscape scales in the mixed-severity regimes of moist and dry forests and less diverse in low- and high-severity fire regime forests.

Tom Iraci

Figure 3-1—This multilayered old-growth Douglas-fir/western hemlock forest on the Willamette National Forest is typical of infrequent/high-severity fire regimes in the moist forests of the region.

Structural elements—
Structural elements common to all old-growth forests of the region include relatively large (24 in+/60 cm+ diameter at breast height) and old vigorous and decadent live (200 to 250+ years old) and dead trees, and spatial heterogeneity of forest structure and composition, which was influenced by disturbance agents such as root rots, dwarf mistletoes, and wind. Other characteristics such as multiple canopy layers, shade-tolerant associates,

Tom Iraci

Figure 3-2—An open, old-growth ponderosa pine forest in which the structure was maintained by frequent, low-severity fire.

and large amounts of dead and down wood are not characteristic of all old-growth forest types across the range of historical disturbance regimes in the Plan area. In addition, old-forest elements (e.g., old live and dead trees) are not restricted to older forests; they can also be found in predominantly younger forests and in areas of early-seral vegetation that developed after high-severity disturbance in older forests.

Fire regimes in the region—

Four major regional fire regimes are recognized: two for moist forests and two for dry forests (fig. 3-3).

In moist forests, the major historical fire regimes are:

- Infrequent (greater than 200 years), high severity.
- Moderately frequent to somewhat infrequent (50 to 200 years), mixed severity.

In dry forests, the major regimes are:

- Frequent (15 to 50 years), mixed severity.
- Very frequent (5 to 25 years), low severity.

Fires of all severities occur in all four regimes, but the regimes differ in proportion and spatial pattern of the area burned by low-, mixed-, and high-severity fire. Of these four regimes, the mixed-severity regimes are the most variable and complex. The regional regime classification and map are only approximations. Local-scale fire regime characterizations are still needed for forest planning and management.

Defining old growth—

Definitions that recognize old-growth structural features as a continuum across stands of various ages and disturbance histories are more ecologically realistic and useful for restoration planning than are definitions of old growth with a single threshold that results in a forest being identified as either old growth or not.

Current definitions of old growth used in monitoring are based on recent forest inventory plots. This means that definitions for dry fire-prone forests (including forests in some drier areas of the moist forest region), which have been heavily influenced by fire exclusion, are not reflective of historical forest structure and composition that were typical of those forest environments. Better definitions and stand-level reference conditions that reflect the variety of old-growth conditions of fire-prone forests are needed for conserving and restoring old-growth and landscape dynamics for fire-prone forest types, including vegetation communities with significant hardwood components.

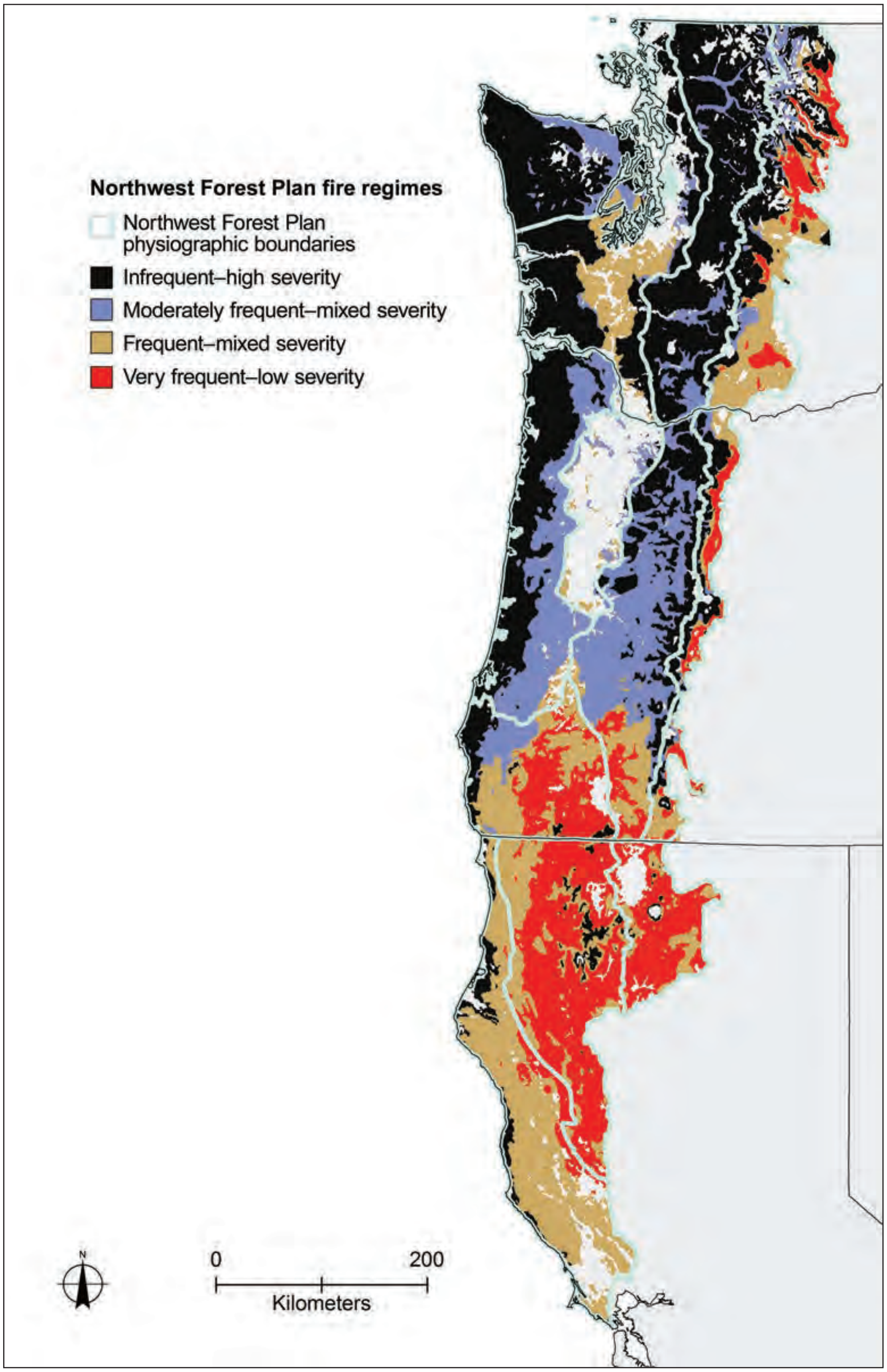

Figure 3-3—Historical fire regimes of the Northwest Forest Plan area. Moist forests occur in historically infrequent and moderately frequent fire regimes, while dry forests occur in frequent and very frequent fire regimes.

Forest Conservation Is About More Than Old-Growth Forests

Although forests with old trees were abundant across the NWFP area prior to Euro-American settlement, forest landscapes were typically a mosaic[3] of grasslands, woodlands, shrublands, hardwood forests, and younger conifer forests. Over the past several thousand years, the forests themselves were dynamic mosaics of successional stages that were often dominated by old-growth conditions.

Early-seral or "pre-forest" vegetation is dominated by grasses, herbs, and shrubs. Most of this vegetation has the potential to become a forest, although it can take many decades for forests to naturally regenerate and form closed canopies (fig. 3-4). Early-seral vegetation is an important component of many landscapes, and historically its occurrence varied over time with fluctuations in climate. High-severity or mixed-severity disturbances create early-seral conditions and provide distinctive biodiversity and ecosystem function across a range of spatial scales. The diverse young vegetation, along with dead trees and legacy trees that survived the disturbance, influence forest development, biotic communities, and ecosystem function for decades to centuries.

All seral stages contribute to native forest biodiversity, wildfire regimes, and resilience to wildfires and climatic changes. They are all essential to maintaining ecosystem functions and services. Thus, conservation of native forest biodiversity is more than managing for a single type of old growth or a single successional stage. Conserving native forest biodiversity is about managing for mosaics of all vegetation types and processes that support them.

Knowledge of historical disturbance regimes and successional dynamics is essential for conserving, restoring, and promoting resilience to climate change, fire, and other disturbances in old forests and all other successional stages. Moist and dry forests have fundamentally different disturbance regimes, developmental pathways, ecological potentials, and abundances and types of old-growth forests.

Historical landscape diversity was linked to disturbances—

The spatial pattern of environments and vegetation conditions at the scale of landscapes (e.g., thousands of acres) varied across the disturbance regimes of the NWFP area. This landscape diversity also varied over time with changes in regional climate. Fires, for example, were relatively common in the moist forest region during the 1500s when the climate was warmer and many of the current old-growth Douglas-fir forests became established. The spatial and vegetation characteristics associated with the historical fire regimes are summarized below.

[3] Even the wettest forest landscapes where fire was rare would have a diversity of vegetation patches as a result of riparian areas, wet meadows, thin soils, and patches of recent blowdown.

Figure 3-4—Early-successional vegetation including tree regeneration 12 years after the 2003 B&B Fire in the western Cascade Range of Oregon. Note the considerable amounts of dead wood in this patch of high-severity fire. This legacy structure, along with the diverse young vegetation, will influence forest development, biotic communities, and ecosystem function for decades to centuries.

- **Infrequent/high-severity fire regime of the moist forests.** Early-seral vegetation was typically uncommon and the landscape was dominated by large patches of mature and dense older forests of complex structure. Successional stages were connected across time and space. Large patches of old growth originated from large patches of early-seral vegetation that were created by large stand-replacement fires. Patches of shrubs and hardwood trees occurred along larger streams.
- **Mixed-severity fire regime of the moist forests.** A more dynamic and complex mosaic of well-connected and dispersed mature and older forests of more variable stand structure (e.g., multiple age cohorts of Douglas-fir) comprised these landscapes. They had patches of different ages and sizes of younger forests and early-seral vegetation, often containing remnant live and dead large, old trees.
- **Frequent/mixed-severity fire regime of the dry forests.** This regime yielded a complex mosaic of forest structural types very strongly controlled by frequent fires, primarily of low to moderate severity. Dense older forest occurred in patches of different sizes and often associated with topography.

- **The very frequent fire regimes** were dominated by low-severity fire that maintained open old forest with infrequent patches of dense older forests found in fire refugia. Early-seral successional conditions would have occurred as small, sinuous patches that blended into areas with older trees. In steep, highly dissected topography (e.g., southwest Oregon and northwest California), the mosaic of forest conditions was more strongly expressed as a function of topography and fine-scale variability in disturbance regimes and successional pathways.

Fire exclusion from suppression and other factors has affected vegetation conditions in both moist and dry forests. The effects of fire exclusion in dry forests, e.g., fuel buildup, are widely known. Less well known are the effects of fire exclusion in moist forests, especially in the drier part of the zone where historical fires were more frequent, mixed-severity effects were more common, and seral-stage patchworks were more varied. The primary effect of fire exclusion in moist forests is a reduction in early-successional vegetation and seral-stage diversity on the landscape, and reduced structural variety of old-growth forests that were subject to low- and moderate-severity fires.

Considering Fire and Forest Dynamics in Reserves

Reserves play a pivotal role for conserving biological diversity in the face of development and many extractive land uses. The literature also indicates that goals and management guidelines for reserves need to be clearly defined. Management within reserves may be needed to restore ecological processes and patterns that have been altered by past land use—including timber harvest—fire exclusion, and invasive species. Relatively little research exists, however, on how to manage reserves—especially in fire-prone landscapes—when disturbance and climate regimes are changing in ways that can lead to relatively abrupt changes in the abundance and boundaries of successional stages and the pattern of physical environments.

Status and trends of old-growth forests in late-successional reserves—
The late-successional reserves (LSRs) of the NWFP area were intended to protect remaining old-growth forests from logging. They were also intended to promote future development of old-growth forest structure through restoration silviculture in existing plantations. Some losses of old-growth forests to fire were expected. To help mitigate this loss, a large proportion of the Plan area was designated as reserves, and many LSRs were relatively large (e.g., >50,000 ac [20 200 ha]). Risk-reduction actions in LSRs in dry forests also were recommended to reduce the risk of losing dense forest patches to fire, but the focus was on younger forests, and few fuel treatments actually occurred.

At the scale of the NWFP area, less than 8 percent of older forest was lost due to wildfire and logging over the 20 years of the NWFP and most of that loss was to wildfire. Significant gains from succession have offset almost two-thirds of the losses from high-severity disturbance. However, old-growth dynamics differed geographically and with scale. Some areas, especially the dry forests of the Klamath region in Oregon and California, have had much higher net losses mainly from a few large fires. Larger LSRs (>50,000 ac [20 200 ha]) had smaller percentage losses than smaller LSRs.

The overall NWFP reserve strategy, which focused on conserving closed-canopy older forests, is currently meeting many of the expectations of the NWFP. However, these trends may not hold with climate change that is leading to elevated mortality of old trees, growth reductions from pathogens and insects, and more frequent and larger patches of high-severity fire that are promoted by dense older forests with continuous canopy fuels and elevated surface fuel loads.

The 2012 planning rule emphasis on managing for ecological integrity (see definition above) sets a new context for conservation on national forests that has implications for management of the LSRs. The planning rule broadens the focus of conservation of biological diversity to ecological integrity and management based on historical dynamics. This is a broader view of coarse-filter conservation than that of the NWFP, which emphasized one successional stage: dense, multilayered old growth. However, basing management on the natural range of variation or historical dynamics is only meant to be a guide and not a target because changes in climate and other human influences may alter what conditions can be sustained.

The 80-year rule—

Under the NWFP, harvesting for any goal, including thinning for old-growth restoration, is generally restricted in moist forest LSRs to stands less than 80 years old. The scientific rationale for using 80 years as the threshold age for stand restoration in LSRs has not improved much since the NWFP was established. The rule was based on expert opinion of stand development from data collected in natural forests of different ages, primarily from the western hemlock zone.

Eighty years is a one-size-fits-all threshold that does not recognize that stand age is a rough proxy for stand structure and development potential, both of which can vary greatly based on site conditions and disturbance history. Depending on the structure and composition of stands, and landscape context and objectives, restoration treatments in moist forests more than 80 years old in LSRs could promote old-growth characteristics (e.g., heterogeneity associated with mixed-severity fire) or reduce them (e.g., by reducing the number of large live and dead trees).

Note that the situation in moist forests is not the same as in dry forests (and some drier parts of moist forests), where active management in older forests in LSRs may be needed to meet ecological integrity and resilience goals.

Alternative silviculture—

The use of alternative silviculture to meet both wood production and ecological goals in stands more than 80 years old in the NWFP matrix of the moist forests remains valid, based on current studies. Studies of variable-retention[4] silviculture suggest that some biodiversity elements (e.g., large live and dead trees and some other taxa) of older forests can be retained in stands managed for a combination of timber and structural and compositional diversity.

Mismatch Between Goals for Late-Successional Reserves and Dry Forest Ecology

The options presented in the Forest Ecosystem Management Assessment Team's (FEMAT) 1993 report set the foundation for the NWFP. These options emphasized science based heavily on moist-zone forest ecology and the standards and guidelines for LSRs in moist forests are most consistent with managing for ecological integrity under the new planning rule. However, the science of the NWFP did not adequately deal with substantially different ecology of forests and landscapes of the dry forest zone, which comprises almost half of the NWFP area. The standards and guidelines of the NWFP in these forests, which emphasize conserving and restoring dense older forests, are generally not consistent with management for ecological integrity and resilience to fire and drought.

Cultivating Resilience to Climate Change and Fire

Given the realities of climate change, land use change, and invasive species, landscape restoration is not about re-creating past conditions, it is more about promoting landscapes that are resilient to these and other disturbance agents and are able to support native species. Future climates, disturbance regimes, and forests will differ from those of the past, but understanding historical ecology can help us identify possible paths to achieving desired ecosystems in the future. Management actions and the dynamics of ecosystems that are beyond the control of managers (e.g., changes in climate and movement of species) will determine the nature of future forests.

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[4] Variable-retention silviculture seeks to retain forest structural elements for at least one forest cycle to maintain environmental values associated with structurally complex forests.

Management Considerations

Management of Late-Successional Reserves Differs in Moist and Dry Forests

- The goals here include protection of old growth from logging and high-severity wildfire. Given the losses and fragmented nature of moist old-growth forest, further losses to high-severity fire are undesirable. Focusing on restoration (such as variable-density thinning) in LSRs with moist forest plantations makes sense from a conservation perspective and can provide jobs and economic returns. However, there will be tradeoffs with some ecological goals (e.g., amounts of dead wood) that will need mitigation or reconciliation.
- Despite increases in fires in recent decades, wildfire in the region is still less frequent than it was historically for most forest types. However, when dry forests burn now under extreme weather, they are more likely to include large patches of high-severity fire that kill most or all of the fire-resistant older trees and create highly altered landscape-scale patch patterns. In the absence of fire, dry forest structure and composition are shifting toward denser forests and shade-tolerant species that lack resistance to wildfire, drought, and other disturbance agents.
- The increased emphasis on ecological integrity and coarse-filter approaches for conserving biodiversity under the 2012 planning rule, and awareness of threats from climate change and wildfire, appear to justify a reassessment of the reserve network and standards and guidelines in both moist and dry forests.

Promoting Seral Diversity in Plantations and Other Forests Older Than 80 Years in the Matrix

- Restoring fire or using fire surrogates (e.g., variable-density thinning) are strategies to promote early-successional vegetation and diversity in plantations and forests older than 80 years in the matrix. These could be used to rebuild bigger patches and blend seral-stage conditions to alter the structure of the fragmented landscape. This type of management could be a win-win for meeting ecological and timber goals. Managing for diverse early-seral stages would require developing landscape-scale prescriptions to ensure that old-growth goals could still be met.

Restoration Strategies for Cultivating Resilience to Climate Change and Fire

- Variable-density or low thinning in plantations in moist and dry forests to increase ecological heterogeneity and accelerate growth of large trees and tree crowns.
- Variable-density or low thinning along with prescribed fire in burning older forests in very frequent/low-severity and frequent/mixed-severity fire regime forests. These would be done to increase resilience to fire and climate change by restoring diverse and fire-tolerant structures and compositions of older forests, and of other successional stages, that will ultimately succeed to old-forest conditions.
- Careful use of prescribed fire and managed wildfires in fire-prone low- and mixed-severity fire regime forests to restore key ecological processes while protecting critical areas of dense, older forest conditions and other values that may not be resilient to fire.
- Creating diverse early-successional habitat where feasible, given other ecological goals and social constraints. The strategy for doing this could include variable-retention silviculture and prescribed fire in plantations and in forests more than 80 years old. Such practices are allowed in the NWFP in the matrix and may be appropriate if they are consistent with other landscape goals (e.g., creating or maintaining resilience to fire and climate change, providing habitat for spotted owls, and creating landscape-scale successional diversity).
- Using landscape-level management and conservation principles based on disturbance regimes, topography, species-specific climate refugia, spatial pattern, and departure from desired historical conditions.
- Management actions that promote resilience to wildfire and drought in fire-prone forest landscapes include thinning and prescribed fire to promote growth and restoration of large fire-resistant trees; reducing the vertical and horizontal continuity of forest fuels; restoring the patchwork of open and close canopy forests and tailoring these conditions to topography; and strategic work in forests with native diseases and insects to promote heterogeneity. These actions would promote a more desirable mix of low-, mixed-, and high-severity fires on the landscape.

Considering the Ecological Tradeoffs Between Management Actions and No Action

All management (including restoration activities and lack of activities) involves ecological tradeoffs. The effects of management actions can differ by spatial scale and time period. Multiscale and multitemporal analysis can reveal how ecological tradeoffs and management effects differ with scale. Below are some possible restoration strategies and tradeoffs to consider.

- Restoration thinning (e.g., variable density) can provide small short-term patches of early-seral habitat, accelerate the development of large live trees, increase habitat quality for some species, and be profitable. Thinning, however, may have short- or long-term impacts on habitat quality for other late-successional species, may increase activity of forest insects and pathogens, and can reduce amounts of dead wood in the future.
- Thinning and restoring fire to forests with a history of very frequent fire can increase resilience to wildfire and increase habitat for fire-dependent species that use more open, older forests. However, these actions can degrade habitat for species that use dense older forests, which developed because of fire exclusion.
- Continued suppression of fire in fire-prone dry-zone forests to protect human values will increase surface and canopy fuel continuity. This increases the potential for large patches of high-severity fire when fires escape suppression and burn under extreme conditions.
- Excluding fire and disturbance from dry-zone forests will also typically increase stand density and species composition toward late-successional species and species that use dense forests; it lowers the resilience of these forests to fire and drought. These changes can also accelerate the loss of large, fire-resistant trees that may not be replaced owing to competition from shade-tolerant trees.
- Excluding fire from moist forests (especially in the drier parts of the moist forests) reduces landscape diversity and the area of diverse early- and mid-successional vegetation.
- Salvage logging after wildfire does not typically generate ecological benefits for species and processes associated with patches of high-severity wildfire. In some cases, however, where fire exclusion led to uncharacteristically dense forests, post-wildfire management may facilitate restoration of

reference conditions or resilience of the site and soil to future fire by reducing the amount of standing and down fuels. Post-wildfire management can reduce safety hazards for future fire suppression activities.

- Tradeoffs among goals are particularly obvious in managing road networks because portions of some existing networks can negatively affect some native species and ecosystem processes. However, road networks also can support landscape restoration, fire management, and active management to support other ecological and socioeconomic goals.

Conclusions

The NWFP began as a novel and comprehensive scientifically based policy experiment to conserve forest biodiversity associated with late-successional and old-growth forest habitats. Although intended as a 100-year plan, the Plan was also intended to be adaptive and subject to change based on monitoring results and new scientific findings and perspectives. Although monitoring indicates that the Plan is meeting some of its original ecological goals (e.g., protecting dense old-growth forests), new concerns (e.g., climate change and altered fire regimes) have arisen, and new policy goals have been added.

The 2012 planning rule, which calls for increased emphasis on managing for ecological integrity, broadens the original ecological focus of the Plan to include ecosystem-scale processes such as natural disturbances that control the dynamic mosaic of vegetation in a landscape. Dense old-growth forests are still an important conservation consideration to be addressed through reserves and management for ecological goals. However, regional differences in the ecology of moist and dry forests have become apparent, as has awareness that other successional stages (e.g., early seral) and old-growth types (open, fire-frequent old growth) are important for regional forest biodiversity and ecosystem integrity.

Our understanding of forest ecology leads us to conclude that current standards and guidelines for late-successional reserves in dry forests, and some drier parts of the moist forests, do not provide for ecological integrity consistent with the historical fire regimes and future climate conditions. Active management within and outside of reserves in moist and dry forests is still important for meeting many of the ecological goals of the Plan, although there will be tradeoffs in ecological outcomes among different management approaches. The spatial distribution of reserves appears to provide a good regional foundation for addressing climate change on federal lands. However, managers may want to reassess the reserve network and standards and guidelines in both moist and dry forest zones to address climate change and the role that frequent fire has played in maintaining resilience of dry forests to climate change, fire, and other natural disturbance agents.

Development, evaluation, and testing of new, highly integrated conservation approaches is crucial to dealing with new knowledge and changing perspectives on fire regimes, climate change, and invasive species. Explicitly acknowledging the tradeoffs among biodiversity goals (e.g., coarse-filter and fine-filter approaches) and between the ecological and social dimensions of forest management is important moving forward.

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A northern spotted owl in the McKenzie River Basin in Oregon. Photo by John and Karen Hollingsworth, U.S. Fish and Wildlife Service.

Chapter 4: Northern Spotted Owl

Damon B. Lesmeister, Raymond J. Davis, Peter H. Singleton, and J. David Wiens[1]

Main Points

- Steady declines in northern spotted owl populations have been identified in every study that has assessed rangewide populations of the owl since standardized monitoring efforts began in 1985.
- Competitive interactions with barred owls have contributed significantly to spotted owl declines. The barred owl is a more prominent and complex threat to the spotted owl than was anticipated by the Northwest Forest Plan (NWFP, or Plan).
- Suitable nesting and roosting habitat for spotted owls has declined. The effects of forest disturbance on spotted owls—whether wildfire, forest management, timber harvests, extreme weather events, or insects and disease—depend on the spatial scale, severity, and the season in which it occurs.
- Without additional intervention, the long-term persistence of spotted owls in the NWFP area is questionable.

Introduction

In 1990, the northern spotted owl (*Strix occidentalis caurina*) (spotted owl hereafter) (fig. 4-1) was listed as threatened under the federal Endangered Species Act. At the time, habitat loss from timber harvest and wildfire was the major identified threat to the spotted owl. The first recovery plan focused on providing adequate amounts of suitable forest cover to sustain this subspecies. This concept drove the design of late-successional forest reserves in the NWFP, along with the emphasis on fostering development of old-forest characteristics.

The reserve design included large, contiguous blocks of late-successional forest. This was expected to provide habitat for many interacting pairs of spotted owls. The reserves were configured to facilitate movement across the geographic range. The selection of reserves generally favored old-growth forest, but some younger forests were also included with the expectation that, over time, the forest structure would develop suitable characteristics to sustain suitable owl populations.

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[1] **Damon B. Lesmeister** is a research wildlife biologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331; **Raymond J. Davis** is the northern spotted owl and old-growth monitoring lead, U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, 3200 SW Jefferson Way, Corvallis, OR 97331; **Peter H. Singleton** is a research wildlife biologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1133 N Western Avenue, Wenatchee, WA 98801; and **J. David Wiens** is a research wildlife biologist, U.S. Department of the Interior, Geological Survey, Forest and Rangeland Ecosystem Science Center, 3200 SW Jefferson Way, Corvallis, OR 97331.

Eric Guzman

Figure 4-1—The northern spotted owl is listed as threatened under the Endangered Species Act. Providing adequate amounts of suitable forest cover for the owl was a primary driver of the reserve design and old-forest restoration under the Northwest Forest Plan.

For at-risk species, understanding their survival and reproduction rates, and factors that affect these rates over time and space, can provide crucial information for management and conservation. As such, population trends and demographics of spotted owls have been monitored closely in the intervening years. Since its listing, demographic rates have been monitored in 14 study areas distributed across the spotted owl's geographic range.

Chapter 4 of the NWFP science synthesis synthesizes 20 years of spotted owl science, focusing particularly on scientific understanding accumulated from 2005 to 2016. We also review key information concerning the ecology of the spotted owl and expectations for its conservation under the Plan. Here, we provide highlights from chapter 4.

Key Findings

Steady Declines in Spotted Owl Populations Since Implementation of the Northwest Forest Plan

The spotted owl monitoring program follows a general framework to estimate demographic parameters and population trends across the owl's geographic range. In the past 10 years, three meta-analyses investigated relationships between the population demography of spotted owls and distribution of suitable forest cover types, local and regional variation in climate, and presence of barred owls (*Strix varia*).

- When the NWFP was developed, spotted owl populations were declining at an estimated 4.5 percent per year.
- This decline was expected to continue for up to 50 years until younger forest in the reserves had matured and could provide suitable structural conditions for nesting and roosting.
- During the first 10 years of the NWFP, the overall rate of population decline in Washington was much greater than in Oregon and California. Three study areas in southern Oregon had stable populations during the first decade.
- The first meta-analysis (published in 2006) revealed an annual decline of 3.7 percent across the NWFP area.
- On federal lands, populations had declined 2.4 percent annually compared to a 5.8-percent annual decline on nonfederal lands, suggesting that implementation of the NWFP had a positive effect on the demography of spotted owls.
- The second meta-analysis (published in 2011) estimated an annual decline of 2.9 percent within the eight federal study areas.
- The most recent meta-analysis (published in 2016) indicated that spotted owl populations were declining by about 3.8 percent per year throughout the range, and declines ranged from 1.2 to 8.4 percent per year depending on the study area. Annual rates of decline were accelerating in many areas.
- For monitored populations, population change was more sensitive to adult survival than to recruitment.

Because of the decline documented in these and other studies, the U.S. Fish and Wildlife Service has been petitioned to change the status of the northern spotted owl from threatened to endangered under the Endangered Species Act.

Defining Spotted Owl Habitat

Differences in defining habitat have long caused confusion and uncertainty when interpreting the amount of spotted owl habitat and trends regarding gains or losses. Habitat for a species is an area that encompasses the necessary combination of resources and environmental conditions that promote occupancy, survival, and reproduction of that species.

Spotted owl habitat has often been characterized as older forests with large trees and a moderate to closed canopy. An advantage of characterizing spotted owl habitat based on forest structure is that these forest types can be mapped for the species' entire range. Other important components of habitat include prey abundance, predation risk, and the presence of competitors. These components are more difficult, if not impossible, to map rangewide. As such, no published model of spotted owl habitat completely reflects the owls' habitat. Here we distinguish between spotted owl habitat and components of that habitat.

Suitable forest for the northern spotted owl—
The NWFP monitoring program considers highly suitable forest to be:

- Multilayered, multispecies forest canopy dominated by large conifer trees (>30 in [76 cm] diameter at breast height [d.b.h.]).
- An understory of shade-tolerant conifers or hardwoods.
- Moderate to high (60 to 80 percent) canopy cover.
- Substantial decadence in the form of large, live coniferous trees with deformities; numerous large snags; large accumulations of logs; and other woody debris.

Mapping of suitable forest cover types is evolving to produce maps that describe a more comprehensive view of habitat. However, even the most recent modeling efforts are not able to reflect the distribution and abundance of prey and barred owls and how that restricts spotted owl distribution in otherwise suitable forest types.

Concentrated areas of older forest are most suitable for nesting and roosting, but a moderate mixture of other forest conditions can have positive effects on the vital rates of spotted owls at the territory scale because other forest types and edges are often used for foraging. Spotted owls typically select for abundant, structurally diverse closed-canopy forest with diffuse late-seral forest edge at the territory scale, and relatively contiguous old forest in nesting areas. Individual owls in territories with more suitable forest cover typically had better survival, fecundity, occupancy dynamics, recruitment, and rate of population change.

The late-successional reserves within the Plan area were designed to support multiple pairs of spotted owls and were configured to facilitate dispersal across their range. Under the NWFP, dispersal was expected to be facilitated through designated riparian reserves, retention of green trees in harvest units in the matrix, protection of 100-ac (40-ha) areas at known owl sites, and other administratively withdrawn areas. However, these assumptions are largely untested. It remains unknown if the NWFP is sufficient to facilitate adequate dispersal, which may be a limiting factor of spotted owl populations.

Nesting and roosting habitat has declined but projected trends on federal land are encouraging—

- About 12.6 million ac (5.1 million ha) of forest suitable for nesting and roosting were distributed across the spotted owl's geographic range at the time of NWFP development. By 2012, suitable nesting/roosting forest cover had decreased 3.4 percent.
- Net decreases during 1993–2012 were 1.5 percent on federal lands (primarily caused by wildfire) and 8.3 percent on nonfederal lands (primarily caused by timber harvest).
- Most losses occurred in the western Cascade Range and Klamath Mountains, whereas gains through forest succession primarily occurred in the Coast Range of California (fig. 4-2).

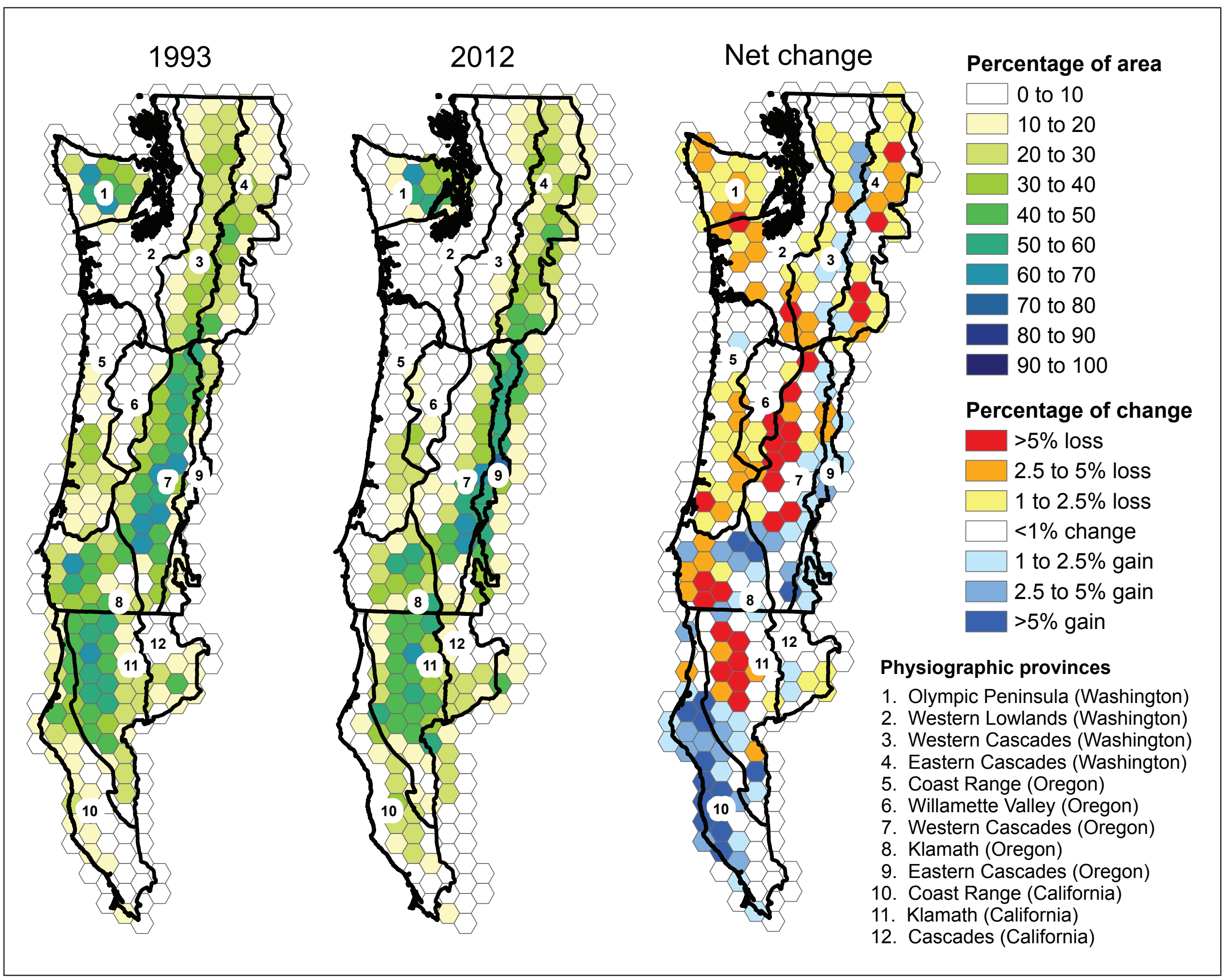

Figure 4-2—Loss and recruitment of forest types suitable for nesting and roosting by spotted owls in 1993 versus 2012 within 19 mi (30 km) hexagons. The gains in the Coast Range of California occurred primarily through forest succession. Most losses occurred because of timber harvest and large wildfires.

- Originally, older forests comprised about 43 percent of the late-successional reserves. In 20 to 30 years from now, older forest cover in these reserves is expected to be 60 percent or more, meeting the threshold assumed to support multiple breeding pairs of spotted owls and population recovery. This significant recruitment of suitable nesting and roosting habitat is expected to offset current rates of loss.

Patrick Kolar

Figure 4-3—A barred owl. Barred owls are causing further declines in northern spotted owl populations. The recent invader is slightly larger than northern spotted owls, has a more diverse diet, and uses a broader range of forest conditions for nesting.

The Barred Owl Is a Prominent and Complex Threat

Once confined to eastern North America, the barred owl (fig. 4-3) now co-occupies and outnumbers spotted owls throughout the NWFP area (fig. 4-4). Barred owl populations may continue to increase in the Pacific Northwest, depending on the availability of resources—such as habitat and prey—that vary by forest composition and climate.

Compared to spotted owls, barred owls are more generalist in diet and habitat. They have higher annual survival, more offspring, and smaller home ranges. Barred owls aggressively defend their territories. This can lead to increased local extinction rates and mortality for spotted owls through agonistic interactions (dominant behavior and territoriality) and direct killings by barred owls (fig. 4-5). Several lines of evidence indicate that the increasing abundance of barred owl has a strong and negative affect on spotted owl populations:

1. Spotted owl occupancy of historical territories is lower.
2. Apparent survival is lower.
3. Reproduction is lower.
4. Population declines more rapidly.
5. Hybridization between the species increases.
6. Detection rates during surveys are lower.
7. Spotted owls alter movements and resource use.

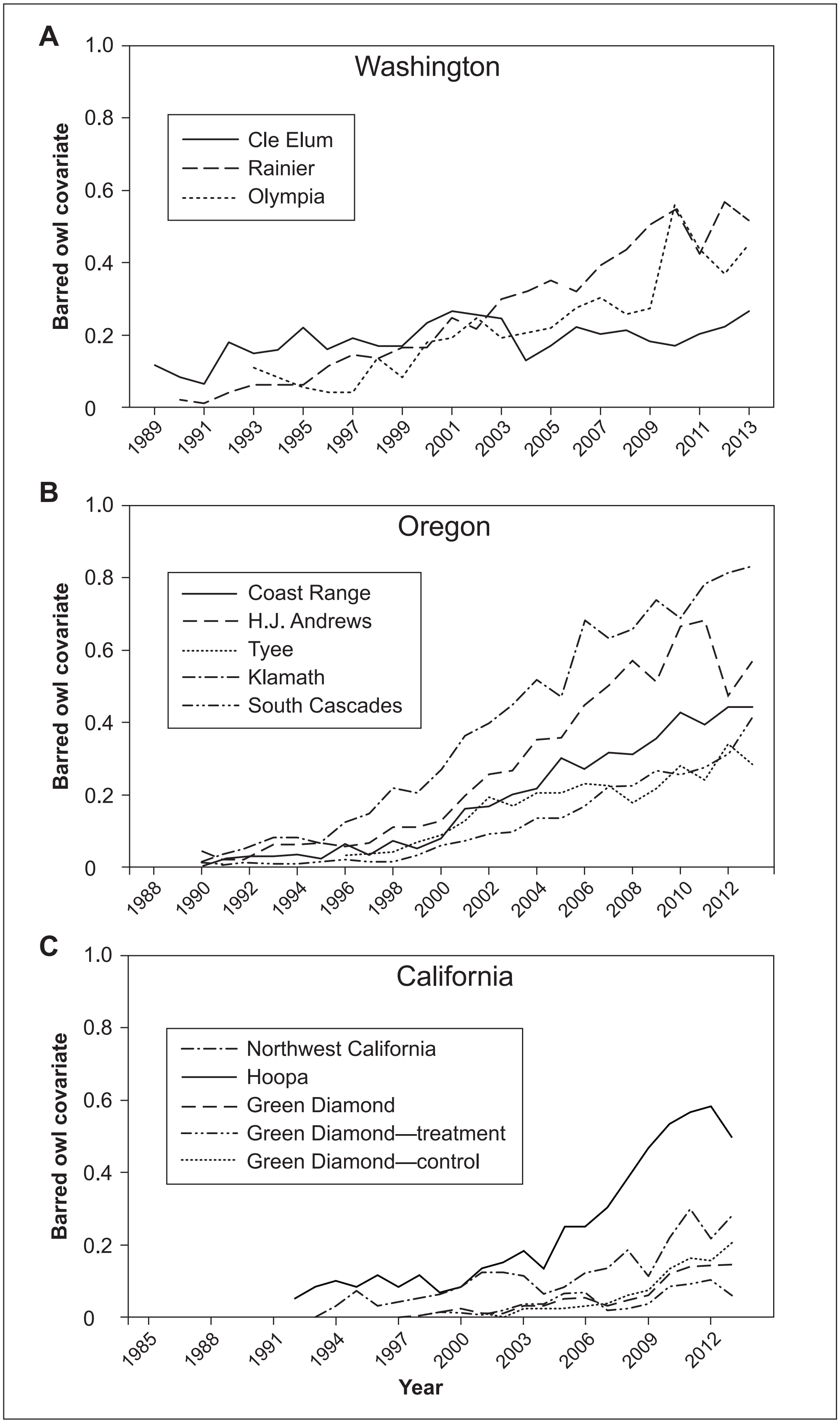

Figure 4-4—Annual increase in the proportion of spotted owl territories with detections of barred owls at study areas in the Northwest Forest Plan area. Estimates for Green Diamond are presented separately for control and treatment areas for barred owl removals (from Dugger et al. 2016).

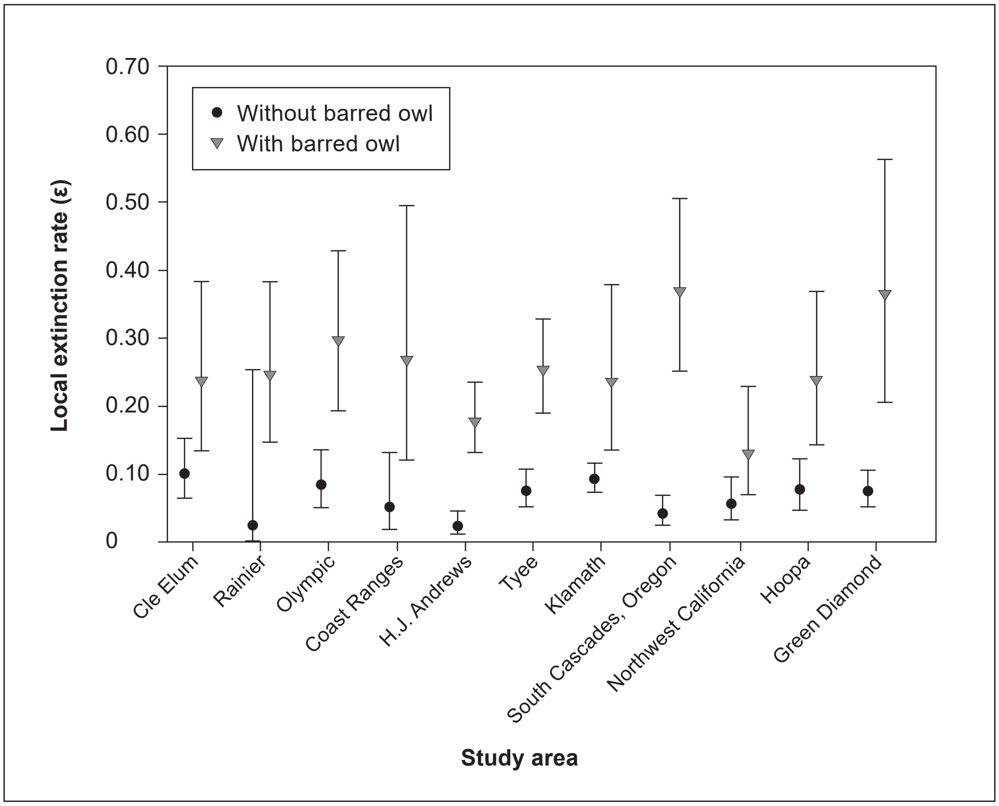

Figure 4-5—Mean annual local extinction rates (with 95 percent confidence limits) for northern spotted owls in 11 study areas relative to with (gray triangles) and without (black circles) barred owls (from Dugger et al. 2016).

Adult survival of both spotted owls and barred owls was higher in home ranges with greater amounts of old forest. Dietary studies also showed that barred owl diet is broader than that of spotted owls, but both species relied on similar prey associated with older forest types.

These findings have important implications for land managers because they suggest that (1) barred owls are able to exploit resources that would otherwise be available to spotted owls, and (2) availability of old forests is a key limiting factor in the competitive relationship between the two owl species. Although spotted owls are known to use recently thinned stands, it remains unclear how such silvicultural treatments can affect the fitness of spotted owls in the long term, or how barred owls may respond to those management actions. Silvicultural treatments that greatly simplify a stand likely increase long-term extinction rates of spotted owls by reducing forest complexity and thus suitability for spotted owls, but not necessarily for barred owls.

Without additional intervention, the long-term persistence of spotted owls is questionable—
Despite continued management and conservation of suitable forest cover on federal lands, the long-term persistence of spotted owls is questionable without additional management intervention. Experimental removal of barred owls on one study area in California suggests that removal of barred owls may have positive effects on population trends of spotted owls. The Fish and Wildlife Service expanded removal experiments to additional sites, and those experiments will yield information about how spotted owls respond and will convey the economic and logistic feasibility of barred owl removal efforts as potential management actions. However, the effectiveness and feasibility of large-scale and long-term barred owl removal for conservation of spotted owls remain to be demonstrated. More detailed studies are needed to better understand how specific tree species, stand densities, or physiographic conditions are negatively associated with barred owls but not spotted owls.

Although some evidence suggests that barred owls are more strongly associated with riparian areas than spotted owls, studies clearly indicate that barred owls exploit virtually all prey and forest types used by spotted owls. In the eastern Cascades, spotted owls used drier midslope areas that were less likely to be occupied by barred owls, possibly as a mechanism to minimize interactions with barred owls. This pattern suggests that barred owls displace spotted owls from highly suitable forest, pushing spotted owls into conditions less favorable to fitness. This finding is consistent with long-term demographic studies of spotted owls.

In addition to impacts on spotted owls, changes in the abundance and distribution of an apex predator like the barred owl can have cascading effects on prey populations and food web dynamics. Differences in space use, abundance, demography, suitable forest, diets, and behavior collectively suggest that the barred owl is not a direct functional replacement of the spotted owl in old-growth forest ecosystems. As a consequence, additional changes in community structure and ecosystem processes are anticipated as a result of barred owl encroachment.

How Does Forest Disturbance Affect Spotted Owls?

Wildfire, forest management, timber harvest, extreme weather events, and insects and disease: these types of forest disturbance occur throughout the NWFP area. Their effects on spotted owls depends on the spatial scales, severity, and season in which they occur.

A disturbance that opens the forest canopy can reduce habitat suitability in the short term. Benefits may develop over time, however, as understory vegetation diversifies in response to more light and less competition for moisture, and development of large-tree, complex forest structure is accelerated. Forest disturbances can create conditions that increase the abundance or vulnerability of some prey species. Conversely, if critical forest structure required by primary prey populations is lost, the disturbance can have a negative effect.

Processes that substantially simplify stand structure or landscapes often have negative impacts on forest suitability. Over the past 20 years, there has been a growing recognition of the contribution of diverse forest conditions to broader ecosystem function and species diversity. This is especially true in historically moderate- and high-frequency fire regime landscapes where fire suppression and forest management have greatly reduced fire and altered forest structure and composition. For example, nonconiferous vegetation, including shrubs and broad-leaved trees, makes an important contribution to the diversity of forest landscapes. Allowing shrubs and hardwood trees to develop and persist in early-seral stands, and curtailing vegetation control, will benefit many wildlife species.

The function and diversity of an ecosystem is enhanced by the presence of high-quality, early-seral patches because they have high species and structural diversity. These early-seral ecosystems can be created by using low-intensity approaches to regeneration, combined with retention of biological legacies to promote the development of structurally diverse closed-canopy forest. Indeed, under normal conditions, natural disturbances frequently result in patches of high-quality early-seral ecosystems, provided that intensive salvage and replanting does not occur post-disturbance.

Wildfire—

Most studies that measured the effects of wildfire on spotted owls focused on short-term effects, and different studies often had seemingly contradictory results. One of the few longer term studies, based on 26 years of demographic data of wildfire on spotted owls, found that moderate and high burn severities negatively affected spotted owl apparent survival (Rockweit et al. 2017). Spotted owls can persist, at least for short periods, in landscapes that have experienced recent wildfires, as long as an adequate amount of suitable forest cover remains.

Spotted owls are adapted to a landscape with a mosaic of successional stages shaped by historical disturbance regimes, accompanied by abundant prey resources, no barred owls, structurally diverse closed-canopy forest with diffuse late-seral edge at the territory scale, and limited fragmentation within nesting areas. Some spatial heterogeneity in forest conditions can have a positive effect on the demography of spotted owls.

The dry-forest provinces in the NWFP area historically experienced frequent wildfire, typically of low to mixed severity. After more than a century of fire exclusion, stand density in many of these forests has significantly increased and forest health has declined. The historical extent of suitable forest types for spotted owls in dry forest was likely limited. In this fire-prone landscape, forest conditions that are more resilient to low- and mixed-severity fires are generally not suitable for nesting and roosting by spotted owls. Areas occupied by spotted owls in these landscapes are often dense, closed-canopy forests with a substantial true fir component and structural diversity. These conditions have been promoted through fire suppression except in topographic refugia such as drainage bottoms where dense forests often persist despite frequent fires.

Postfire salvage logging—

At the territory scale, a mosaic of older forest interspersed with other vegetation types can be beneficial, but spotted owls do not persist in areas with past timber harvest, high-severity fire, and salvage logging. Coupling wildfire and salvage logging results in a high probability that a site will become unoccupied by spotted owls for several decades.

Postfire salvage logging can have other significant negative consequences to a forest ecosystem, especially when conducted over large areas. The practice disrupts abiotic and biotic processes, reduces or eliminates biological legacies, simplifies post-disturbance structural complexity, alters vegetation recovery, diminishes natural patterns of landscape heterogeneity, facilitates invasion of nonnative species, decreases native biodiversity, increases susceptibility to erosion and repeated high-severity disturbances, and eliminates the restorative benefits of disturbance events.

Forest restoration treatments—

In the drier forests of the NWFP area, management treatments have focused on accelerating the development of old forest conditions and on restoring or promoting fire-resilient forest structure, species composition, and landscape pattern. The large tree, multistory canopy forest covers used for nesting and roosting by spotted owls is less flammable under most fire conditions. But these cover types are susceptible to burning intensely in extreme weather.

Land managers implementing forest restoration treatments face challenges in balancing the tradeoffs between short-term negative impacts versus potential benefits of reducing losses from high-severity wildfire. Standard treatments focused on increasing resilience to wildfire remove important forest cover elements for spotted owls and their prey. Prescribed fire treatments as part of fuel reduction projects can further reduce under- and mid-story canopy complexity, and can consume logs and snags, potentially causing additional negative impacts to suitable forest for spotted owls and their prey. Silvicultural practices that promote spatial and structural complexity have been proposed for retaining suitable forest for spotted owls while also reducing fuel loads, but the effectiveness of these management practices is unknown for these drier forests.

Thinning treatments in forests on the west side of the Cascade Range—
On the west side of the Cascade Range, the forests become progressively moister and less prone to frequent wildfire. When wildfires do occur, however, they tend to be mixed to high severity. The old forests in these landscapes retain more moisture and have cooler microclimates compared to other forest types. These characteristics make them more resistant to high-severity wildfire under normal fire weather conditions and may enhance biodiversity and buffer against the negative effects of a changing climate.

Silvicultural treatments in moist forests have attempted to accelerate development of old-forest conditions in younger closed-canopy stands. Typical thinning treatments that create canopy gaps in these forests can stimulate relatively rapid increases in understory vegetation diversity and productivity. Abundance of mice, terrestrial voles, and shrews often increased immediately following thinning, but northern flying squirrels and red tree voles—important prey species for spotted owls—decreased dramatically in abundance in treated areas. However, when assessing the potential effects of thinning on prey species, the landscape and temporal context should be considered.

The effects of thinning within heterogeneous landscapes with well-connected, intact old-forest cover may be less detrimental to northern flying squirrels than if thinning occurs within a highly fragmented forest landscape. Some degree of landscape heterogeneity resulting from forest restoration activities in west-side forests does not adversely affect spotted owls, provided that sufficient large-tree, closed-canopy forest is available for nesting and roosting.

Management Considerations

Forest Management and Barred Owls

- As barred owls continue to increase in number, the most effective conservation of the spotted owls will include protections for old forest and ameliorating the negative effects of barred owls.
- Current evidence suggests that a combination of habitat protection and active management of barred owls are the two highest priorities for stabilizing declining trends in populations of spotted owls.

Habitat, Wildfire, and Active Management

- Disturbances have different impacts on spotted owls depending on the scale under consideration.
- Disturbance processes that increase stand or landscape heterogeneity can have long-term benefits for spotted owls, as long as enough suitable forest cover for nesting and roosting remain within the territory.
- Conversely, disturbances that substantially simplify stands or landscapes often have long-lasting negative impacts on spotted owls and their habitat.

Conserving Occupied and Vacated Sites

- Conserving sites currently occupied by spotted owls as well as sites that they are known to have historically occupied is important.
- Spotted owls, for example, have abandoned many sites where suitable forest cover has been disturbed or they have been displaced by barred owls. These sites, however, may maintain structure suitable for nesting and roosting. Remaining spotted owls likely represent unique behavioral characteristics, while remaining sites likely represent forest characteristics that may not yet be fully recognized. Conserving the unique forest structural conditions of those remaining sites will likely have a positive benefit for the long-term persistence of spotted owls.

Conclusions

The northern spotted owl is a resilient subspecies but faces significant challenges. Research and monitoring efforts over the past two decades have documented population declines and risks to spotted owls, despite conservation measures.

The framework, standards, and guidelines of the NWFP have been both critical and necessary for spotted owl conservation. However, because of barred owls and continued forest perturbations outside of federal lands, the Plan alone is not sufficient for spotted owl recovery. Additional measures beyond the NWFP would be needed for long-term persistence of spotted owls.

Suitable habitat continues to decline because of current and lingering effects of extensive forest disturbance, and the recent invasion of barred owls has reduced the space available for spotted owls. The need to provide habitat for spotted owls has been a critical component of conservation plans and was a major catalyst for developing the NWFP.

Although spotted owl populations have continued to decline, the Plan has improved the conservation status of spotted owls because if logging had continued at pre-Plan levels, spotted owl populations certainly would have declined more rapidly over the past 20 years. Recruitment of suitable forest (primarily through succession), as protected under the NWFP, has put federal lands on a trajectory for providing enough forest with suitable structure for recovery of spotted owl populations over the next several decades.

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Marbled murrelet. Photo by Kim Nelson, Oregon State University.

Chapter 5: Marbled Murrelet

Martin G. Raphael, Gary A. Falxa, and Alan E. Burger[1]

Main Points

- The assumptions of the Northwest Forest Plan (NWFP, or Plan) remain relevant for marbled murrelet conservation.
- Large late-successional reserves (LSRs) in moist coastal forests have successfully protected nesting habitat for the marbled murrelet in the short term. It would be important to evaluate any possible changes to the LSR system against the likelihood of adversely affecting murrelets.
- A long-term goal of the NWFP is to create more nesting habitat than existed on federal lands in 1994. Trends indicate that progress is being made toward this goal.
- Uncertainties remain around the effects of climate change on the murrelet's marine prey and nesting habitat. Future management and design of reserves will benefit from accounting for the anticipated effects of climate change.

Introduction

The marbled murrelet (*Brachyramphus marmoratus*) (fig. 5-1) is a small seabird of the family Alcidae. Its summer distribution along the Pacific Coast of North America extends from the Aleutian Islands of Alaska to Santa Cruz, California (fig. 5-2). It forages primarily on small fish and krill in the nearshore (0 to 2 mi [0 to 3 km]) marine environment. Unlike other alcids, which nest in dense colonies on the ground or in burrows at the marine-terrestrial interface, murrelets nest in more dispersed locations up to 55 mi (90 km) inland.

Throughout the forested portion of the species' range, murrelets typically nest in areas containing characteristics of older forests. The marbled murrelet population in Washington, Oregon, and California nests in most of the major coniferous forest types in the western portions of these states, wherever older forests remain inland of the coast at elevations primarily below the extent of the true fir zone, generally <4,000 ft (1220 m) and close enough to the coast to allow nesting murrelets to commute between their inland nests and foraging areas in coastal marine waters.

[1] **Martin G. Raphael** is a research wildlife biologist (retired), U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3625 93rd Avenue SW, Olympia, WA 98512; **Gary A. Falxa** is a wildlife biologist (retired), U.S. Department of the Interior, Fish and Wildlife Service, 1615 Swanson Lane, Eureka, CA 95503; **Alan E. Burger** is an adjunct professor, University of Victoria, Department of Biology, and a wildlife consultant, P.O. Box 2539, Merritt, British Columbia V1K 1B8.

Martin Raphael

Figure 5-1—The marbled murrelet is a small seabird that forages in the marine environment and typically nests in older coniferous trees as far as 55 miles inland.

Map by Terry Sohl from NatureServe data

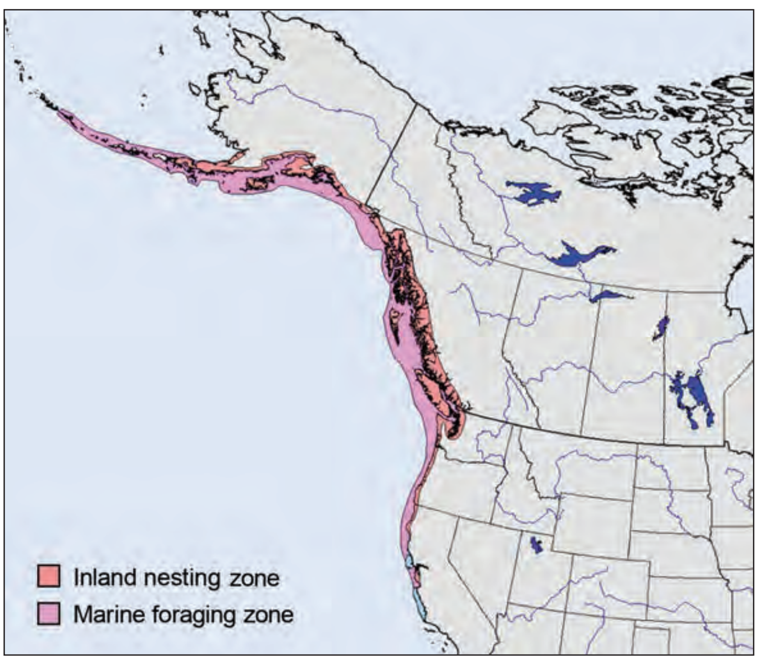

Figure 5-2—The North American range of the marbled murrelet extends from the Aleutian Islands to northern California.

Because murrelets depend on marine conditions for foraging and resting, and on forests for nesting, both marine and forest conditions could limit murrelet numbers. Population declines attributed to loss of mature and old-growth forest from harvesting, low recruitment of young, and mortality at sea led this species to be federally listed as threatened in Washington, Oregon, and California in 1992 (USFWS 1997) and listed as threatened in British Columbia (Rodway 1990). The murrelet's association with late-successional and old-growth forests and its listed status under the Endangered Species Act made conservation of the murrelet an explicit goal in the design of the NWFP.

The conservation strategy embodied in the NWFP evolved from numerous relatively small management areas to an approach that designated and protected fewer large areas, each designed to conserve functioning late-successional and old-growth ecosystems, support multiple pairs of northern spotted owls (*Strix occidentalis caurina*) and marbled murrelets (fig. 5-3), and conserve habitat for other species associated with older forests.

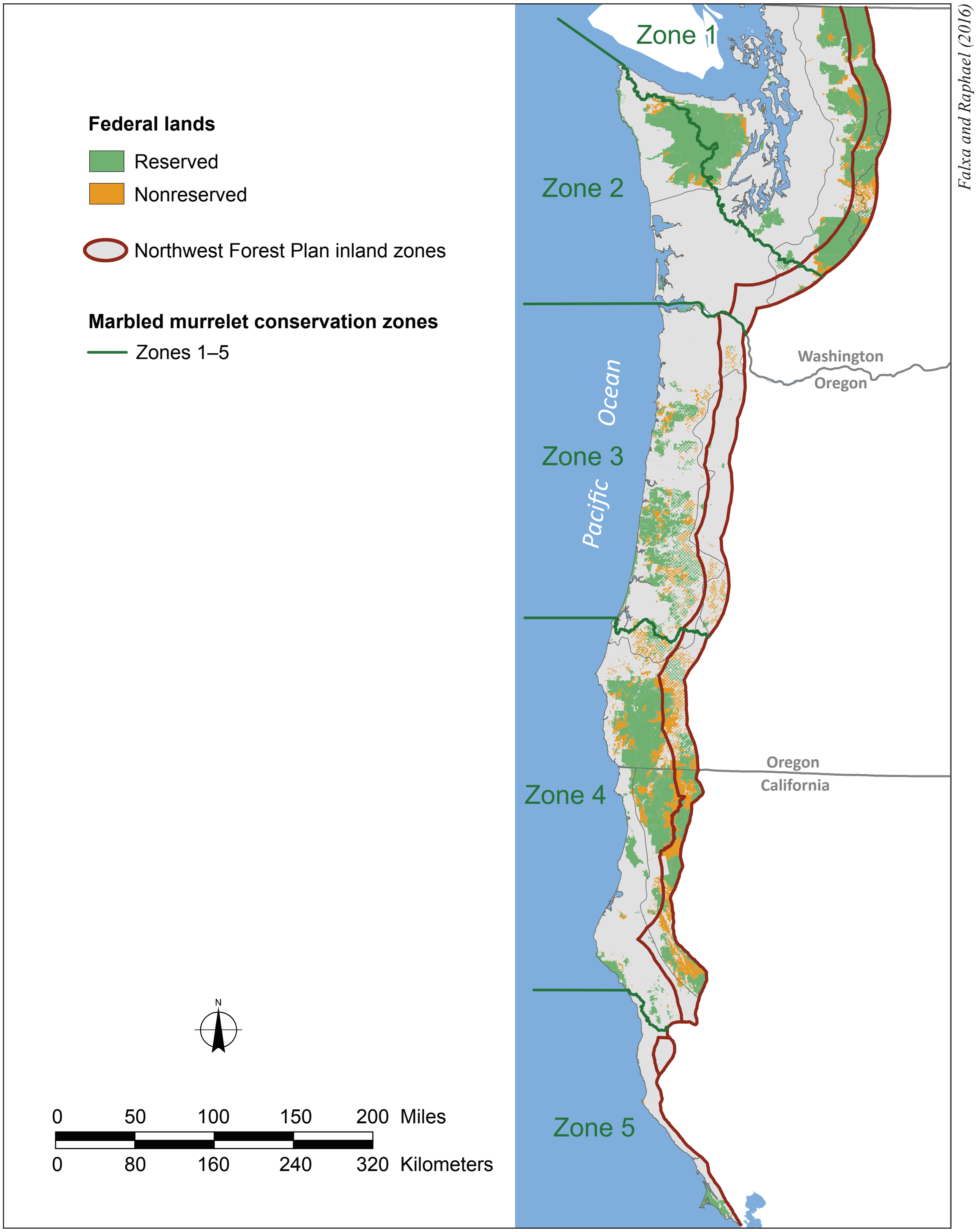

Figure 5-3—The five marbled murrelet conservation zones and locations of federal reserves, other federal lands, and nonfederal lands. Also shown are boundaries of the inland zones designated by the Northwest Forest Plan.

Chapter 5 of the NWFP science synthesis reviews recent science on the ecology and status of the marbled murrelet, with an emphasis on the portion of the species' range that falls within the NWFP area. Below is a summary of the current state of knowledge.

Key Findings

Although murrelet nesting habitat characteristics may vary throughout the species' range, some general habitat attributes are characteristic throughout:

- Presence of nesting platforms.
- Adequate canopy cover over the nest.
- Larger patch size of mature forest.
- Commuting distance to the marine environment.

Because murrelets do not construct nests, they depend on the availability of nesting platforms that are typically tree limbs with moss or other thick substrate, such as piles of needles collected on limbs near a tree bole, sufficiently large for laying their single egg and raising a nestling.

Much has been learned about individual tree attributes that provide conditions suitable for nesting. These attributes include large branches, averaging 13 in (33 cm) in diameter in the Plan area; forked branches; deformities (e.g., broken tops); dwarf mistletoe infections; witch's broom; or growth of moss or other structures large enough to provide a platform for a nesting adult.

Nesting platforms are generally 33 ft (10 m) or higher from the ground. They are typically found in old-growth and mature forests but may be found in a variety of forest types, including younger forests containing remnant trees. Since 1996, research has confirmed that the presence of platforms is the most important characteristic of murrelet nesting habitat.

Tree diameter and height can be positively correlated with the size and abundance of platforms, but the relationship may change depending on tree species and forest types. Overall, nest trees in Washington, Oregon, and northern California have been greater than 19 in (48 cm) diameter at breast height and greater than 98 ft (30 m) tall. Northwestern forests and trees typically require 200 to 250 years to attain the attributes necessary to support murrelet nesting.

Marbled murrelets are reported to nest disproportionately on lower slopes and near streams, possibly because murrelets can better access these sites from at-sea flyways.

Population Trends

Murrelet populations remain at risk, but protections appear to have helped stabilize populations in some areas—

- Based on population monitoring done at sea, the total murrelet population for the NWFP area is roughly 20,000 birds. This includes those nesting on federal as well as nonfederal lands. Population estimates are highly variable from year to year and have fairly wide 95 percent confidence intervals, averaging about ±22 percent for estimates at the NWFP scale.
- Based on trend analyses summarized over the three states, murrelet populations may have been stable or nondeclining in Oregon and northern California since monitoring began in 2000, but have declined substantially in Washington from 2001 to 2015.
- Threats to population persistence include loss of nesting habitat, poor recruit-ment of young owing primarily to nest depredation by jays and crows, and changes in prey abundance and quality in the marine environment. These changes in prey could be in response to climate change or other human-caused disturbances in the marine environment.

Nesting Habitat

The NWFP remains relevant for marbled murrelet conservation—Protections under the NWFP have conserved much of the existing nesting habitat on federal lands, but losses continue on nonfederal lands (fig. 5-4).

- As of 2012, the majority (66 percent) of about 2.2 million ac (0.9 million ha) of suitable murrelet nesting habitat within the NWFP region occurs on federal lands, and more than 90 percent of this occurs within NWFP reserved lands.
- Losses of suitable nesting habitat on federal lands totaled about 2 percent during the first 20 years of the NWFP (1993–2012), compared to about 27 percent on nonfederal lands.
- Fire was the major cause of lost nesting habitat on federal lands, with some habitat losses resulting from timber harvest and insect damage or disease. Timber harvest caused most of the loss on nonfederal lands.
- Although some habitat losses can be expected (such as from fire and windthrow) even with existing NWFP protections, the NWFP strategy of large LSRs appears to have succeeded in protecting most habitat.
- Nesting habitat conditions for murrelets should improve over time as younger forest within reserves continues to mature and eventually develop into suitable nesting habitat (fig. 5-5).

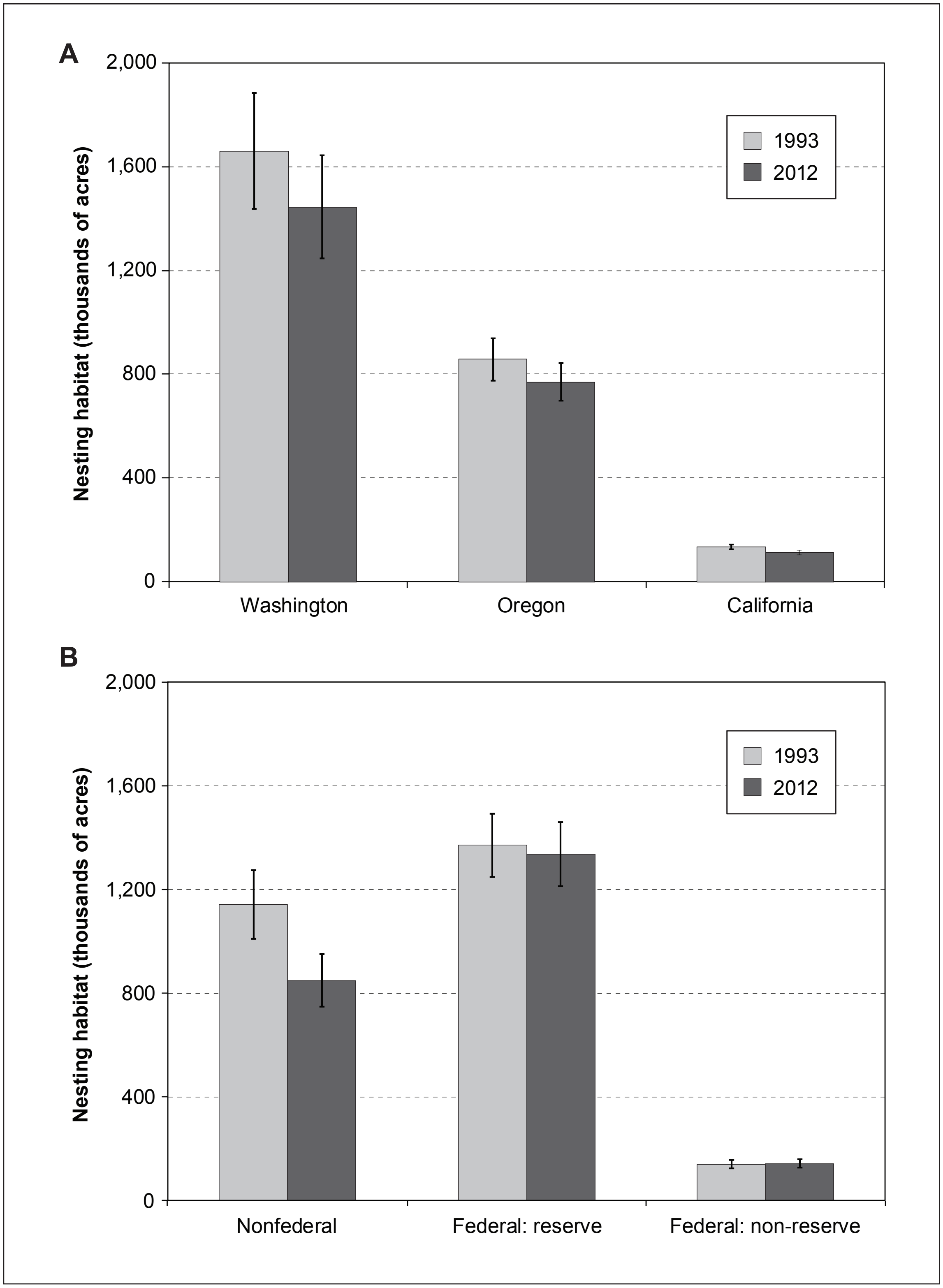

Figure 5-4—Estimated amounts of higher suitability nesting habitat of the marbled murrelet in 1993 and 2012, by (A) state, and (B) land allocation (Falxa et al. 2016). Error bars are 95 percent confidence intervals from 25 replicated model runs.

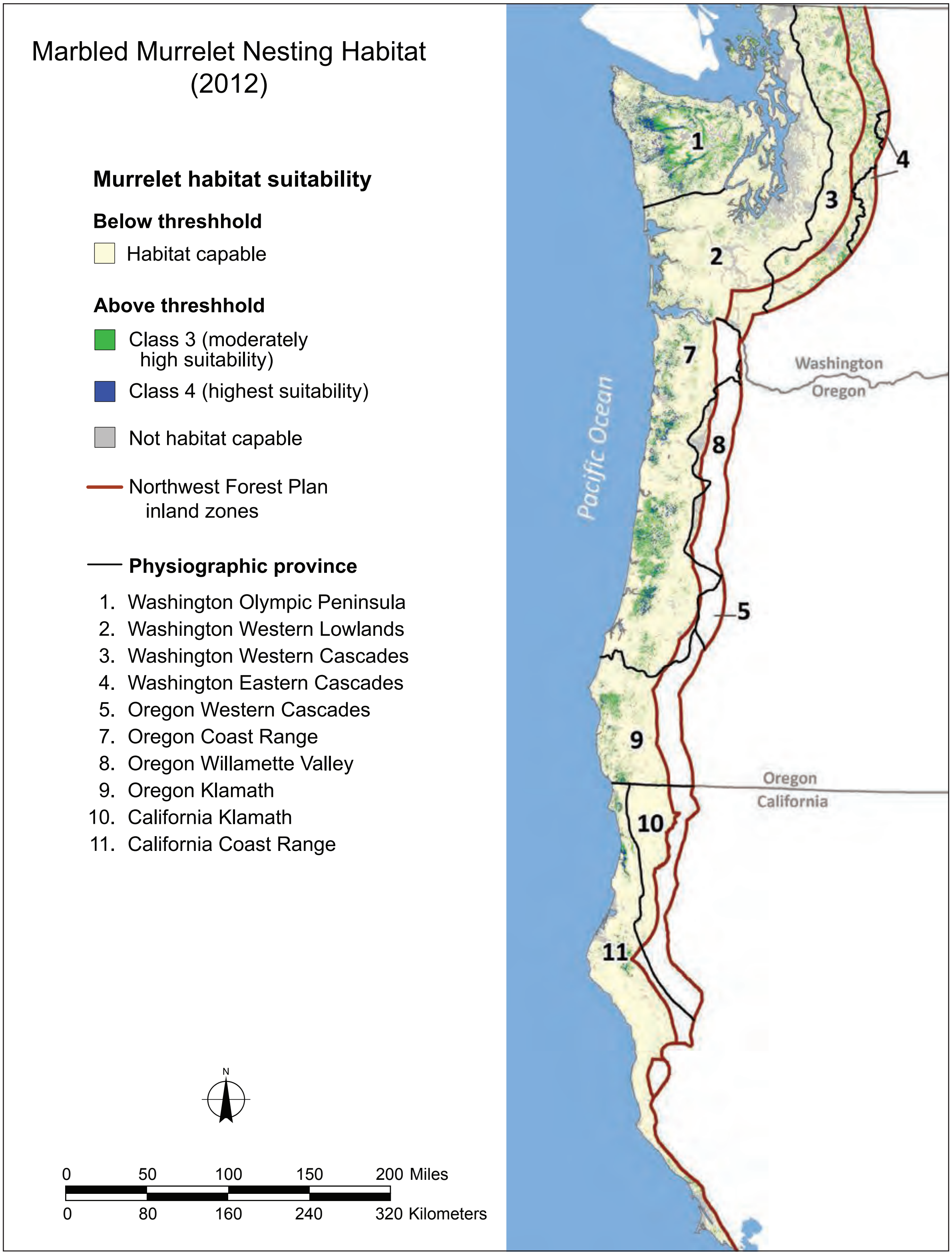

Figure 5-5—Map of suitability for marbled murrelet nesting habitat, 2012 (Falxa et al. 2016).

A review of the current science and best available information supports the validity of the NWFP's landscape-scale LSR system design for meeting the Plan's goal of stabilizing and increasing murrelet populations by maintaining and increasing murrelet habitat, while reducing its fragmentation. Taken as a whole, research to date suggests that apart from increasing the amount of nesting habitat and reducing its fragmentation, managing forest structure to reduce nest predation risk should be approached with consideration given to local factors that might affect predator densities.

Uncertainties Remain That Challenge Murrelet Conservation

Several key questions about murrelets and their needs remain. For example:

- What factors have caused murrelet numbers to decline in Washington since 2000, while appearing to stabilize (at least in the short term) in recent years to the south of Washington?
- What is the pattern and magnitude of murrelet movements (emigration, immigration, and seasonal) within the Plan area, and between the Plan area and areas to the north?
- How are murrelet population sizes influenced by the amount of nesting habitat versus variation and trends in ocean conditions that affect foraging habitat?

Our review of the current scientific literature (Raphael et al. 2018) points toward nesting habitat as the primary driver, but the relationships are correlational. Cause-effect relationships have not been established. Further work is needed to confirm if these correlations reflect true underlying causes.

- How fast is nesting habitat developing within reserves?
- Better models of forest development would allow projections of amounts and distribution of murrelet nesting habitat.

Other questions remain about murrelet prey in the marine environment.

- How do prey resources (quantity, quality, distribution) differ over space and time? And how do these affect murrelet numbers and distribution?

Climate change will affect murrelet foraging habitat (prey abundance and distribution in the marine environment) and nesting habitat (e.g., extent of fog zone and abundance of epiphytic plants that help create nesting platforms), but the magnitude and consequence of these effects is difficult to predict at this time. Future management and design of reserves will benefit from accounting for climate change, including increased risks to murrelet nesting habitat from fire and other natural disturbances.

Refined understanding of inland nesting range—

- A refined understanding of murrelets' inland nesting range will better meet management objectives and avoid problems with managing for murrelets in areas where none are really expected to exist. This will require additional survey work and a synthesis of existing observations.
- To guide management and increase its effectiveness in achieving nesting habitat expansion, modeling tools are needed to help forecast site-specific future nesting habitat development and structural characteristics of potential murrelet nesting habitat.

Management Considerations

Protecting and Increasing Nesting Habitat

- Maintaining and creating larger blocks of suitable nesting habitat area on federal lands will likely help stabilize and eventually lead to recovering murrelet populations.
- The current NWFP reserve system (including riparian buffers and other set-asides) appears well designed to accomplish this goal. Because it can take many decades for murrelet nesting habitat to develop, protection of existing habitat for the next several decades will continue to be key to minimizing habitat losses, both within and outside of reserves.
- Changes to land management, such as the Bureau of Land Management's revised resource management plans in western Oregon, create more uncertainty about the status of current and future murrelet nesting habitat owing to the possibility of increased timber harvests in nesting habitat. Additional monitoring will be needed to evaluate potential effects of these changes on the status and trends of murrelet populations and nesting habitat.
- Boundaries of reserves (including making them larger) may be reconsidered if revised boundaries might better conserve nesting habitat in the face of anticipated effects of climate change.
- Changes to the LSR system should be approached cautiously to avoid adversely affecting murrelets and the probability of achieving the NWFP goal for murrelets. Adverse effects could be triggered by actions that (1) reduce the amount of current or future suitable nesting habitat; (2) maintain or increase the degree of nest habitat fragmentation, or prevent future forest development that would reduce fragmentation within reserves; or (3) create better habitat for jays, crows, and other nest predators.

- Forest planning and management can positively affect murrelet status by managing human recreation activities that might promote murrelet nest predator populations (e.g., ravens, crows, and jays in campgrounds). Implementing education programs, limiting garbage, and controlling predators could have positive effects.

Federal Lands May Not Be Enough

- Maintaining a broad distribution of large nesting habitat blocks over the NWFP landscape will likely help to minimizing the risk to the population from nesting habitat loss to fire, wind, or other disturbance agents.
- Conservation of existing nesting habitat on federal lands may not be sufficient to conserve murrelet populations in the short term. Contributions from nonfederal lands could augment strategies on federal land to achieve objectives for the murrelet, and support the larger goal of murrelet conservation and recovery. This might be approached by collaborative programs to increase murrelet conservation on nonfederal lands, particularly those adjacent to NWFP lands, and in key areas (such as southwest Washington and northwest Oregon) where few federal reserves exist.

Active Management May Help Accelerate Development of Nesting Habitat

- Active management actions could include thinning in plantations to accelerate growth of potential nest trees and development of nesting platforms, but care will be needed to prevent simultaneously increasing numbers of nest predators attracted to more diverse understory conditions. Moreover, such management should also be careful not to increase the suitability of older forests to harbor barred owls (*Strix varia*), which may prey on murrelets and also reduce forest suitability for northern spotted owls.
- Restoration in plantations and younger natural forests can benefit murrelets by incorporating knowledge of stand shape, extent of higher contrast edges, and forest features that promote habitat for nest predators such as corvids. Proximity of nest and occupied habitat should be considered.
- Treatments that evaluate risk to existing suitable nesting habitat along exposed edges as a result of windthrow would also contribute to conservation of existing nesting habitat.

- Development and implementation of forest management practices that protect (short term) and develop (long term, i.e., over many decades) suitable murrelet nesting habitat on NWFP lands within the murrelet range would be beneficial in recovering murrelet populations.

Conclusions

The NWFP had a short-term objective for murrelets: conserve much of the best remaining nesting habitat. As implemented, the NWFP has been successful in meeting this objective. The NWFP also has a long-term objective: create a system of reserves containing desired sizes and distributions of large blocks for suitable nesting habitat that would eventually provide substantially more suitable nesting habitat for murrelets on federal lands than existed there in 1994. Evidence suggests that nesting habitat trends on federal lands are on course toward this objective, but many more decades will be needed to observe whether, as implemented, the Plan has been successful in achieving its goal of stabilizing and increasing murrelet populations by maintaining and increasing nesting habitat.

We have shown that the NWFP has been remarkably successful in conserving nesting habitat over its first 20 years of implementation, but much work remains. Murrelet numbers continue to decline in the northern portion of the NWFP area. Assuming no large fires, we believe that the current decline in amount of murrelet nesting habitat will reverse on federal lands, leading to a net increase in the amount of nesting habitat, and that murrelet populations should also increase in response. How many decades before this reversal in trend occurs is unknown, but at-sea monitoring suggests that the first step of possible population stabilization may be occurring in the southern Plan area. Lastly, climate change has emerged as an external force that may affect future murrelet populations, their nesting habitat, and, in particular, their food resources.

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Table Rock Wilderness, Oregon. Photo by USDI Bureau of Land Management, Oregon-Washington State Office.

Chapter 6: Other Species and Biodiversity in Older Forests

Bruce G. Marcot, Karen L. Pope, Keith Slauson, Hartwell H. Welsh, Clara A. Wheeler, Matthew J. Reilly, and William J. Zielinski[1]

Main Points

- The Northwest Forest Plan (NWFP, or Plan) established the Survey and Manage program to help assure persistence of rare and little-known species associated with late-successional and old-growth forests. The program produced guidelines and approaches on natural history and management considerations for many of these species.
- Scientific understanding has greatly expanded for some old-forest-associated species, but many such species—particularly fungi, lichens, bryophytes, soil and canopy invertebrates, and others—remain poorly known, as does the suite of ecological functions of organisms contributing to native biodiversity of the region.
- Studies on mammalian carnivores—fisher, Pacific marten, lynx, and wolverine—have reinforced guidelines for conserving large trees and down wood, but new threats of habitat fragmentation, predation, rodenticides, wildfire, and down wood removal have been identified.
- Adaptive-learning and management programs as initially specified under the NWFP were never manifest but still may be vital for providing needed information.
- A combination of coarse-filter (ecosystem) and fine-filter (species) approaches for restoring and maintaining resilience and integrity of forest conditions is necessary to help ensure conservation of species and biodiversity of forest ecosystems.

[1] **Bruce G. Marcot** is a research wildlife biologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 620 SW Main Street, Suite 502, Portland, OR 97205; **Karen L. Pope** is a research wildlife biologist, **Keith Slauson** is a research fellow, **Hartwell H. Welsh** is a research wildlife biologist emeritus, **Clara A. Wheeler** was an ecologist, and **William J. Zielinski** is a research ecologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521; **Matthew J. Reilly** is a postdoctoral researcher, Humboldt State University, Department of Biological Sciences, 1 Harpst Street, Arcata, CA 95521. Wheeler currently is a technical writer/editor, U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center, 5785 Highway 10 W, Missoula, MT 59808.

Introduction

Forests of the Pacific Northwest teem with life: much is hidden from human view within soil, under logs, or high in the tree canopy (fig. 6-1). This wealth of biodiversity ranges from lichens, fungi, and vascular plants to mollusks, insects, mammals, and birds; all contribute to the resilience, integrity, and function of the ecosystems they inhabit

The NWFP was developed as an ecosystem management plan to provide for the full suite of biodiversity at all taxonomic and functional levels in late-successional and old-growth forests, under an adaptive learning and management approach. The first decade of the NWFP, however, focused on the status of species, and no biodiversity monitoring program per se has been instituted under the NWFP (Marcot and Molina 2006). Since then, a broad assumption has been made that older forest biodiversity in its full capacity would be provided by two complementary approaches: (1) managing for "coarse filter" ecosystem elements such as the dispersion and distribution of late-successional forest reserves and aquatic and riparian corridors, and (2) managing for "fine filter" elements of habitat used by selected, individual species associated with late-successional and old-growth forest.

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Figure 6-1—The vertical structural diversity of mature and old-growth conifer forests of the Northwest Forest Plan region includes deeply furrowed tree bark, dense epiphyte cover by mosses and lichens, and multilayered and deep tree canopies. These characteristics contribute to the overall biodiversity of the region's forests. Location: Eagle Fern Park, Clackamas County, Oregon.

Much has been learned since the 2006 science synthesis about a wide array of organisms, biological processes, and biodiversity of late-successional and old-growth forests within and beyond the Plan area. This is due in large part to the NWFP's Survey and Manage program, which initially was devised to identify older-forest species requiring additional site survey, monitoring, and management activities to help ensure their conservation in the NWFP area. It subsequently produced guidelines and approaches on natural history and management considerations for hidden, rare, or little-known species.

In recent years, the Survey and Manage program has undergone legal challenges and administrative changes. At present, oversight of Survey and Manage standards and guidelines implementation, at least in part, is consigned to staff members within the Interagency Special Status and Sensitive Species Program (ISSSSP) (U.S. Forest Service Pacific Northwest Region and Bureau of Land Management [BLM] Oregon/Washington State Office; formed in 2005) and the Pacific Southwest Region Regional Wildlife Program Manager within the Ecosystem Conservation staff.

The ISSSSP partners with a variety of research and academic institutions to provide key information on rare species of conservation concern within its geographic venue. The current list of Survey and Manage species dates to December 2003 and includes 298 species: 189 fungi, 15 bryophytes, 40 lichens, 12 vascular plants, 36 snails and slugs (mollusks), 4 amphibians, 1 mammal (red tree vole), and 1 bird (great gray owl).

Of the many social changes since 1994, of particular note for its potential effect on biodiversity management and monitoring is the Forest Service's 2012 planning rule. The 2012 planning rule puts more weight on coarse-filter approaches and ecological integrity (based in part on natural range of variation) than did the previous 1982 planning rule that guided the NWFP. Land and resource management plans (forest plans) for national forests currently are in line for revision in accordance with the 2012 planning rule. On BLM land in the Plan area, resource management plans are in effect from records of decision signed in August 2016. These BLM plans are intended to protect northern spotted owls, listed fish species, and water resources, as well as provide for jobs, recreation, and timber harvest; older-forest species are addressed through the ISSSSP.

Chapter 6 of the NWFP science synthesis reviews what is known about the ecology and conservation of species and biodiversity associated with late-successional and old-growth forests. It also addresses a set of questions posed by resource managers, including how well the NWFP has provided for these species; and reviews results of research on effectiveness of site buffers for species conservation; effects of disturbance events, particularly wildfire and climate change; how agency programs have served to provide new information for managing species of older forests; and what key uncertainties remain. Here, we present highlights from that chapter.

Key Findings

The Northwest Forest Plan Is Generally Providing Habitat for Species Associated With Late-Successional and Old-Growth Forests

The conservation evaluations done through the Survey and Manage program, and more recently the ISSSSP, provide evidence that the NWFP is generally providing habitat for late-successional and old-growth-associated species either under the late-successional, aquatic, and riparian buffer reserve system (coarse-filter management), or additionally through species-specific inventories, monitoring, and site protection (fine-filter management).

Additional federal listing of late-successional and old-growth species as threatened or endangered, beyond northern spotted owls, marbled murrelets, and salmonids, has generally not proved necessary. Still, it is unknown how the legacy of past forest harvesting patterns coupled with stressors of climate change, and attendant effects of drought, wildfire, and other factors, may affect many species associated with older forests. For many of the rarer species in the NWFP area, little to no information is available on population size and trend, including their demographics across the managed forest matrix outside of reserves, although information is available on the general distribution or occurrence of some such species.

Fungi—
Fungi are an important part of forest ecosystems. Their occurrence is influenced, at least in part, by the type and intensity of disturbances, time since disturbance, and vegetation development, and by forest stand management and forest age class. Many fungi species are soil dwellers and mostly subterranean. Determining their presence can be difficult, but they can play major roles in nutrient uptake by trees and other plants and in aiding coarse-wood decomposition, contributing to soil organic matter, and maintaining overall forest health (fig. 6-2).

Lichens—
Lichens play important ecological roles such as in nutrient cycling in late-successional and old-growth forests of the Pacific Northwest. Many species of lichens are difficult to detect, inventory, monitor, and study because they require specialized expertise in the field and the laboratory, and may occur largely in forest canopies

Figure 6-2—Recreational collection of mushrooms on federal public lands within the area of the Northwest Forest Plan is a popular and increasing activity. However, no studies have been conducted on the effect of collection on rare fungi associated within late-successional and old-growth forests of the region. Location: Columbia River Gorge, Washington.

that are difficult to reach. To address such problems, the Survey and Manage program spurred the development of methods for statistically determining the occurrence and frequency of rare species of lichens.

Bryophytes—

Bryophytes—including hornworts, liverworts, and mosses—are a conspicuous component of many late-successional and old-growth forests of the Pacific Northwest, and many species have been part of the Survey and Manage program. Many late-successional and old-growth-associated bryophytes may be sensitive to disturbance and may require old-forest stands larger than 2.5 ac (1 ha) or with more than 15 percent retention of older green trees in dispersed retention harvests.

Pacific Northwest forests are the main source of commercially harvested moss in North America, with dozens of species likely affected by the practice. The main mosses collected are epiphytes that may require 15 to 25 years to recover. These mosses are most abundant in riparian and low-elevation forests and absent or much less abundant in young (<70 years old) Douglas-fir plantations. However, there is no regional program established to monitor the effects of moss harvest on species viability and conservation.

Vascular plants—

The response of understory vascular plants to management is known primarily from western hemlock–Douglas-fir forests and generally suggests that certain management activities can increase later seral species in previously managed stands (i.e., clearcuts). Precommercial thinning can increase the compositional similarity of shrubs and herbs between young- and old-growth stands and increase the abundance of late-seral herbs. Conversely, thinning in 60- to 80-year-old stands can increase diversity and the abundance of early-seral species but have little effect on late-seral species. Effects of fire exclusion on understory communities in late-successional and old-growth forests where fire was historically frequent is poorly understood.

Invertebrates—

The wide array of invertebrates in old forests highlights their many key ecological roles (fig. 6-3). Many soil invertebrates are fire sensitive and occur in high diversity in upper watersheds. Threats include invasive species.

Invertebrates differ in their sensitivity to disturbance and to forest canopy closure and tree density conditions. Some late-successional and old-growth-associated invertebrates, particularly dispersal-limited species such as terrestrial

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Figure 6-3—Centipedes (family Lithobiidae; order Lithobiomorpha) are one component of the wide array of soil invertebrates found in late-successional and old-growth forests of the Northwest Forest Plan region. Centipedes perform key ecological functional roles as predators of other invertebrates including spiders, worms, and other species. This is but one ecological role of soil invertebrates, that collectively contribute to the function, resilience, and diversity of forest ecosystems. Location: Columbia River Gorge, Oregon.

carabid beetles and flightless saproxylic weevils, can serve as indicators of biodiversity and climate change risk, and as indicators of response of species groups to stand thinning.

A fairly recent management concern is the reduction in populations of pollinators on federal lands. In the Pacific Northwest, native bee populations are declining because of parasites, pathogens, pesticides, and invasive species.

Amphibians and reptiles—

Recent studies have determined that the assumed dependence of terrestrial salamanders on late-successional and old-growth forests is more nuanced than previously thought (fig. 6-4). Substrate type and availability are important correlates of some species. Maintaining cool and humid refugia may be central in protecting populations in areas that may experience disturbances.

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Figure 6-4—An immature coastal giant salamander *(Dicamptodon tenebrosus*). Research has shown that this species occurs in greater abundance and occurrence in streams within uncut forests than in logged forests. Location: Tryon Creek State Park, Oregon.

Recent conservation assessments conducted on seven salamander species highlight the value of riparian buffers, down log retention, and protection of headwater streams. Providing linkage areas between adjacent watersheds and using various combinations of alternative management approaches (riparian buffers, thinning, down wood, leave islands, and uncut blocks) to retain forested areas along headwater ridgelines may facilitate upland dispersal and connectivity between subpopulations.

Still-water environments such as lakes, ponds, and wet meadows, and their adjacent riparian and terrestrial environments, also provide for species diversity. Modifications and disturbances to these environments (e.g., damming to increase water storage, ditching to increase drainage, siltation owing to timber harvest in the watershed, and overgrazing), combined with the spread of fungal diseases and invasive species such as American bullfrogs and brook trout have resulted in some population declines of native frogs (fig. 6-5).

The threat of novel diseases entering populations of amphibians of the Pacific Northwest appears increasingly pressing. The deadly amphibian disease, chytridiomycosis, emerged in the 1970s and has become a prominent threat to amphibian biodiversity worldwide. The fungus that causes chytridiomycosis is widespread in the region.

The effects of large disturbances such as wildfire and broad-scale timber harvest on populations have not been adequately studied for many of these amphibians associated with older forests, and monitoring programs are not in place to assess the status of species and effectiveness of the NWFP in protecting these species.

Climate change may influence the distribution of suitable environments, which can result in fragmenting populations and shifting or retracting species ranges, particularly of species closely associated with cool-water streams (e.g., tailed frog), dispersed pond habitats (e.g., chorus frog), and intermittent headwater streams (lungless salamanders). More precipitation during autumn and winter

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Figure 6-5—American bullfrog (*Lithobates catesbeianus*) in pond wetland. Bullfrogs are invasive in wetlands within the region of the Northwest Forest Plan and are voracious predators of native species of fish and amphibians. Location: Tualatin National Wildlife Refuge, Washington County, Oregon.

may lengthen the period of surface activity, but warmer and drier summers could result in fewer available surface and subsurface refugia that prevent desiccation. Forest management practices that retain canopy cover, and maintain or supplement surface refugia such as down wood and logs, may somewhat help to ameliorate the effects of climate change.

Birds—
Natural disturbance patterns, including fire, windthrow, and other forces, can leave remnant and legacy elements of older forests such as old-forest patches, large-diameter green trees and snags, and large-diameter down wood as key habitat elements for a variety of species (fig. 6-6). Subsequent regrowth of the vegetation through secondary succession then creates early-seral structures more complex than those resulting from final timber harvests such as clearcuts. The complexity of naturally regenerating vegetation following natural disturbances often can contain habitat for a wide variety of birds and other wildlife associated with early-successional environments. For information on northern spotted owls and marbled murrelets—both specifically tied to late-successional and old-growth forests in the NWFP area—see chapters 4 and 5.

Carnivores—
Regarding mammalian carnivores—fisher, Pacific marten, lynx, and wolverine—studies have reinforced habitat guidelines for conserving large trees and down wood. These carnivores have been documented in new locations over the past two decades, but current threats include habitat fragmentation, predation, rodenticides, wildfire, and down wood removal. The U.S. Fish and Wildlife Service (USFWS) had determined that the West Coast distinct population segment of fisher does not warrant federal listing status; however, that finding has been litigated and reopened. Regarding the Humboldt marten, the USFWS determined that there is insufficient data to warrant listing, although that decision was appealed, and USFWS must submit a new finding or proposed listing rule. The Canada lynx continues to be listed as threatened. The wolverine is currently proposed for federal listing as threatened, but formal listing has not yet occurred.


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Figure 6-6—An old-growth western redcedar snag riddled with feeding cavities created by pileated woodpeckers (*Dryocopus pileatus*) in the Bureau of Land Management's Medford District, Oregon.

Among state-level listings, the fisher is listed as endangered in Washington, is a state-critical species in Oregon, and is fully protected in California with petitions to uplist it to endangered status. The Humboldt marten can still be trapped in Oregon, but petitioners are seeking to have its trapping status removed. In California, the Humboldt marten is under review as a state candidate species. The wolverine is a candidate for threatened status in Washington, is listed as threatened in Oregon, and is fully protected as endangered in California.

Red tree vole—

Much work has taken place on the morphology, genetics, and taxonomy of red tree voles and related species since 2006. These voles are found only in old-growth forests and are prey for northern spotted owls; leading threats to its habitat are logging, fire, and fragmentation.

Bats—

At least 14 species of bats are found within the NWFP area. Some of these species are associated with late-successional forests, and the habitats are likely provided by NWFP reserve guidelines. Studies are incomplete, however, and few studies are available on the response of bats to fire.

A growing concern is the 2016 discovery of white-nose syndrome in a bat found 30 mi (48 km) east of Seattle, Washington. White-nose syndrome, caused by a fungus, has killed more than 6 million bats in the Eastern United States since 2006. Whether white-nose syndrome will spread geographically or among species in the Pacific Northwest, or to bat species using roost situations other than caves, such as large trees with sloughing bark and dense canopy foliage, is unknown.

Habitat Corridors Between Reserves Can Hedge Against Climate Change Impacts

Much has been learned over the past decade about a wide variety of species and their occurrence, distribution, and rarity. Still, many species groups remain poorly studied. What we have learned about their ecology reaffirms the importance of maintaining late-successional and old-growth forest reserves and conserving aquatic systems and riparian buffers in providing habitat for many such species. The importance of retaining old-forest components and substrates in the managed forest matrix to serve as connections among the reserves is increasingly clear. These connections can be provided by slowing harvests of late-successional and old-growth forests in the federal matrix lands, maintaining the current critical habitat designation for northern spotted owls to protect all remaining owl habitat, and retaining old-forest structures in early-seral vegetation within the forest matrix. The ways in which young stands in the forest matrix are managed will have a significant bearing on the future of old-forest ecosystems, and their species and biodiversity, throughout the NWFP area.

Uncertainties and Research Needs

Much scientific uncertainty remains over using surrogate species, including indicators, sentinels, flagships, umbrellas, keystones, and others, as effective means of ensuring conservation of all species associated with older forests in the NWFP area. Recent scientific publications have continued to suggest using management indicator species and umbrella species only with due caution and empirical evaluation. Some science findings suggest that using an ecological functional basis for species and biodiversity management, rather than using simpler proxies of indicator species, is more likely to succeed for meeting overall conservation objectives, particularly if complemented with application of ecological forestry methods.

Climate change is a major conservation concern in the Pacific Northwest. Much remains to be studied to better understand its direct and indirect effects on species, their habitats, and their ecological functions, and also to better understand its complex role in the suite of existing and new threats to species and biodiversity of older forests of the NWFP area. How this can influence any redesign of reserves under the NWFP would require further study.

There also remains much to learn about soil microorganisms and mesoarthropods, along with the suite of poorly known fungi that collectively play crucial roles in organic matter breakdown, nutrient cycling, and maintenance of forest health, and how their biodiversity affects overall ecosystem resilience, integrity, and functioning.

No analysis has been conducted on threats to older-forest species comparing threat levels perceived under the NWFP as initially envisioned, with the NWFP as currently implemented. Still, thanks to the ISSSSP, sufficient information likely exists on some species by which their management status could be effectively reevaluated. However, the program has not been charged with conducting species reviews in the spirit of an adaptive learning and management process as was conducted previously with Annual Species Review panels under the NWFP. It is likely that some species originally ranked as having low potential for persistence might be viewed as having higher potential, particularly if their older-forest habitats and specific habitat elements are better provided throughout the matrix over time. Other species tied to specific locations that are vulnerable to fire and disturbances might not fare as well, but no evaluation is currently available.

Management Considerations

Information Remains Limited on Population Demography and Viability

The degree to which remaining late-successional and old-growth forest is adequately providing for persistent and sustainable populations of rare and uncommon species is known only for those few species for which demographic and monitoring studies have been conducted, such as northern spotted owls and marbled murrelets, although ongoing studies of selected carnivores, such as marten, fisher, and wolverine, are producing some information on their population distribution and status.

Response to Fire Depends on Species

Species and ecosystems of the NWFP area occupy diverse forest types and experience diverse disturbance regimes. The research findings on effects of fire on rare and uncommon species associated with older forests are limited and mixed. For some species, such as the white-headed woodpecker, small patches of prescribed burning can be used to create or elevate the quality of their habitat. For other species, prescribed fire and associated fuels reduction activities can diminish key late-successional and old-growth habitat components such as large hollow trees, large snags, and large down logs, in turn reducing habitat for a wide variety of denning and cavity-using wildlife species, including fishers, Humboldt marten, and other mammalian carnivores.

Effects of high-severity, stand-replacing wildfire are perceived as largely adverse to species that use dense, multilayered older forests, although much of the literature has not clarified levels of wildfire intensity, extent, and location when speculating or concluding about wildfire effects. Research suggests that high-severity fire can reduce beneficial mycorrhizal and other desirable fungi, but for the most part the effects of wildfire on individual, rare, and uncommon late-successional and old-growth species are largely unstudied. Insofar as atypically severe wildfire can reduce canopy closure and fragment dense, contiguous-canopy stands, it adversely affects habitat for red tree voles.

Static Placement of Late-Successional Reserves May Not Meet All Needs of Species Associated With Older Forests

Habitats and population connections of other species of late-successional and old-growth forests are likely more vulnerable to the static placement of existing late-successional reserves than previously envisioned, as disturbance events and shifts in fire regimes may serve to reduce or isolate such forest locations. A dynamic approach addressing the long-term scheduling of forest management activities and additions of reserves to further connect existing reserves and supplement them in higher elevations could be useful to account for the influence of changing fire regimes, climate, and use of natural resources.

Riparian Buffers Appear to Protect Riparian Habitat

In general, riparian stream buffers, including unthinned riparian vegetation and adjacent upland forests, have been shown to have immense conservation value, particularly for amphibians. Buffers of sufficient width along streams and wetlands can serve as movement corridors and landscape linkages for aquatic frogs, salamanders, reptiles, and birds.

Benefits to Be Gained From Fully Implementing a Biodiversity Monitoring Program

Little effectiveness monitoring has been conducted on site buffers to confirm that they are indeed providing for all species persistence at those sites. More extensively, no overall biodiversity monitoring program as envisioned in the NWFP—one that focuses not only on species but also on biological processes and other dimensions of biological diversity—has yet been instituted.

Coarse-Filter, Fine-Filter, and Landscape-Scale Management

Environmental conditions that influence habitat and resource elements needed by the full suite of late-successional and old-growth forest species and biodiversity will undoubtedly shift under climate change and disturbance dynamics. Regardless of the filter approach used, the influence of shifting environments will likely need to be at least intermittently reevaluated.

Maintaining the biota and biodiversity of late-successional and old-growth forests may not be achievable with only old-forest reserves, and only on federal forest lands. The conservation of regional biodiversity may require coordinated efforts across ownerships.

Dead Wood Is Valued Habitat

About two-thirds of Survey and Manage species are associated in some way with partially dead trees, snags, and down wood. Opportunities may exist for enhancing wildlife habitat through dead wood management that develops connections among late-successional reserves and matrix lands, but in balance with consideration for wildfire and fuels management.

Conclusions

In general, the NWFP is providing specific older-forest reserves, locations, and habitats for many associated species. More is now known about some of these species, and surveys have revealed many new locations allowing some species to have been removed from survey lists. Many older-forest species, however, remain rare, vulnerable, or poorly understood.

Both coarse- and fine-filter approaches to conservation are needed. Using one alone will likely fail to provide for conservation of the full suite of species and biodiversity of older forests. Successfully combining system and species approaches depends on clearly articulating management objectives. It also requires further monitoring and research to determine the efficacy of management and to identify needed changes in management. At present, many aspects of biodiversity, particularly regarding biological and ecological functions, depend largely on untested assumptions of the coarse-filter approach.

Maintaining old-forest biodiversity is further challenged by the imbalance in seral stages, increased fire severity, and the effect of climate change on forest conditions and disturbances. Solutions may include restoring natural early-successional vegetation and providing a full range of environmental conditions in a sustainable balance under changing climate and disturbance regimes. Contributing to species and biodiversity conservation may include connecting old-forest reserves through matrix lands and across elevations, particularly for carnivore habitat.

Recent scientific literature has also focused on the role of young successional vegetation and the full ecological and geographic range of conditions and environments in the managed forest matrix. An approach where a species focus complements ecosystem-level research and management of ecological processes across all successional stages can effectively meet early visions of sustainable forestry that conserves late-successional and old-growth forests and their biodiversity.

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Molalla River, Oregon. Photo by Jeff Clark, USDI Bureau of Land Management, Oregon-Washington State Office.

Chapter 7: The Aquatic Conservation Strategy: Relevance to Management of Aquatic and Riparian Ecosystems

Gordon H. Reeves, Deanna H. Olson, Steven M. Wondzell, Peter A. Bisson, Sean Gordon, Stephanie A. Miller, Jonathan W. Long, and Michael J. Furniss[1]

Main Points

- The fundamental tenets and ecological framework of the Aquatic Conservation Strategy (ACS) are sound. Monitoring results indicate that aquatic and riparian ecosystems in the Northwest Forest Plan area are improving as expected, albeit slowly.
- When the ACS was developed in the early 1990s, it was assumed that aquatic and riparian ecosystems were relatively stable through time. Recent science suggests, however, that these systems may be very dynamic in space and time and that aquatic organisms are adapted to this dynamism.
- Options exist for managing riparian reserves based on a dynamic ecological context rather than with a uniform prescription.
- New tools based on new understanding of aquatic ecosystems are available to reassess the key watershed network and to ensure its effectiveness.

Introduction

The goal of the ACS of the Northwest Forest Plan (NWFP, or Plan) was to maintain and restore aquatic and riparian ecosystems on federal lands within the range of the northern spotted owl (*Strix occidentalis caurina*). The scientific basis of the ACS is still sound and is supported by new science produced since the Plan's inception by the Forest Ecosystem and Management Assessment Team (FEMAT) in 1993.

[1] **Gordon H. Reeves** is a research fish ecologist, **Deanna H. Olson** is a research aquatic ecologist, and **Steven M. Wondzell** is a research geologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331; **Peter A. Bisson** is a research fish ecologist (retired), U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3625 93rd Avenue SW, Olympia, WA 98512; **Sean Gordon** is a research assistant professor, Institute for Sustainable Solutions, Portland State University, 1600 SW Fourth Avenue, Portland, OR 97204; **Stephanie A. Miller** is the Riparian Program lead, U.S. Department of the Interior, Bureau of Land Management, 20 M Street SE, Washington, DC 20001; **Jonathan W. Long** is a research ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1731 Research Park, Davis, CA 95618; **Michael J. Furniss** is a hydrologist (retired), Pacific Northwest Research Station, 1700 Bayview Drive, Arcata, CA 95521-6013.

The ACS is a coarse-filter approach designed to protect and restore ecological processes that create and maintain favorable habitat conditions for native anadromous salmonids. This approach assumes that if conditions are favorable for these organisms, then conditions should be suitable for other aquatic and riparian-associated organisms. We have learned much about the relationships among riparian vegetation and stream habitats in space and time. With this knowledge, we have refined and modified some of the hypotheses that were used to develop the ACS.

Chapter 7 of the NWFP science synthesis addresses eight guiding questions from land managers about the scientific basis of the ACS, based on research conducted over the past 23 years, and on management of aquatic and riparian ecosystems. We summarize key findings and management considerations from that chapter below.

Key Findings

The Scientific Foundation of the Aquatic Conservation Strategy Is Sound

The ACS's focus on ecological process is still supported by science, but since 1993, additional factors have come to the fore. More aquatic species have been considered for listing as threatened and endangered; some require a consideration of threats on a case-by-case basis and more focused attention than is provided by the regional scale of the ACS. Aquatic invasive species have emerged as an elevated concern because of their effects on native species, and these effects may be magnified by climate change. Human disturbances from timber-harvest activities, including road building and maintenance, remain key concerns for aquatic-riparian ecosystems. New concerns about the extent and severity of wildfire and climate change have emerged as research and monitoring priorities.

Other components of the ACS merit further research. It may be possible to conduct watershed analyses more efficiently, for example. Watershed analysis is the designated tool for developing baseline conditions against which to assess improvement in biological and physical processes, relative to the natural range of variability. The process could consider the appropriate spatial scale for analysis. If focusing on a smaller watershed of interest, for example, assessing its context within the larger basin may provide useful information. The larger scale context is particularly relevant for effective landscape-scale planning, such as is required by the 2012 Forest Service planning rule.

The ACS identified key watersheds that were intended to serve as refugia, particularly for at-risk fish populations, and that had the greatest potential for restoration. Evidence is emerging that the key watersheds do not have the capacity to support and provide favorable habitat for fish listed under the Endangered Species Act (ESA) to the extent that was originally assumed. The assumption that habitat in old-growth forests creates the most favorable habitat for native salmonids also is being questioned. During development of the NWFP, the potential effectiveness of the key watershed network was not formally evaluated, nor has such an evaluation since been attempted. Now, new tools based on a new understanding of aquatic ecosystems are available to reassess the key watershed network and ensure its effectiveness.

Aquatic and Riparian Ecosystems Are Dynamic in Space and Time

When the ACS was developed in the early 1990s, aquatic and riparian ecosystems were assumed to be relatively stable through time, which supported a more uniform management approach. Recent science suggests, however, that these systems may be very dynamic in space and time—similar to terrestrial systems—and that aquatic organisms are adapted to this dynamism. Implementing this dynamic ecosystem perspective in management actions will be challenging. Managing for a complex set of changing conditions across landscapes, for example, is not consistent with many current regulatory approaches that require that aquatic and riparian ecosystems meet a given standard.

Unaltered aquatic and riparian ecosystems likely exhibit a wide range of conditions locally and across the Plan area over time, depending on the magnitude and frequency of the associated disturbance regime. For example, headwater streams tend to be dominated by conifers, although headwater streams that have experienced landslides may be dominated by alder trees. The biological processing of decaying leaves, wood, and other allochthonous material that fall into the stream are the primary energy source for downstream fish-bearing streams.

The riparian zone in the middle of the stream network comprises a mix of conifers and deciduous hardwoods. Here, hardwoods are particularly important sources of allochthonous materials that fuel system productivity. Hardwoods are now scarce in many areas because past management harvested trees to stream edges. As a result, conifer-dominated plantations comprise an estimated 30 to 50 percent of riparian reserves. The resulting effects on productivity in aquatic systems could be further explored.

Fire exclusion and climate change are likely altering aquatic and riparian ecosystems in ways that are not fully recognized or appreciated at this time.

Understanding the Effects of "No Action"

A relatively small percentage of riparian reserves has been actively managed for restoration. For example, riparian restoration could include selective thinning to encourage development of large trees that would in turn supply large wood to stream channels. Concerns by regulatory agencies about the potential negative consequences of streamside management activities, as well as lack of public trust, have led to passive restoration approaches to riparian forests in streamside buffers. A passive approach assumes that taking no action is synonymous with having no adverse effect. But is this true? Our analysis revealed a need to understand and assess the effects of "no-action" management options and tradeoffs of managing for one factor (e.g., water temperature or wood recruitment, fig. 7-1) on other ecological processes or attributes.

Benefits of Restoration Around Streams Without Fish

Non-fish-bearing streams can comprise more than 70 percent of the stream network. They are important sources of nutrients, energy, wood, sediments, and cool water for fish-bearing streams further downstream. They also provide habitat for headwater-associated species. The ACS appears to be protecting their integrity. Directing restoration efforts at these upper portions of stream networks will be particularly important for addressing potential effects of climate change.

Lee Benda

Figure 7-1—The largest down trees in streams generally come from areas closest to the channel.

Considering Buffer Widths in a Dynamic Ecological Context

The riparian reserve network was intended to identify the outer boundary of the aquatic/riparian ecosystem, and the scientific foundation for the reserves is valid. Some studies suggest, however, that the second site-potential tree-height on fish-bearing streams may not be required to maintain microclimatic conditions within the first tree-height. It may be possible to move away from fixed-width riparian buffers toward riparian management that considers the variability in ecological context within the stream network and specifies management depending on ecological importance and risk.

New analytical tools and processes are available that could be used to improve decisionmaking regarding riparian-reserve widths and make them more cost effective. However, the ability of the Forest Service and other federal land managers to conduct such analyses may be limited by declining workforce levels and technical competency.

Assessing Effects of Roads, Segment vs. Network

Roads and their effect will continue to be a major issue in the NWFP area. Continued research on road effects and development of analysis tools (e.g., the Geomorphic Roads Analysis and Inventory Package [GRAIP]) are important. There is a pressing need to understand the consequences of focusing on the environmental effects of small road segments rather than entire road networks. The same is true for understanding the effects of culverts on ecological processes and the movement of aquatic biota. Roads and ditches accelerate runoff, increasing the delivery of water and fine sediment to streams. Climate change is expected to increase winter precipitation in some parts of the Plan area and to intensify winter storms. Reducing the hydrological and biological effects of forest roads in the Plan area would improve watershed resilience to the adverse effects of climate change on aquatic ecosystems.

Understanding how to balance fire management, recreation, and other access needs against the potential negative aspects of roads will require a concerted cooperative effort among resource managers; physical, biological, and social scientists; and other stakeholders.

Salmon Will Benefit From Cross-Ownership Habitat Protection and Restoration

Although populations of many fish in the region protected under the ESA have increased since development of the NWFP, federal lands do not have as much capacity as was originally assumed to contribute to their recovery. Federal habitat protection and restoration efforts alone are likely to be insufficient to reach the comprehensive goals of the NWFP relative to recovery of listed fish, particularly many evolutionarily significant units of Pacific salmon. However, federal lands remain very important to the conservation and recovery of ESA-listed fish because they are sources of high-quality water for many streams on nonfederal lands. It will be important for the Forest Service to work closely with adjoining landowners and other interested parties to develop more comprehensive efforts across species ranges.

Water Contributions From Federal Lands Will Be Increasingly Important

The capacity of federal lands in the NWFP area to contribute water for a suite of purposes varies widely among forests, ranging from less than 20 percent of the total flow in some basins to more than 40 percent in others. The importance of these contributions is likely only to increase in the future as growing human populations demand more water. Forested watersheds close to urban centers will likely have the greatest increases in water demand for increasing human needs, including drinking water, recreation, and other uses.

Climate Change Will Necessitate New Approaches and Strategies

Climate change effects will likely differ widely within and among watersheds and geographic areas (fig. 7-2), necessitating new approaches to identify this variation and help craft strategies and programs for mitigation and adaptation. The ACS has the potential to meet these challenges, but it will take a focused effort to do so. It will require shifting the focus of management and restoration from increasing the populations of aquatic and riparian organisms to increasing their life-history diversity.

The primary effects of climate change in the Plan area will be warmer water temperatures, lower streamflows in summer, and higher streamflows in winter. The intensity of these changes will vary depending on location, local topographic features, and hydrophysiographic processes. Changes in ocean conditions (water temperature, acidification, and timing of upwelling), which are beyond the influence of federal land management agencies, may exert a stronger influence on populations of anadromous fish than changes in freshwater ecosystems.

Some organisms will adapt and thrive while others are likely to decline (fig. 7-3). Critical future research will include an examination of how species may be affected by climate change, and how these changes may cascade through life-history stages. It will also be essential to understand community-level changes. Also important is an understanding of the effects on water quantity and quality,

Figure 7-2— (A) Current and (B) projected (2040) summer water temperatures (°C) in the study basins in the Treaty of Olympia area, Washington (from Reeves et al. 2016a). Increased water temperatures are not expected to occur in a uniform pattern among adjacent watersheds.

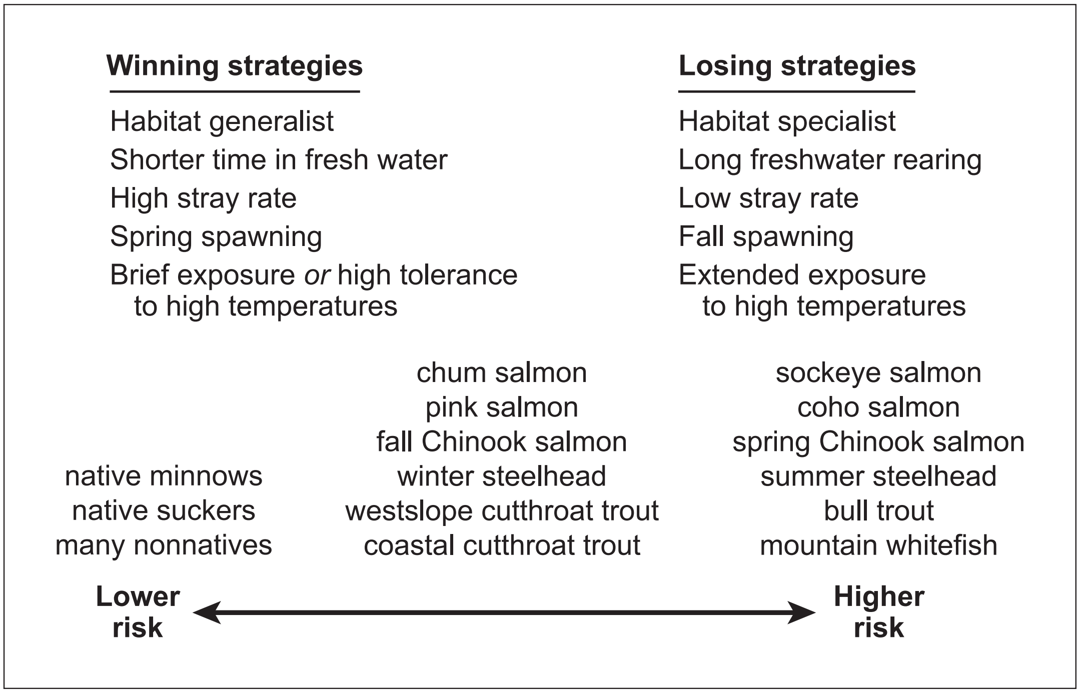

Figure 7-3—Lifecycle and habitat-preference strategies of freshwater fish that may determine if they are "winners" or "losers" in future climates of the Northwest Forest Plan area. Beneath the lists of winning and losing strategies is a grouping of fish along a gradient of low to high risk from climate effects. These groupings, somewhat subjective, are based on current knowledge of each species' life histories, spawning and rearing locations in watersheds, and residence time in fresh water.

particularly across spatial scales within watersheds, among watersheds, and across seasons and years.

Aquatic invasive species have emerged as a threat that can potentially transform ecosystems through their interactions with native species and alteration of ecological processes. The potential impacts of aquatic invasive species will likely increase as a result of climate change, human activities, and other factors.

Having the capacity to do the needed analysis will also be critical for the involved agencies to successfully meet this challenge in a timely and effective manner, particularly in an era when budgets and personnel for federal land management agencies are declining. Thus, development of cost-effective and scientifically sound analysis procedures performed with close collaboration between research and management is key to addressing this need.

Monitoring

Results from the Aquatic and Riparian Effectiveness Monitoring Program (AREMP) suggest that conditions in aquatic and riparian ecosystems in the NWFP area are improving, albeit slowly, as was originally expected owing to the extensive amount of past degradation and lengthy time needed for recovery. Four independent parameters—water temperature, aquatic macroinvertebrates, and physical conditions in upslope–riparian areas and in-channel—all showed improvements to varying degrees. Improvements likely can be attributed to a reduction in the extent of roads in key watersheds and an increase in the number of large trees in riparian reserves. Wildfire has affected these parameters in some places in the NWFP area. The ecological significance of this interaction is unclear and merits examination.

Explore new monitoring approaches—

Monitoring the effectiveness of the ACS continues to be important, although some meaningful uncertainties remain regarding the aquatic-riparian monitoring approaches. When using multiple independent measures of watershed attributes, it is difficult to assess the overall condition of a watershed, leading to uncertainty about results. The lack of concordance about the direction of change among the monitored parameters in a given watershed also makes it difficult to assess the overall condition and trend of aquatic ecosystems. Some scientific literature suggests that if one parameter of interest in a sampling unit (reach or watershed) is outside the threshold value for suitable conditions, the unit as a whole is outside the suitable range. Exploration of a variety of available approaches is merited and timely.

It is unclear if AREMP's current approach is capable of capturing the effects of the ACS on a wide range of ecological processes and species of aquatic and riparian ecosystems. Uncertainty exists about what some of the parameters in the 20-year assessment by the AREMP represent ecologically. It is important to clearly describe the ecological context of aquatic-riparian monitoring to determine the extent to which AREMP should focus on environmental parameters that measure habitat for native salmonids or on other aquatic and riparian-dependent organisms.

Development of aquatic-riparian monitoring programs requires clearly articulating which biota and associated functional characteristics of habitats and ecosystems are being considered, tying these to our understanding of patterns of change over space and time, and developing criteria to assess how they are likely to be altered as a result of the actions of interest.

Research is also needed to better understand how the productivity of aquatic biota, which include organisms other than salmonids, relates to different upland vegetation and in-channel successional stages or restoration treatments. This type of information can feed into watershed assessments to better ensure that the effects of the ACS are captured more comprehensively relative to the biota that are a key ecosystem service of aquatic-riparian ecosystems.

The 20-year assessment employed the use of reference conditions to assess the effectiveness of the ACS, which was different from previous assessments. When developing reference conditions, for comparison with current conditions, including the entire natural range of conditions that an ecosystem can experience (natural range of variability) is key. This is critical for evaluating the implications of change. Reference conditions that are too narrowly or too broadly defined can skew the interpretation of monitoring results and introduce uncertainty to the process. We suggest exploring further the use of reference conditions and their potential utility for diverse analytical approaches. For example, can they be used in concert with state-transition models to consider and evaluate novel potential conditions in the future? As our understanding of these ecological systems advances and new analytical tools are developed, we anticipate refining the objectives and approaches of aquatic-riparian monitoring programs, including AREMP. Advances in watershed-condition assessment procedures will be important to ensure the validity and reduce the uncertainty of future results and their implications for management.

We lack information about the amount, pattern, and type of restoration activities that have occurred in upland and riparian forests. Implementation monitoring has not been adequate to enable a sufficient understanding of the consequences of restoration actions (or lack of actions), especially relative to how they may have altered aquatic ecosystems in space and time.

Management Considerations

Utilizing New Watershed Assessment Tools

New watershed assessment tools could be used to address watershed-specific integrated effects of climate change, fire, landslides, roads, wood recruitment, and timber harvest.

Working With a Dynamic-Ecosystem Perspective

- Human impacts have altered riparian ecosystems extensively. As a result, riparian and aquatic ecosystems do not resemble historical conditions.
- Addressing a dynamic-ecosystem perspective in management actions will be challenging, but may be necessary to meet the historic range of variability requirement in the 2012 planning rule.

Active Restoration May Be Needed

- Active restoration may be needed to restore altered conditions to those that are suitable for native aquatic and riparian organisms. Passive restoration, which assumes that "no activity equals no effect," may not be able to attain desired conditions or could take hundreds of years. Additionally, the assumption that no action can restore aquatic-riparian ecosystems is questionable, and "no activity" may actually compromise or eliminate key ecological processes such as development of the largest trees.

Riparian Restoration

- Restoration of riparian areas on small, headwater streams may be critical in future efforts to restore key ecological processes such as delivery of wood, sediments, and nutrients to fish-bearing streams.

Considering Tradeoffs Associated With Riparian Management Along Fish-Bearing Streams

- There is evidence that the original justification for the second site-potential tree-height, included to address concerns about microclimate, is not supported by the scientific literature. However, there are other functions (e.g., movement corridors for terrestrial organisms) that would be compromised if the boundary were to be adjusted to one tree-height.
- Options exist for managing the riparian reserves based on a dynamic ecological context rather than with a uniform prescription.

Working With Adjoining Landowners

Greater cooperation and coordination with nonfederal landowners will be needed for the recovery of listed fish populations. Incentive programs will likely be important in building partnerships for fish-habitat management across land ownerships.

Working With the ACS to Address Climate Change

The effects of climate change on aquatic ecosystems in the NWFP area will likely differ widely within and among watersheds and geographic areas.

The ACS has the potential to meet these challenges, but it will take a focused effort to do so, including:

- Conducting local-scale analyses and addressing projected variable conditions within individual watersheds.
- Considering "all lands" in adaptive-management approaches to retain and restore ACS components.

- Shifting the focus of management and restoration from increasing population sizes to retaining the life-history diversity of aquatic and riparian organisms, and considering species adaptive capacity in management actions.
- Recognizing that there will be "winners" and "losers." Because of their inherent capacity to adapt, some organisms will thrive while others are likely to decline.

Reviewing AREMP Procedures to Ensure that the Program Yields Relevant Results

The Aquatic and Riparian Effectiveness Monitoring Program is key to understanding and evaluating the effectiveness of the ACS. However, there are questions related to priority ecological metrics and ecosystem services about the approach being employed for watershed-condition assessment. In this light, a thorough and objective review and assessment of AREMP procedures, and other monitoring, is critical to ensure the effectiveness of the program and the relevance of results.

Conclusions

The Aquatic Conservation Strategy was based on our understanding of the behavior and management of aquatic and riparian ecosystems in 1993. It was fully expected that the implementation and interpretation of the ACS would change over time as new knowledge and understanding about aquatic and riparian ecosystems developed. This assessment finds that the basis for the ACS remains sound and is supported by science produced since 1993. However, options exist for implementing parts of the ACS differently to achieve its goals, particularly around the riparian-reserves where more active management may help to address potential concerns about the effects of the lack of disturbance (primarily wildfire) and climate change.

There is a strong foundation for meeting the requirement of the 2012 planning rule that calls for managing for ecological integrity by including ecological disturbances and processes. However, this may require use of new analytical tools by a capable and sufficient workforce, increased cooperation with nonfederal landowners, and communication to the public, regulators, policymakers, and other interested groups about the basis for necessary actions and changes in future management.

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Log deck resulting from a mechanical forest thinning operation in a Washington Douglas-fir forest. Photo by Robert Keefe.

Chapter 8: Socioeconomic Well-Being and Forest Management in Northwest Forest Plan-Area Communities

Susan Charnley, Jeffrey D. Kline, Eric M. White, Jesse Abrams, Rebecca J. McLain, Cassandra Moseley, and Heidi Huber-Stearns[1]

Main Points

- Federal timber harvests in the Northwest Forest Plan (NWFP, or Plan) area declined steeply following the listing of the northern spotted owl under the Endangered Species Act (ESA) and adoption of the Plan. This cutback in federal timber was one of many variables causing declines in the region's wood products industry, however.
- The NWFP affected communities in different ways, according to their degree of economic dependence on the wood products industry, the role of federal timber in supporting that industry, and the extent to which local residents were employed by the Forest Service.
- In general, socioeconomic impacts of the NWFP were greater at the community than county scale, in communities closer to federal forests, in nonmetropolitan communities, and during the first decade following adoption of the Plan.
- The social and economic bases of many traditionally forest-dependent communities have changed since the NWFP was implemented. Better understanding of the economic development trajectories taken by different communities will help identify forest management activities that best contribute to community well-being. Providing a diverse set of benefits from federal forests may help communities diversify economically.
- In addition to timber harvesting and processing, community benefits from federal forests stem from recreation on federal land, forest restoration activities, harvesting of nontimber forest products, and other ecosystem services.
- Methods for quantifying the value of these different benefits and evaluating how they are affected by federal actions are in various stages of development and application.

[1] **Susan Charnley** is a research social scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 620 SW Main Street, Suite 502, Portland, OR 97205; **Jeffrey D. Kline** is a research forester, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331; **Eric M. White** is a research social scientist, Pacific Northwest Research Station, 3625 93rd Avenue SW, Olympia, WA 98512; **Rebecca J. McLain** is an assistant research professor, Institute for Sustainable Solutions, Portland State University, 1600 SW Fourth Avenue, Suite 110, Portland, OR 97201; **Cassandra Moseley** is a research professor and director of the Ecosystem Workforce Program, **Heidi Huber-Stearns** is an assistant research professor and associate director and **Jesse Abrams** is a research associate of the Ecosystem Workforce Program, Institute for a Sustainable Environment, University of Oregon, 130 Hendricks Hall, Eugene, OR 97403.

Introduction

The NWFP sought to balance the conservation and restoration of late-successional and old-growth forest ecosystems with sustainable production of forest products from federal forest management to create social and economic benefits for rural communities (fig. 8-1). Securing social and economic benefits for communities and the public has been a goal of the Forest Service and Bureau of Land Management (BLM) since the founding of these agencies. Legislation passed during the first half of the 20th century emphasized providing a continuous flow of timber from federal forests to promote economic stability in the forestry industry and forest communities. Legislation since then has increased emphasis on environmental goals and planning requirements, while reaffirming the agencies' traditional social and economic goals. With adoption of the NWFP in 1994, the goal of providing social and economic benefits to communities has continued alongside an increased focus on environmental protection and restoration. A shift, however, has been to view community benefits from federal forest management as derived not solely from traditional timber harvesting and milling, but also from a broad spectrum of other management activities, including ecosystem management, forest and watershed restoration, outdoor recreation, and nontimber forest products (NTFPs).

The socioeconomic well-being of rural forest communities in the NWFP area (72 counties in western Washington, western Oregon, and northwestern California) has been the focus of NWFP socioeconomic monitoring since the Plan was adopted.

Susan Charnley

Figure 8-1—Coos Bay, Oregon, historically supported a diversity of logging and milling operations.

In chapter 8 of the NWFP science synthesis, we examine the literature pertaining to the impact of the NWFP on rural communities in the Plan area; how social and economic conditions in rural communities have changed over the past two decades; how goods, services, and opportunities from federal forests contribute to community socioeconomic well-being; how rural communities contribute to federal forest management; and what the implications of changes in land use and land ownership over the past two decades are for federal forest management. Here, we summarize our key findings and related management considerations.

Key Findings

Impact of the Northwest Forest Plan on Rural Communities

The primary concern relating to socioeconomic well-being and federal forest management in NWFP-area communities historically has been the impacts that reduced timber harvesting from federal lands has had on wood products workers, businesses, and timber-dependent communities. The listing of the northern spotted owl (*Strix occidentalis caurina*) as threatened under the ESA in 1990 led to a steep decline in timber harvests, and federal timber harvests from the Plan area since then have not met expected levels (fig. 8-2). Private forests currently contribute the vast majority of logs processed by mills in the NWFP area, with federal timber accounting for about 10 percent of the regional timber supply from all land ownerships in 2012 (fig. 8-3). Consistent with national trends, over the long term and under varying levels of federal timber supply, the number of operating mills and employees in the wood products sector has declined in Washington, Oregon, and California since 1980. By 2012, the timber sector accounted for 3 percent of jobs in nonmetropolitan counties in the Plan area. Overall declines in milling capacity also occurred in Pacific Coast States during this period, although aggregate milling capacity in Oregon has stayed relatively constant and has increased slightly in Washington. However, changes in the forest products industry in the Plan area were not solely a result of declines in timber harvesting on federal forest lands. The most significant factors influencing the industry have been:

- Market conditions (e.g., demands for lumber and paper products)
- Technological advances in wood processing
- Foreign and domestic competition
- Cost of labor and manufacturing equipment
- Currency exchange rates
- Timber availability.

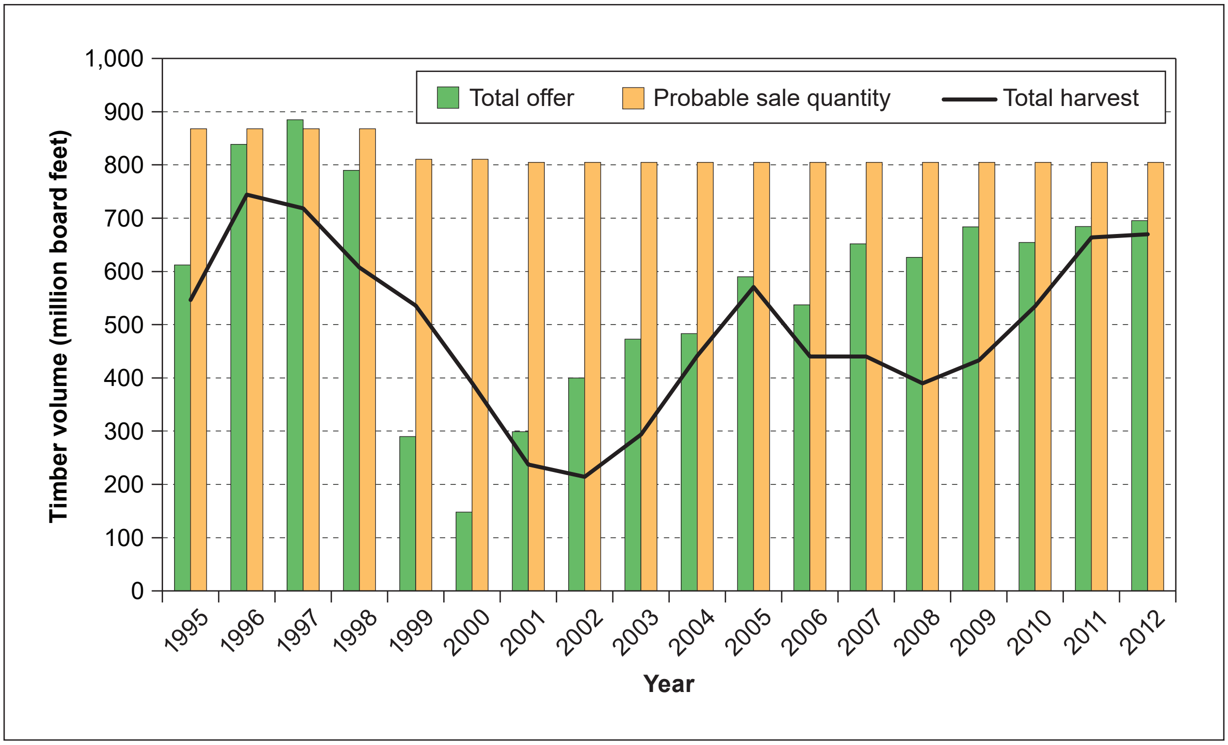

Figure 8-2—Timber offered for sale and harvested from federal forests in the Northwest Forest Plan area in relation to the probable sale quantity (PSQ), 1995–2012 (adapted from Grinspoon et al. 2016). PSQ is an estimate of average annual timber sale levels likely to be achieved over a decade from the matrix lands and adaptive management areas identified by the Plan.

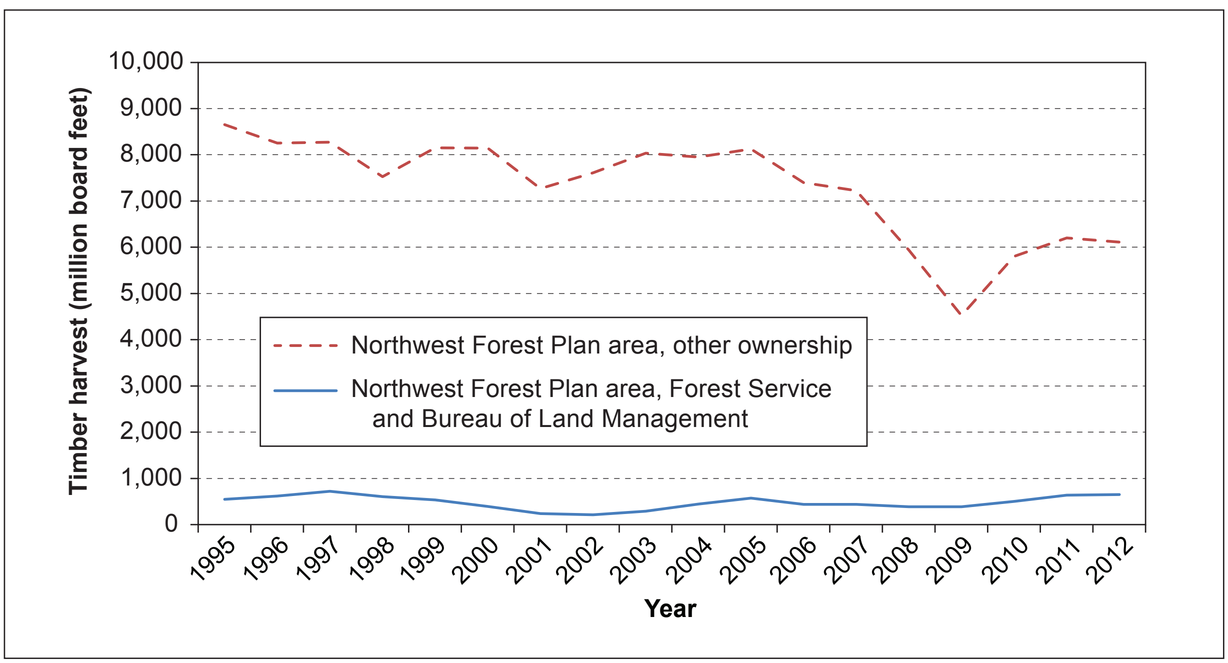

Figure 8-3—Since the 1990s, the majority of timber harvested in the Northwest Forest Plan area has come from nonfederal lands (Grinspoon et al. 2016).

Any future declines in harvest volumes from federal forests would further reduce the contribution of federal timber supply to the traditional forest and wood products sectors of local economies within the NWFP area. If that happened, the forest and wood products sectors would become even more reliant on timber from private and state-owned forests.

Following adoption of the NWFP, the limited social acceptability of clearcutting and of harvesting large-diameter and old-growth trees has largely confined federal harvests west of the Cascade Range to existing densely stocked "plantations" of younger, smaller trees within areas known as matrix lands, which under the NWFP were to be managed for multiple uses, including timber harvest. Timber harvests on federal forests could be increased by using "ecological forestry" to create early-seral vegetation that has been reduced by fire exclusion (chapter 3).

Over the past two decades, the spotted owl listing and the NWFP have affected communities primarily through:

- Cutbacks in federal timber harvesting.
- Loss of federal agency jobs.
- Reductions in federal contract spending.
- Setting aside of reserve lands that exclude intensive timber production.

Most studies have evaluated these impacts by using secondary indicator data pertaining to population change and economic variables such as employment, income, poverty levels, and property values, rather than primary data (data gathered at the community scale directly from community residents). Research examining the nature and extent of these impacts on communities has produced different findings and can be generalized as follows:

- Population growth and decline have both been attributed to the NWFP, as have increases and decreases in socioeconomic well-being and increases and decreases in economic indicators. Some studies found no NWFP impact on population and economic indicators.
- NWFP impacts on communities differed at the community and county scales and depended on local social, cultural, economic, and environmental contexts.
- Impacts (both positive and negative) were greater during the first decade of the NWFP than during the second decade.
- Impacts (both positive and negative) were greater in communities closer to national forests, or to reserved lands set aside by the NWFP, and in communities that had experienced a mill closure (not necessarily as a result of the Plan).

- Impacts were greater at the community scale than at the county and regional scales, and were greater in nonmetropolitan counties than in metropolitan counties.

These differences in findings may be attributed to the unit of analysis used to assess impacts (i.e., region, county, community); the time period considered (first vs. second decade of the Plan); and the different datasets and indicators used to assess impacts.

Not all communities were affected in the same way, or to the same extent—Case-study research was undertaken in 17 NWFP-area communities using a mix of quantitative indicators and qualitative accounts from community residents and agency personnel following the first decade of the Plan. This body of work provides additional insight to the indicator-based studies of NWFP impacts summarized above. Researchers found that not all communities were affected in the same way, or to the same extent. The effects of the NWFP depended on the:

- Relative strength of the wood products industry as an economic sector around 1990.
- Extent to which federal timber supported that sector.
- Degree to which local residents depended on federal jobs (as agency employees or contractors).

Communities were heavily affected if they participated heavily in the wood products industry in the late 1980s and early 1990s, if loggers worked mainly on federal forest lands, or if local mills obtained most of their wood from federal forests (fig. 8-4). Communities with a large number of Forest Service or BLM

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Figure 8-4—Happy Camp, California, is an example of a forest community heavily affected by the Northwest Forest Plan owing to the predominance of federal land surrounding it, high dependence on local employment in the wood products industry during the 1970s and 1980s, presence of mills that obtained most of their wood from federal forests and subsequently closed, and a Forest Service district ranger office that lost employees from the timber program in particular.

employees were also heavily affected. In communities where tribal or private forest lands were the main source of supply for the industry, the NWFP had a minor impact.

Although timber workers and agency employees experienced impacts, at the community level, the effects of the NWFP also depended on economic activity in other sectors. In places where other industries were also in decline (e.g., the fishing industry in coastal communities), the NWFP added to these impacts. In places with more diversified local economies, its impacts were somewhat mitigated, although jobs in other sectors did not necessarily provide opportunities for those who experienced NWFP-related job loss. In communities where the timber industry had declined prior to the late 1980s, or was never prominent—as in some agriculturally oriented communities—the NWFP had little impact.

Social and Economic Change in Plan-Area Communities

Social science research from the NWFP area has examined how communities have changed in the two decades since the NWFP was implemented. It forms part of a broader literature on rural restructuring in the American West that followed the decline in natural resource extraction as a prominent economic activity. Over the past two or three decades, many rural communities in the NWFP area have undergone demographic and economic changes following declines in commodity production. Although the population of the NWFP area has been increasing at a faster rate than for the United States as a whole, the majority of population growth has occurred in metropolitan areas, while population trends in nonmetropolitan communities have been variable.

One change in NWFP-area communities has been associated with "amenity" fueled growth. Many communities that are fairly accessible and situated near desired natural amenities, such as mountains, water bodies, and other landscape features associated especially with outdoor recreation and lifestyles, have experienced population growth owing to in-migration by people who are seeking an improved quality of life or are fleeing cities, telecommuting, becoming creative entrepreneurs, or living off of retirement or investment incomes. Such "amenity migration" is a factor driving local community development in some locations. Alternatively, some communities have sought to maintain traditional modes of economic activity; they have continued to rely on forestry production, albeit at lower levels, while seeking to attract other forms of commodity production as well as service-oriented enterprises to bolster their local economy. Some of these new businesses may be perceived as less desirable than more traditional timber-related jobs but they nevertheless provide jobs, at least in the short term. Others may be illegal (e.g., marijuana cultivation on federal lands), or may seek to use natural resources in new and diverse ways through investments in sustainable agriculture and natural resource production and management. Many communities pursue a range of strategies, and their diverse development pathways increase their resilience to future socioeconomic uncertainty.

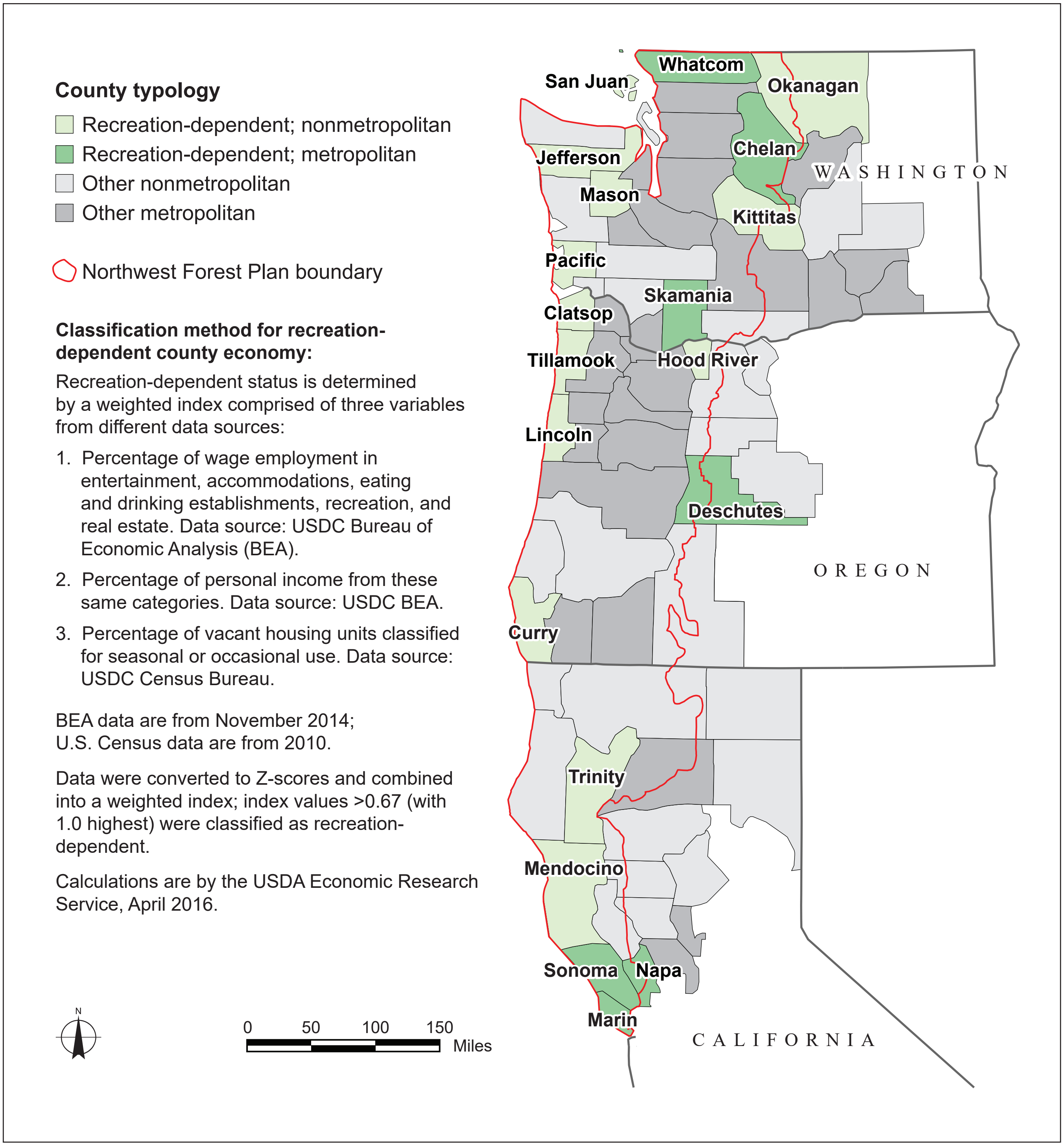
Some communities have found it difficult to recover from declines in commodity production, however, and have experienced population and employment declines. Nevertheless, these communities have latent potential for development associated with the availability of labor, land, natural resources, or infrastructure that may become valuable in the future. Gaps in the published literature prevent us from quantifying the number of communities in the NWFP area that have followed different trajectories of change. These gaps also limit our ability to characterize the geographic distribution of different community types. However, other researchers have developed typologies that classify counties according to variables that help to characterize socioeconomic conditions there (e.g., fig. 8-5).

Many Goods, Services, and Opportunities From Federal Forests Contribute to Community Socioeconomic Well-Being

Federal forest management in the NWFP area contributes to socioeconomic well-being in rural communities in many ways that go beyond providing timber and associated jobs in the wood products industries. Examples include jobs in forest restoration and firefighting, NTFP gathering opportunities, economic activity associated with recreation on federal forests, and the production of other ecosystem services.

Restoration contracts could be a significant source of forest-based jobs—Restoration of federal forest lands benefits forest communities through associated economic activity that is generated from restoration work (e.g., stream rehabilitation, fish passage improvement, road decommissioning, riparian planting, forest fuel reduction treatments, and thinning projects designed to introduce structural heterogeneity to second-growth stands). These activities entail employment in planning, implementation, oversight, monitoring, or other duties, and some produce byproducts that can be used for bioenergy, with associated economic impacts. Restoration contracting, therefore, represents a potentially significant source of forest-based jobs in rural communities.

The ability of Pacific Northwest communities to compete for and obtain contracts for restoration work on nearby federal forests, and to retain local dollars, is an important factor contributing to their adaptive capacity. Understanding where contractors are located sheds light on where and how contracting businesses create local community benefit. In some regions, the restoration contracting industry has transitioned to lower-skill, labor-intensive jobs (e.g., thinning trees and clearing



Mark D. Adams

Figure 8-5—Recreation-dependent counties in the Northwest Forest Plan area. Source: U.S. Department of Agriculture, Economic Research Service 2015 county typology data.

brush); Forest Service contracting practices for such jobs tend to favor mobile businesses that employ a high proportion of temporary and migrant laborers. The Pacific Northwest also has a high concentration of both hand crew and equipment-based fire suppression contracting businesses, many of which also engage in forest restoration contracting. As both Forest Service and BLM budgets and workforces decline, and are constricted further by a larger proportion of the budget going to wildfire suppression, agencies are contracting out an increasing amount of their land management work, including forest restoration and some wildfire suppression. This suggests a continued (yet unpredictable) demand for forest-based restoration and fire contracting activities across the NWFP area. Although in some places the type of forest-related contracting has changed, many nongovernmental organizations and private businesses still depend on jobs in forest restoration for economic and social benefits and continue to build their business around meeting federal agency needs for forest management activities.

Harvesting of nontimber forest products yields economic and social benefits—Federal forests in the NWFP region are also important sources of commercial and noncommercial NTFPs, such as moss, mushrooms, cones, grasses, and firewood (table 8-1). These products provide important safety nets for rural and urban households. Additionally, activities surrounding their harvest, processing, and use often help build social relationships and cultural identities among harvesters and strengthen human-nature connections. The retail value of NTFPs in the United States is estimated to be at least $1.4 billion, with much of that coming from the NWFP region. Studies that have measured NTFP employment in the Pacific Northwest have estimated that roughly 10,000 individuals work as harvesters, buyers, or processors in the floral greens/bough sector, and an equivalent number of people earn income in the wild mushroom sector. State recreation surveys for Oregon and Washington suggest that the rate of participation in NTFP gathering and collecting (excluding hunting and fishing) exceeds that of many other outdoor activities. The 10- and 20-year NWFP socioeconomic monitoring reports indicate that the Plan likely reduced physical access to NTFPs through road closures, and restricted legal access to NTFPs owing to harvesting prohibitions in some late-successional and riparian reserves and restrictions on the harvest of special status plants. However, the most important impact of the NWFP on NTFP resources is likely the landscape-level changes in forest structure and composition brought about by the Plan's management provisions. These changes may bode well for NTFPs such as matsutake and moss that do well in late-successional forests, but will lead to reduced supplies of NTFPs found in early-seral forests, such as salal and boughs.

Table 8-1—Commonly-harvested commercial nontimber forest product species in the Northwest Forest Plan area

Species	Scientific name
Floral greens:	
Salal	*Gaultheria shallon*
Evergreen huckleberry	*Vaccinium ovatum*
Beargrass	*Xerophyllum tenax*
Tall Oregon grape	*Berberis aquifolium*
Western redcedar	*Thuja plicata*
Noble fir boughs	*Abies procera*
Deer fern	*Blechnum spicant*
Western swordfern	*Polystichum munitum*
Mushrooms:	
Morel	*Morchella* spp.
Chanterelle	*Cantharellus cibarius*
Matsutake	*Tricholoma magnivelare*
Bolete	*Boletus* spp.

Sources: (1) Blatner, K.A.; Alexander, S. 1998. Recent price trends for non-timber forest products in the Pacific Northwest. Forest Products Journal. 48(10): 28–34; (2) Lynch, K.A.; McLain, R. 2003. Access, labor, and wild floral greens management in western Washington's forests. Gen. Tech. Rep. PNW-GTR-585. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 61 p.; (3) Schlosser, W.E.; Blatner, K.A. 1995. The wild edible mushroom industry of Washington, Oregon, and Idaho. Journal of Forestry. 93: 31–36; and (4) Weigand, J. 2002. Overview of cultural traditions, economic trends, and key species in nontimber forest products of the Pacific Northwest. In: Jones, E.T.; McLain, R.J.; Weigand, J., eds. Nontimber forest products in the United States. Lawrence, KS: University of Kansas Press: 57–64.

Recreation in Plan-area national forests generates about $612.6 million annually—

Recreation visitor spending is a significant driver of economic activity in many forest communities within the NWFP area. Recreation on federal forests supports economic activity in local forest communities because visitors spend money while on recreation trips, and federal agencies spend money maintaining recreation resources (translating into jobs). Recreation visitors to Plan-area national forests spend about $612.6 million in the communities around those forests each year. That spending supports employees and proprietors of businesses that sell goods and services to recreationists, and generates additional economic activity through the multiplier effect. In general, the amount of economic activity around federal forests from recreation visitor spending depends on (1) the amount of recreation use, (2) the types of trips (i.e., day or overnight, local or nonlocal) taken by recreationists, and (3) the size of the local economy. The activity of recreationists can influence some patterns in spending, but is less important than trip type. All else being equal, those visitors taking overnight trips spend five to eight times more in communities near federal forests than do those on day trips.

Ecosystem services benefit communities near and far from federal forests— In addition to providing the socioeconomic benefits identified above, federal forests also provide other important ecosystem services to local communities and more distant urban populations. These include fresh water, food and fiber, wildlife habitat, and outdoor recreation opportunities, among others. Federal agencies are beginning to develop methods and protocols for evaluating ecosystem services and how they are influenced by various federal actions. Within the NWFP area, efforts largely have focused on identifying and quantifying key ecosystem services produced from the region's national forests. Although these efforts have made significant progress in raising awareness and concern for these important forest benefits, formal methods for routinely including ecosystem services values into national forest management largely are still in development by the Forest Service and other organizations.

Local Workforces and Business Infrastructure Contribute to Federal Forest Management

Just as federal forest management can contribute to community well-being, communities can contribute to federal forest management. A skilled workforce and strong business infrastructure are important ways that economically healthy communities contribute to ecologically healthy forests and help federal agencies accomplish their management goals. Wood processing infrastructure in communities near federal forests has declined throughout the NWFP area since the 1980s. Not only has this decline adversely affect some Plan-area communities, lack of local infrastructure for processing timber and small-diameter wood make timber sales and removal of small-diameter material that constitutes hazardous fuels less economical, creating a financial barrier to forest restoration.

Agency budgets, the number of agency employees, and the number of field offices have dropped substantially since the NWFP was adopted, particularly for the Forest Service and especially in the Pacific Northwest Region. These declines have reduced agency capacity to manage federal lands in the NWFP area, including capacity to undertake forest restoration work. One way in which the Forest Service has dealt with declines in budget and personnel is by outsourcing work to contractors, partners, or volunteers (fig. 8-6). Community-based organizations, local business partners, environmental and recreation organizations, and other groups have also helped raise money and provided labor to accomplish forest management on federal lands, filling critical gaps. But communities must have an interest in such activities, as well as the capacity to do so, and these are linked to their assets and overall community health and well-being.

Susan Charnley

Figure 8-6—A partnership between the Six Rivers National Forest and the California Conservation Corps helps make it possible to accomplish trail work on the national forest.

Implications of Land Use and Ownership Changes for Forest Management

In addition to its significant area of federal and other public lands, the NWFP area includes a notable private land base, most of which is forested (figs. 8-7A and 8-7B). Nonfederal lands totaled more than 11 million ac (4.45 million ha) in 2009 in western Oregon, or about 57 percent of all land in the region. In western Washington, nonfederal lands totaled more than 10 million ac (4.05 million ha) in 2006, or about 65 percent of all land in that region. In NWFP-area counties in California, nonfederal lands comprise 48 percent of all forest land.

Private forest lands, including both industry- and nonindustry-owned, often augment federal and other public lands in providing ecosystem services, despite having forest structural attributes that may differ from those that characterize forests on federal and other public lands. The uneven distribution of ecosystems, ownerships, and management activities across the NWFP area is one reason it may be difficult to meet diverse biodiversity objectives on federal lands alone. The area of public land in forest cover is expected to remain constant or increase in

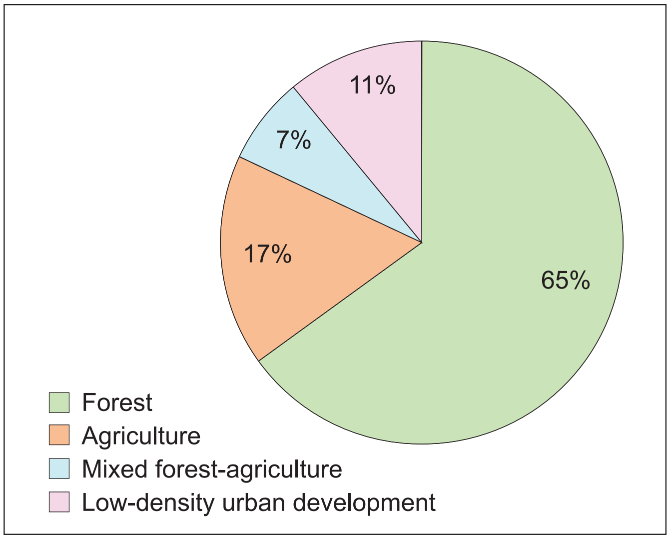


Figure 8-7A—Land use of nonfederal lands in western Oregon (11 million ac [4.45 million ha]) (Lettman 2011).

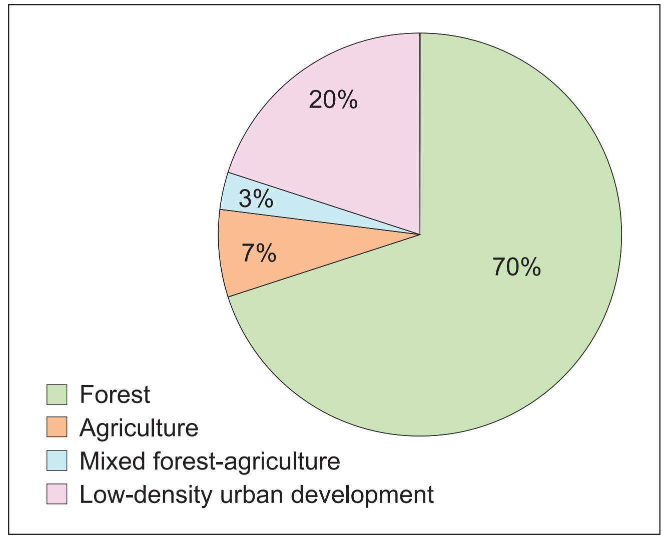


Figure 8-7B—Land use of nonfederal lands in western Washington (>10 million ac [4.05 million ha]) (Gray et al. 2013).

the foreseeable future. But private forest lands are subject to conversion to nonforest land uses, including agriculture (less likely) and residential, commercial, and industrial development associated with population growth (more likely). Forest conversion for development both fragments and reduces the total area of forest land, with negative ecological consequences. To date, conversion of private forest land to developed uses in the NWFP area has occurred more on nonindustrial than on industrial private forest lands. Although timberland investment management organizations and real estate investment trusts have been involved in several large acquisitions of previous industrial forest land in both Oregon and Washington, what this means for future management of such holdings, as well as longer-term forest land ownership trends within the NWFP area, remains uncertain. Federal and other public lands also can attract development to adjacent private lands, potentially leading to increased road densities, more human-caused wildfire ignitions, and greater demands for recreation, among other changes affecting federal lands.

Population growth in the region and corresponding changes in land use and ownership, particularly those that involve conversions of forest land to low-density and urban development, are likely to remain a significant factor affecting the NWFP area. Loss of forest land to development, associated fragmentation of the remaining forest land base, and accompanying changes in how remaining private forest lands are managed suggest that policymakers and managers cannot assume that forest land surrounding federal lands will be the same in coming decades and available to contribute to NWFP objectives.

Management Considerations

Federal Timber Harvests Can Help Maintain Local Wood Processing Infrastructure and Local Workforce, but Are Subject to Market and Industry Conditions

Meeting the NWFP goal of producing a predictable and sustainable supply of timber—one that contributes to community socioeconomic well-being—is a continuing management challenge. Efforts to pursue management strategies, such as increased use of alternative silvicultural methods or expanded restoration treatments, could increase the timber volume produced from federal forests. The influence that any increase in harvest volume from federal forests might have on the wood products industry and private forest land in the region is uncertain, and would be heavily affected by market and industry conditions largely outside of local and federal government control.

Increased federal timber supply may be especially important in locations where it provides the means to maintain local wood processing infrastructure and a forestry workforce, where federal agencies are the primary owner of local timberlands, or where the local forest products industry is attempting to expand into new wood products markets or produce niche products.

Timber Supply From all Ownerships Is Important for Maintaining Industry Infrastructure

With federal timber harvests declining in recent decades, forest managers and policymakers might want to consider the capacity of private forest lands to continue supplying a sustainable volume of timber to existing processing mills within the NWFP area into the future. Production from private forest lands is important because it supports the business infrastructure needed for timber sales and restoration treatments on federal lands.

Structuring Work Contracts so Local Businesses Can Bid Competitively May Benefit Community and Forest Health

Finding ways to create forest restoration jobs for local residents will help build skills, capacity, and infrastructure needed to support management activities on federal forests, including fire suppression response, while promoting both healthy forests and healthy communities. Opportunities for local communities to see expanded economic activity from federal forest management are strongly conditioned by existing wood products processing capacity within communities, the structure of work contracts, and other factors.

To promote more beneficial linkages between rural communities and nearby public lands, agencies could consider structuring contracts in ways that make them more accessible to businesses in local communities. For example, they could consider the effect of restoration contract size and scope relative to local contracting capacity, and provide restoration contracts in a variety of sizes to support business diversity. Community capacity to participate in the restoration economy is also a function of the consistency and predictability of contracts over time. Using a variety of tools (e.g., stewardship contracts, developing markets for biomass) may help build a predictable, sustainable program of restoration work that can justify investments in contracting and processing capacity.

Planning to Attract Long-Term Investment in Processing and Workforce Capacity

Planning by communities and national forest units over large spatial scales and long timeframes could help create the consistency of work needed to attract investments in processing and contracting capacity. Doing so provides a more predictable employment base in local communities and the business capacity required to accomplish forest restoration.

Encourage Development of Local Contracting Capacity for Fire Suppression

Given the erratic nature and small windows of demand for wildfire suppression contracting, local contracting capacity for fire suppression may be concentrated in particular regions where there is other work for businesses to do when they are not fighting fires. Related to this, the mobile and national nature of fire suppression means that local businesses trained in fire suppression will often be dispatched to fires outside their local community, where they spend money on lodging, food, fuel, and other supplies, and where fire camp support services are located. Thus, it may be difficult for many communities to capture fire suppression-related dollars locally.

When fire resource needs and dispatch procedures allow for it, linking local fire suppression response capacity to less mobile resources (e.g., local fire districts, other fire suppression resources not signed up for national or regional deployment) might improve both local response and economic capture.

Building Agreement Regarding Biomass Harvesting and Processing Can Set the Stage for Further Economic Benefits Related to Restoration Work

The harvesting and processing of biomass materials may also help deliver economic benefits from restoration work, but biomass production has often been controversial and economically challenging in the NWFP area. Working closely with community members and other key stakeholders to build agreement on biomass harvesting and processing projects is important for improving opportunities for positive outcomes.

Informal Aspects of the NTFP Sector Support Community and Household Well-Being

A key to supporting a robust and resilient NTFP sector in the NWFP region is to recognize that many of the informal aspects of that sector (i.e., outside the formal market context) provide sufficient flexibility for some individuals and households to survive unforeseen crises and improve their quality of life. Informal NTFP activities also function to link people to each other, and strengthen human-nature connections.

When developing forest management policies and regulatory frameworks, agencies may wish to consider how they will affect the informal economic activities associated with NTFPs and weigh carefully how the ecological benefits of large-scale area closures for commercial NTFP harvesting and increased formalization stack up against the costs of decreased community and household well-being.

Overnight Trips by Visitors Are Moneymakers

The key factor explaining how much money recreation visitors spend in local communities during their recreation trips is whether they stay overnight away from home (either in a public campground or private business accommodations). Communities seeking to generate the greatest amount of visitor spending locally would do well to focus on efforts that:

- Increase the likelihood visitors will spend the night in their community.
- Support businesses that supply the types of services, goods, and experiences that recreation visitors' desire.

Tailoring Communications About Wildfire Management to Specific Community Types

Wildfire management has become an important management concern for communities located near federal forests. Communities sharing similar characteristics are likely to encounter similar challenges and opportunities in adapting to wildfire risk. Thus, agencies and others seeking to assist communities in the wildland-urban interface in becoming more resilient to wildfire could develop communication and outreach strategies tailored to each different community type.

Conclusions

Rural communities are not all alike, forest management policies and practices affect different communities differently, and the social and economic bases of many traditionally forest-dependent communities have changed in the years since adoption of the NWFP. Better understanding and consideration of the economic development trajectories of different communities will help identify forest management activities that best contribute to their well-being. Providing a diverse set of benefits from federal forests may support communities in their efforts to diversify economically, and help build community resilience to future change.

Local relationships are important. Building constructive relationships with place-based nongovernmental organizations and other intermediaries that are working to help communities become more resilient to external stressors can contribute to community resilience, for example, by helping communities capture the economic benefits from forest management activities. The stressors affecting communities include changes in federal forest management policy, markets for forest products, development, wildland fire, and climate change. These same organizations may also be able to contribute resources and capacity to help address unmet needs on National Forest System lands, including (but not limited to) maintaining trails and other recreational infrastructure, filling gaps in planning capacity, building local business capacity to undertake forest restoration, and leading collaborative efforts.

Healthy forests and healthy communities are linked; thus it is in the interest of federal forest management agencies to contribute to community socioeconomic well-being, and it is in the interest of local communities to contribute to the capacity of agency managers to accomplish forest management work.

Future research that could help fill some of the remaining knowledge gaps include:

1. Studies to identify products for which wood products manufacturers in the NWFP area may have a competitive advantage given the realities of global markets for commodity wood products such as dimension lumber and structural panels.

2. Research to better understand the full suite of costs and benefits associated with biomass energy development under different market and public policy scenarios, and to understand where and under what conditions biomass harvesting may help complement other forest management activities.
3. Community-level studies that provide a richer understanding of how socioeconomic well-being in the Plan area has changed over time and its links to federal forest management.
4. Examining how connections between the Forest Service, BLM, and local communities can be strengthened through the use of innovative contracting tools, partnerships arrangements, agreements, and new institutional arrangements in which community-based organizations help fill gaps in federal capacity to conduct forest management and restoration.
5. Basic research about the social, economic, and ecological aspects of NTFP harvesting (fig. 8-8).
6. Research on how federal forest resource conditions and management influence recreation use and recreation behavior of local residents and visitors.
7. Analysis of land use change, its policy drivers, and its potential effects on whether NWFP goals can be met in the future.
8. Characterizing how federal forest management under the NWFP influences various ecosystem services, and simulating how alternative landscape-level management regimes over time influence potential futures and tradeoffs in the production of ecosystem services.

Rebecca McLain

Figure 8-8—Much remains to be learned about the harvesting of even the most important nontimber forest products in the Northwest Forest Plan area, such as wild mushrooms and firewood.

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Participants map their favorite destinations in the Mount Baker–Snoqualmie National Forest, Washington, during a human ecological mapping workshop. Photo by Lee Cerveny.

Chapter 9: Understanding Our Changing Public Values, Resource Uses, and Engagement Processes and Practices

Lee K. Cerveny, Emily Jane Davis, Rebecca McLain, Clare M. Ryan, Debra R. Whitall, and Eric M. White[1]

Main Points

- The social dimension of natural resource management in the Northwest Forest Plan (NWFP, or Plan) area is dynamic and inherently complex. Systematic monitoring of public values, attitudes, and beliefs is critical for understanding what is important to those who live in the NWFP area or have a stake in its future.
- Change in social systems, such as population dynamics or market shifts, can affect the natural environment. Likewise, fire, poor forest health, and other ecological changes can affect social systems. By considering the Plan area as an integrated social-ecological system, major shifts in the system can be identified and addressed.
- People and communities form meaningful attachments to places based on their history of use, cultural ties, family traditions, symbolic importance, and lived experiences. Outdoor recreation and stewardship activities are an important way that people form ties to natural places. These connections with place often shape their attitudes and beliefs about how natural resources are managed, which can be captured through place-based planning and public engagement processes.
- Collaborative groups involving the Forest Service and citizen stakeholders have proliferated in the past two decades. Collaboration can build trust and strengthen relationships among stakeholders and agencies, but research is still underway to determine if collaborative groups effectively achieve social and ecological goals.

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[1] **Lee K. Cerveny** is a research social scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 400 N 34th Street, Suite 201, Seattle, WA 98103; **Emily Jane Davis** is an assistant professor and extension specialist, Oregon State University, College of Forestry, 321 Richardson Hall, Corvallis, OR 97331; **Rebecca McLain** is an assistant research professor, Institute for Sustainable Solutions, Portland State University, 1600 SW Fourth Avenue, Suite 110, Portland, OR 97201; **Clare M. Ryan** is a professor, University of Washington, School of Environmental and Forest Sciences, Box 352100, Seattle, WA 98195; **Debra R. Whitall** is assistant director of resource, planning and monitoring, U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, 1222 SW Third Avenue, Portland, OR 97204; **Eric M. White** is a research social scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3625 93rd Avenue SW, Olympia, WA 98512.

Introduction

The social context of the NWFP area has changed since the Plan was adopted in 1994. Public values, attitudes, and beliefs about forests and the management of forest resources shift over time. Changing demographics related to urbanization, migration, or population growth can lead to shifts in environmental values, beliefs, and place connections. Moreover, public uses of and recreational preferences in national forests and other federal lands evolve with changes in consumer trends, economic factors, new technologies, or climate conditions.

Also changing are the ways that citizens engage in natural resource management and share their views with land management agencies. Many people now seek direct involvement in decisionmaking about public lands. Emerging collaborative structures that attempt to bring together multiple agencies and stakeholders to deliberate and plan for resource management have become prevalent.

The social dimension of natural resource management in the NWFP is dynamic and inherently complex. Effective management requires significant resources, strong social networks, and collective engagement of agencies, institutions, and individuals in diverse policy arenas within the NWFP planning area. Collaborative management and expanded emphasis on transparent public processes that engage diverse stakeholders can help navigate this terrain. Although there is no guarantee that these efforts will result in an outcome that is widely embraced, a process that generates mutual understanding, leads to informed decisions, incorporates new knowledge, and recognizes diverse uses and values would be a step forward.

Scientists and forest managers are updating their thinking about the variety of forest benefits that serve society; they are also developing methods for measuring and comparing a diverse array of tangible and intangible forest benefits. Cultural ecosystem services provide a framework for considering the diversity of spiritual, aesthetic, recreation, heritage, discovery and learning, and therapeutic benefits associated with forest settings. As managers seek strategies for more integrated and holistic resource management by using an ecosystem services approach, the importance of considering an array of public values (including aesthetic, recreational, spiritual, and heritage) becomes paramount.

In the past two decades, scientists have explored and embraced new conceptualizations of ecosystems and ways to describe their benefits to people. Scientists increasingly recognize that conservation initiatives are more likely to lead to better-informed decisions when ecological and social elements are linked. By considering the NWFP area as an integrated social-ecological system, with a complex web of interactions, forces, dynamics, and elements, we can recognize and address major shifts in that system and understand their corresponding effects on the natural and social environment. This system includes public and private lands, governing agencies (federal, state, tribal), communities of place (municipalities, counties), and communities of interest (stakeholders, user groups). We recognize that the social dimensions of the NWFP area influence how ecological goals are established and addressed.

This integrated social-ecological knowledge can help land managers assess how forest management practices and policies, as well as human activities, can alter forest conditions. It can also illuminate how large-scale ecological processes, such as fire or invasive species, can fundamentally modify human-environmental relationships. Integrated and interdisciplinary research efforts can be designed to capture the critical intersection of human and natural connections.

Chapter 9 of the NWFP science synthesis is organized around a series of questions provided by land managers to the science team; we relied on available literature to respond to these questions. Key findings and management considerations from that chapter are summarized below.

Key Findings

Environmental Values Appear to Be Shifting

Americans appear to be shifting their environmental values, preferring a balance between resource protection and production rather than a prominent emphasis on production. This trend is apparent in the NWFP area, although survey data suggest subregional variability.

Systematic monitoring of public values, attitudes, and beliefs held by people in the NWFP area would enhance our understanding of what is important to those who have an interest in the future of these lands. As population changes occur, new migrants can influence the existing composition of values and attitudes. Periodic monitoring would reveal shifts over time as well as regional variations.

Surveys indicate public support for harvest strategies that mimic natural processes—

Existing studies in the NWFP area show that in locales studied, respondents generally did not support clearcutting as a harvest strategy and did not favor harvesting old growth. Additional research about the social acceptability of harvest practices is warranted, with emphasis on public knowledge and perceptions of ecological forestry as well as traditional forms, reactions to a diversity of treatment types and setting conditions (e.g., old-growth forest), and a focus on understanding the role of trust and communication on shaping public responses. Without adequate data on public preferences for forest and rangeland management practices, land managers are left to make decisions based on information gathered in public meetings or in small studies that are not coordinated regionally and may not be generalized to the broader population.

Recreation

Short trips to developed sites are the norm—

Most visits to national forests are relatively brief, lasting less than one-half day, and are focused on recreation at developed sites (e.g., day-use areas, campgrounds, visitor centers). These visits tend to focus on general activities such as hiking, viewing nature and wildlife, and visiting nature centers.

Population growth will drive future increases—

At the national level, the numbers of people participating in outdoor recreation will increase in coming decades with continued population growth.

The greatest barriers to participating in outdoor recreation include:

- Lack of discretionary time.
- Distance to national forests.

New research is needed to understand how the Forest Service can accommodate current and future demands for the full suite of leisure preferences by Americans and specific desired outcomes from national forest recreation.

Valuing Place

People can form strong emotional attachments to places—

- Ties with places can be based on repeated experiences of that place and by stories, symbolic representations, and memories.
- Place attachments can affect public attitudes toward management of those places and trigger "place-protective" behaviors.
- Place attachments are potential drivers of volunteer stewardship and collaborative engagement.

Place meanings are dynamic and constantly being renegotiated—

- A public engagement process that emphasizes multiple ways of collecting information about place meanings and that is designed to reach out to a broad spectrum of the public can be used to capture the range of meanings.
- The variability that exists in place meanings, together with the strong feelings involved in people-place relationships, suggest that broad-based public engagement processes are critical early in the planning process.

Cultivating Trust Through Public Engagement

Trust can be enhanced through participation in various types of public engagement opportunities and in collaborative or co-management groups, in which procedural, rational, and affinitive trust may be cultivated.

Research has identified and defined multiple types of trust in the context of natural resource management:

- **Dispositional** (one's natural inclination to trust).
- **Rational** (stemming from predictable behavior, past performance, and reasoned logic).
- **Affinitive** (based on personal relationships and familiarity that develop through repeated encounters).
- **Procedural** (based on having processes that are viewed as fair, just, and open).

For broader trust in natural agencies to be activated, at least three of the four types of trust are needed.

Integrating foundational methods and practices of public engagement into programmatic forest planning can increase the likelihood that land management decisions better reflect the diverse range of public and tribal interests.

Social science provides methods for understanding values, attitudes and beliefs; stakeholder and social network analysis; and place identity and attachment through tools like public participation geographic information systems (fig. 9-1).

Lee Cerveny

Figure 9-1—Participants map their favorite destinations in the Mount Baker–Snoqualmie National Forest, Washington. This process was used to identify priority destinations as part of travel management planning for the forest.

Agency-Citizen Collaboration

The durability of collaborative groups depends on deep investment of resources and staff time. Research is still underway about the effectiveness of collaborative groups for achieving social and ecological goals.

Despite the proliferation of collaborative groups in the NWFP area, it is not possible to say if communities are more engaged in dialogue with the agency than they were prior to the Plan because no indicators for engagement have been established.

Few systematic scientific evaluations have been conducted to determine collaborative success in achieving resource management goals, or social or economic objectives. No studies measure these goals or outcomes, or identify what can be attributed specifically to collaboratives as opposed to other variables such as economic change, agency or other organizational change, efforts from programs, or activities occurring outside the collaboratives. However, research has shown that collaboration can strengthen relationships among stakeholders and agencies and build trust.

Until we have definitive results, we do not know if collaboration is the ultimate answer. Research on collaboratives tends to occur via singular case studies, which are not generalizable to broader scales. Large-scale, comprehensive studies of collaborative forest management and its effects on forest health and socioeconomic well-being are needed.

Management Considerations

Understanding Public Values, Attitudes, and Beliefs Is Advantageous

This understanding enables managers to anticipate conflicts in values and develop strategies for communicating with stakeholders.

Land managers who have access to current information about the values, beliefs, and preferences of both the general public and a variety of stakeholders and socioeconomic groups will be better equipped to understand characteristics of their social system and anticipate the need for change.

Stakeholders and Citizens in the NWFP Area Generally Do Not Support Clearcutting, Particularly in Old Growth, as a Desirable Silviculture Strategy

Northwest Forest Plan-area residents embody a range of views related to the social acceptability of various harvest practices and these views are based on their values and attitudes, connections to places, knowledge of harvest practices, awareness of management goals and predicted outcomes, and degrees of trust.

Recreation Visits Are Expected to Grow in Day-Use Settings and Developed Facilities

Information on current use patterns and projected trends is useful when considering the amount of resources committed to managing general, common recreation activities versus more specialized, but perhaps higher profile, activities in which fewer people are engaged.

Addressable barriers to recreation—
Factors that the Forest Service has the ability to influence include:

- Improved personal safety at recreation sites.
- Improved signage.
- Availability of quality information for recreation visitors.
- Appropriate setting to meet needs of diverse forest users.

Places and the Meanings That Are Bound Up in Them Have Real Implications for Forest Ecosystem Management

Participatory mapping is useful for visualizing the diversity of place connections. Place-based planning ensures that place connections are integrated with broader planning efforts. A growing emphasis on cultural ecosystem services will allow resource managers to recognize the variety of benefits associated with a forest and stakeholder attachment to sets of these benefits.

Managers can harness the positive power of place. The bonds that people have with places can motivate them to engage in forest stewardship projects. By recognizing and appealing to these bonds, managers may attract volunteers with substantial knowledge of social and ecological conditions to accomplish objectives.

Trust and Decisionmaking Processes

Developing decisionmaking processes and protocols that are consistent, reliable, fair, and transparent can help improve institutional trust—
The degree of trust established among public agencies, stakeholders, and communities is an important factor in public support for resource management decisions. Public trust of natural resource agencies may vary between the local (or project) level and the national (broad-based) level. Mutual accountability is critical for building long-term trust. Having clearly stated objectives, consistent communication, transparent processes, reasonable timelines, honored commitments, and opportunities for candid deliberation can enhance trust. Enduring personal relationships also are important.

The quality of a resource management decision is strongly dependent on the quality of the process that leads to it—
Designing public involvement strategies that resonate with a dynamic and diverse range of interests helps ensure sound decisionmaking. Best practices for inclusive decisionmaking processes include:

- A philosophy of empowerment, equity, and inclusiveness.
- Systematic assessment of potentially relevant stakeholders and strategies to encourage participation.
- Engaging stakeholders early and providing opportunities for frequent interactions throughout the process.
- Clear objectives, timelines, and parameters.
- Skilled facilitation.
- Integrating local and scientific knowledge.
- Enduring agency commitment to the process.

Collaboration and Public Engagement

Collaboration takes time, resources, and long-term commitment from all parties—
Managers seeking to initiate or participate in a collaborative group process may want to ensure that they have adequate resources and staffing to support a long-term relationship.

Elements of successful agency participation in collaboration include:

- Open communication.
- Clear expectations.
- Realistic information about internal priorities, plans, and decisionmaking latitude.

Collaborative groups may be part of the solution to increasing trust and social license for forest management to meet NWFP and other goals.

Different phases of forest plan revision or any management decision process may call for different levels of public engagement—
The key is defining these various levels of public participation prior to initiation of plan revision. This will help support a meaningful and robust public participation process.

When "collaboration" is used as a catch-all term for public involvement, it leads to conflicting expectations—
This can reduce trust and willingness to participate in long-term planning.

Collaboration is not the answer for every situation—
Not every stakeholder will be eager to participate in an organized collaborative group or process. The scope, scale, and projected outcomes of a given collaborative effort may make it more relevant and accessible to some stakeholders than others. In some cases, the outcome from an agency appeal or court ruling may be preferred over collaboration.

Conclusions

Conservation goals are most often met when ecological and social elements are integrated. Changes to society, including demographic shifts, changes in human settlement patterns, and new governance structures or regulations can affect interactions with the natural environment. Conversely, large-scale landscape and climate variations can affect human institutions, such as markets and communities. Greater awareness about how social and ecological systems intersect will help resource managers improve the quality of their decisionmaking. This includes greater understanding of human values and management preferences, place-relations, resource uses, and visitation patterns.

New participatory strategies have attempted to democratize and deepen citizen engagement in environmental decisionmaking. The proliferation of collaborative institutions has the potential to influence future management of ecological systems. As agencies expand their conceptualizations of forest resources from "sustained yield" to "ecosystem management" to "ecosystem services" in the NWFP area, this will certainly have on-the-ground implications. Greater recognition of diverse stakeholder values and place attachments, of shifting visitation patterns across the forest landscape, and of the opportunities for public expression of these values will enhance efforts to understand the Plan area as a dynamic and integrated ecological and social system.

Further Reading

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Chapter 10: Environmental Justice, Low-Income and Minority Populations, and Forest Management in the Northwest Forest Plan Area

Susan Charnley, Delilah Jaworski, Heidi Huber-Stearns, Eric M. White, Elisabeth Grinspoon, Rebecca J. McLain, and Lee Cerveny[1]

Main Points

- The Northwest Forest Plan (NWFP, or Plan) monitoring program did not explicitly consider environmental justice in terms of how the NWFP affects low-income or minority populations, other than American Indian tribes, in the Plan area. As a result, we cannot specify what the socioeconomic effects of the NWFP on environmental justice populations other than American Indian tribes have been.
- Environmental justice populations in the Plan area are increasing. In particular, the percentage of the population identifying as Hispanic or Latino has doubled in nonmetropolitan counties since the 1990s, and nearly tripled in metropolitan counties.
- Poverty rates were uniformly higher in nonmetropolitan counties than in metropolitan counties in the Plan area between 1990 and 2012, and were higher than the national average, although poverty rates for the Plan area as a whole were lower than the national average.
- Growth in environmental justice populations, and their prominence in the environmental workforce and in commercial gathering of nontimber forest products on federal forest lands in the Plan area, point to the need for ongoing research into how these populations relate to federal forests and are affected by federal forest management.

[1] **Susan Charnley** is a research social scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 620 SW Main Street, Suite 502, Portland OR 97205; **Delilah Jaworski** is a social scientist, U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, 1617 Cole Boulevard, Lakewood, CO 80401; **Heidi Huber-Stearns** is an assistant research professor and associate director of the Ecosystem Workforce Program, University of Oregon, Institute for a Sustainable Environment, 130 Hendricks Hall, Eugene, OR 97403; **Eric M. White** is a research social scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3625 93rd Avenue SW, Olympia, WA 98512.; **Elisabeth Grinspoon** is a regional social scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, 1220 SW 3rd Avenue, Portland, OR 97204; **Rebecca J. McLain** is an assistant research professor, Portland State University, Institute for Sustainable Solutions, 1600 SW 4th Avenue, Suite 110, Portland, OR 97201; **Lee Cerveny** is a research social scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 400 N. 34th Street, Suite 201, Seattle, WA 98103.

Introduction

Environmental justice includes the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (USEPA 2013). The 1994 Executive Order (E.O.) 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, requires federal land managers to identify and address any disproportionately high and adverse human health and environmental effects of agency programs, policies, and actions on minority and low-income populations. An environmental justice population is a group of people that meets the criteria for low-income or minority status under E.O. 12898.

Northwest Forest Plan socioeconomic monitoring has not explicitly monitored Plan impacts on low-income or minority populations other than American Indian tribes; thus we are unable to specify how the NWFP has affected these populations. However, federal land managers in the Plan area submitted several priority management questions pertaining to environmental justice and forest management for consideration in the NWFP science synthesis. We focus on two:

1. What are the trends in the size of low-income and minority populations in the NWFP area since the Plan was adopted, and what is their current geographic distribution?
2. How do low-income and minority populations interact with federal forests in the NWFP area?

In the absence of monitoring data, we relied mainly on existing scholarly research studies to address these guiding questions. American Indian tribes are the subject of chapter 11; here the focus is on other minority populations. The published literature about environmental justice populations and their relations with federal forests in the Plan area deals primarily with the environmental workforce, commercial nontimber forest product (NTFP) gathering, and recreation. Two emergent topics that are less well documented but for which research is ongoing are (1) nonrecreational camping on federal forests, particularly homelessness; and (2) the impacts of wildfire management activities on environmental justice populations.

Here we summarize key findings from chapter 10 of the NWFP science synthesis and their implications for forest management in the NWFP area.

Key Findings

Trends in Low-Income and Minority Populations in the Northwest Forest Plan Area

U.S. Census data provide the best available information on low-income and minority populations across the 72 counties (32 metropolitan, 40 nonmetropolitan) that comprise the Plan area. According to census data, the size and percentage of environmental justice populations have increased since the NWFP was adopted, consistent with national trends. This increase has occurred both in the size of low-income populations (measured by number of people living below the poverty line), and the number of people belonging to minority groups specified by E.O. 12898.

Poverty rates increased but were lower overall than the national rate—
The poverty rate in the NWFP area as a whole increased from 11.2 to 14.7 percent of the region's population between 1990 and 2012 (table 10-1). Nevertheless, this was lower overall than the national poverty rate during the three periods reported here. Although poverty rates fell in many subregions of the Plan area between 1990 and 2000, those improvements were more than offset by increases in poverty across the Plan area between 2000 and 2012.

Table 10-1—County-level poverty rates in the Northwest Forest Plan (NWFP) area, 1990, 2000, and 2012

	1990 poverty rate	2000 poverty rate	2012 poverty rate
		Percent	
United States	13.5	11.3	15.0
All NWFP counties	11.2	10.0	14.7
All metropolitan counties	10.3	9.1	13.9
All nonmetropolitan counties	15.3	14.2	19.0
All California NWFP counties	11.4	11.1	15.4
All California metropolitan counties	9.6	9.0	13.1
All California nonmetropolitan counties	15.6	16.4	21.7
All Oregon NWFP counties	12.2	10.4	16.9
All Oregon metropolitan counties	11.4	9.7	16.4
All Oregon nonmetropolitan counties	15.2	13.2	19.2
All Washington NWFP counties	10.5	9.4	13.2
All Washington metropolitan counties	9.9	8.8	12.8
All Washington nonmetropolitan counties	15.1	13.3	16.7

Source: U.S. Census Bureau small-area income and poverty estimates.

In summary:

- Poverty rates were uniformly higher in nonmetropolitan counties than in metropolitan counties during the analysis period, and they were also higher than the national average.
- Overall, poverty rates were highest in Oregon and lowest in Washington in both 1990 and 2012. However, in California, nonmetropolitan counties area had the highest poverty rates within the Plan area during that period, and also experienced the greatest increase in poverty.
- The highest poverty rates are concentrated in northern California and southern Oregon (fig. 10–1). Counties with the lowest poverty rates are concentrated around the greater San Francisco, Portland, and Seattle metropolitan areas.

Racial and ethnic diversity increased—

The percentage of the population identifying as a racial or ethnic minority grew in both metropolitan and nonmetropolitan counties within the Plan area between 1990 and 2012 (table 10-2). Most notably, the percentage of the population identifying as Hispanic or Latino doubled in nonmetropolitan counties, and nearly tripled in metropolitan counties in the Plan area. The percentage of the White population declined more in metropolitan counties than in nonmetropolitan counties. Plan-area counties with high concentrations of minority residents are clustered near California's Central Valley and east of the Cascade Range crest in Washington (fig. 10-2).

Table 10-2—Minority populations in the Northwest Forest Plan area, 1990, 2000, and 2012

	1990			2000			2012		
	Plan area	Nonmetropolitan	Metropolitan	Plan area	Nonmetropolitan	Metropolitan	Plan area	Nonmetropolitan	Metropolitan
					Percent				
American Indian and Alaska Native	2	3	1	2	3	1	2	3	2
Asian, Native Hawaiian, other Pacific Islander[a]	4	1	4	5	1	6	7	2	9
Black or African American	3	1	3	3	1	3	3	1	4
White	92	95	92	88	93	86	84	90	82
Hispanic or Latino[b]	5	6	5	9	7	8	14	12	14
≥ two races[c]				3	2	3	4	4	4

[a] The 1990 Census grouped Asians and Pacific Islanders into one category. In 2000, this category was divided into two: Asian, and Native Hawaiian and other Pacific Islander. For consistency across years, we have grouped these two back into one category.

[b] Hispanic or Latino is a category of ethnicity. Individuals may identify as Hispanic or Latino and any of the racial categories (e.g., Hispanic or Latino and White, Hispanic or Latino and Black). Therefore, table totals will not sum to 100 percent.

[c] This category was not available on the 1990 census form.

Source: U.S. Census Bureau population estimates.

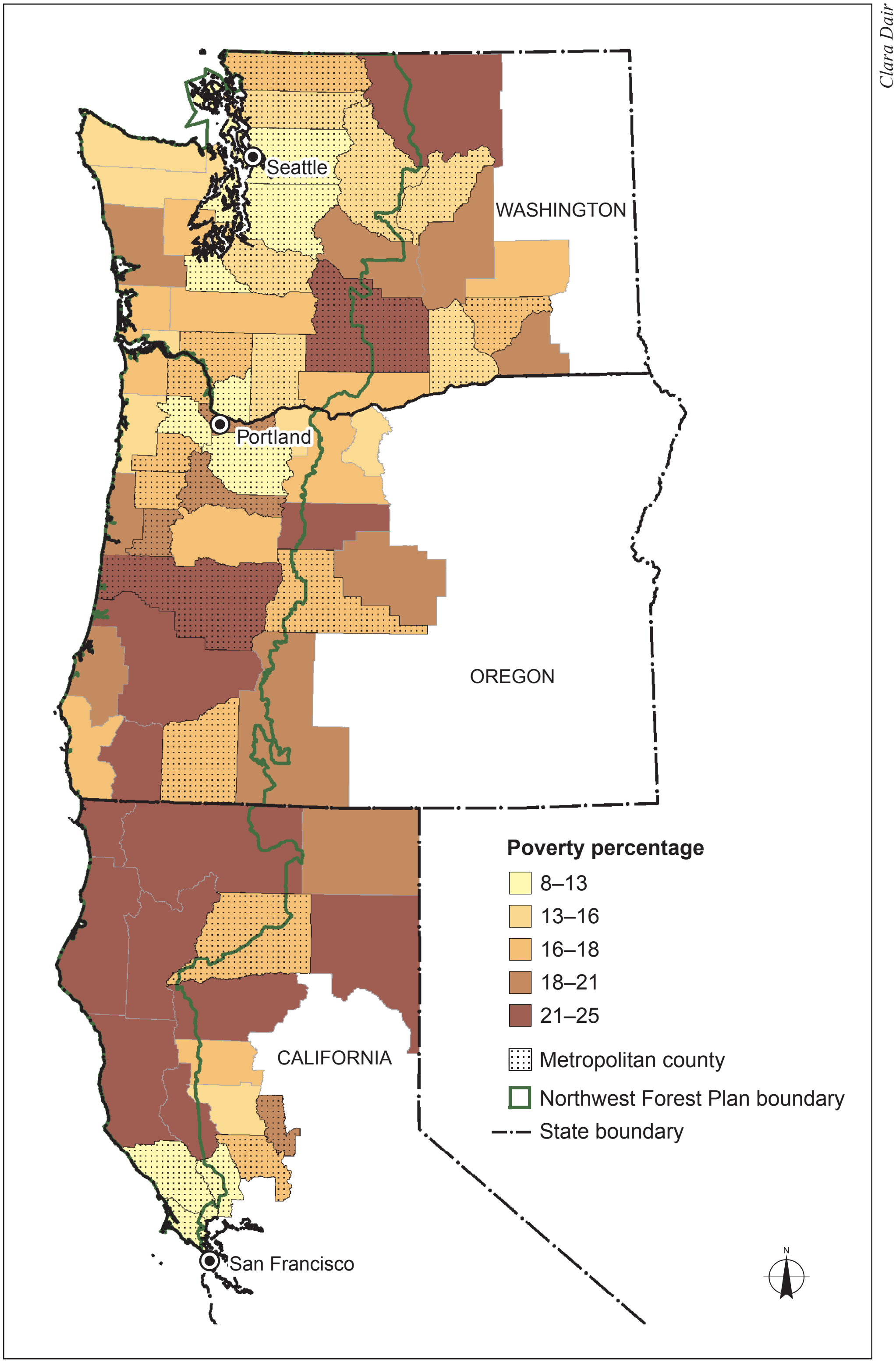

Figure 10-1—Percentage of people living in poverty in Northwest Forest Plan-area counties, 2012.

Clara Dair

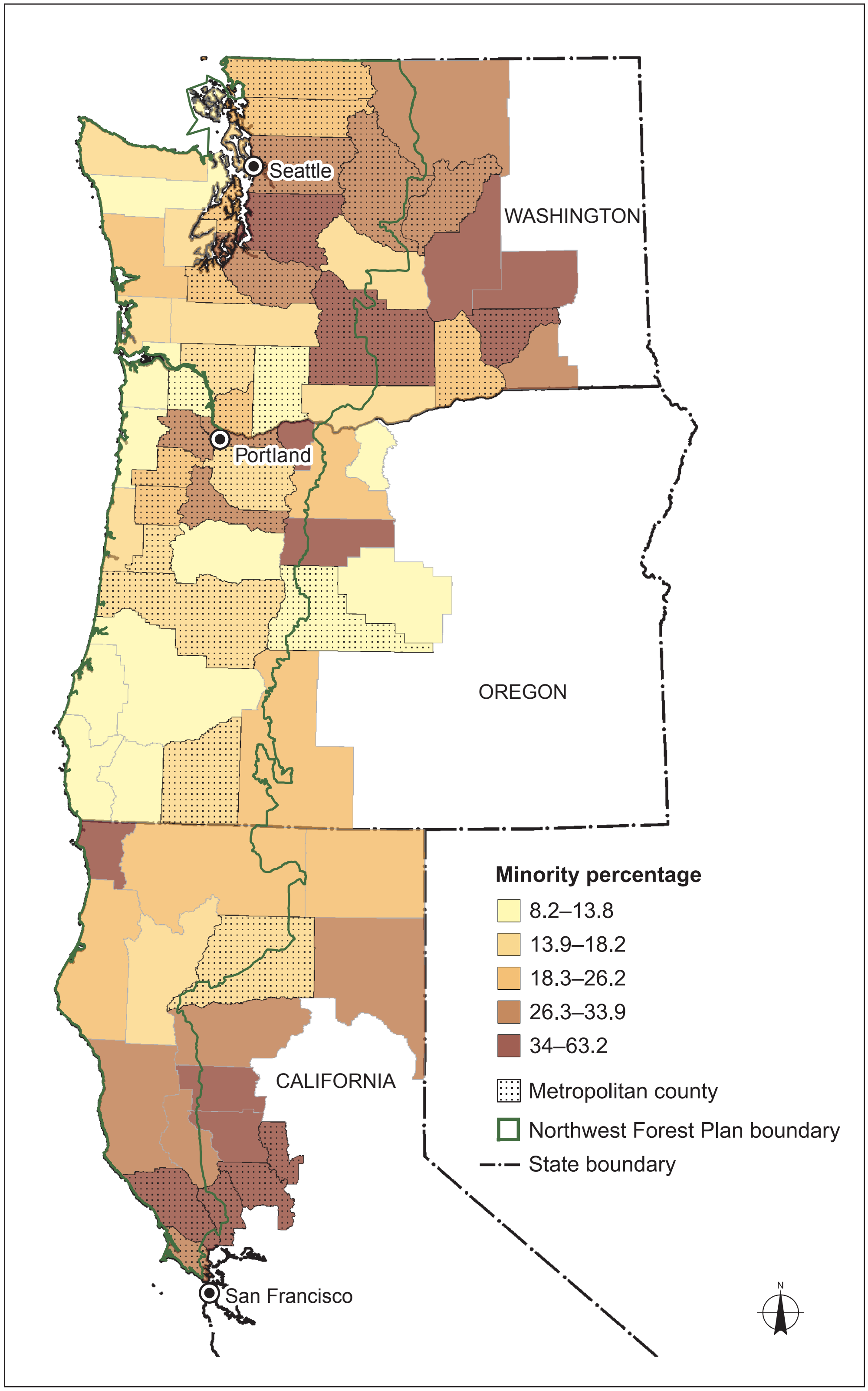

Figure 10-2—Percentage of minority populations (combined) in Northwest Forest Plan-area counties, 2012.

The NWFP area had a higher percentage of the total population that was American Indian or Alaska Native, and Asian, Native Hawaiian, and other Pacific Islander compared with the nation as a whole in 2012, but a substantially lower percentage of the total population that was Black or African American, or Hispanic or Latino, compared with the nation as a whole.

- American Indian and Alaska Native populations were more prevalent in nonmetropolitan counties than in metropolitan counties of the Plan area between 1990 and 2012. In 2012, they accounted for a higher percentage of the population in nonmetropolitan counties in California than in other subregions.
- Black or African American, and Asian, Native Hawaiian, and other Pacific Islander populations formed a higher percentage of the population in metropolitan than in nonmetropolitan counties, and the highest percentage population for both was in metropolitan counties in Washington.
- The percentage of the population identifying as Hispanic or Latino was high relative to other minority groups in the Plan area as a whole, and was similar between metropolitan and nonmetropolitan counties.
- The percentage of the population that was Hispanic or Latino was highest in California counties.

Many poor counties in the Plan area also have large shares of minority residents. However, poverty is not limited to those areas having high concentrations of minorities. We did not examine how trends in minority group populations and poverty rates may be linked. Nevertheless, at the national level, Black or African American, American Indian, and Hispanic or Latino populations in the United States experience significantly higher rates of poverty than White and Asian populations.

Use of Federal Forests in the NWFP Area by Low-Income and Minority Populations

Different populations maintain different relations to federal forests, have different use preferences, and face different constraints that influence their use of federal forests, though variation within groups exists (as it does among all demographic groups). The scientific literature regarding relations between environmental justice populations and federal forests in the Pacific Northwest is limited, and as already noted, focuses mainly on participation by low-income and minority populations in the environmental workforce, the gathering of NTFPs, and recreation.

A strong presence in the environmental workforce—

Regarding the environmental workforce, forest workers in the NWFP area are predominantly Hispanic or Latino. They work as contractors who perform a variety of labor- and equipment-intensive forestry work on federal forests (fig. 10-3), in addition to participating in fire-suppression crews. Much of the published literature about forest workers draws attention to the low job quality they have experienced over the past few decades. These poor working conditions include low wages, lack of stable employment, no benefits, long travel distances to work sites, disrespectful treatment, little opportunity to advance, unsafe working environments, high rates of injury and fatality, lack of training opportunities, and fear of retaliation or deportation if they complain. Although there have been some improvements in recent years, especially in the area of fire-suppression work, debates over how to address these poor working conditions remain unresolved. To date, federal agencies have not notably changed their oversight of service contract crews or enforcement of labor law provisions.

Susan Charnley

Figure 10-3—Forest workers cut and pile roadside brush on the Six Rivers National Forest in California. Forest workers in the Northwest Forest Plan area are predominately Hispanic or Latino.

Active in commercial NTFP harvesting—

Environmental justice populations in the NWFP area—particularly Southeast Asians, Hispanic or Latinos, and low-income Whites—also play an active role in the commercial NTFP industry, with Hispanic or Latinos especially prominent in the floral greens industry and Asians prominent in the wild mushroom industry (fig. 10-4). National forests and Bureau of Land Management (BLM) lands are important harvesting sites, but there has been virtually no published research documenting the impact of the NWFP on environmental justice populations who harvest NTFPs there. Although these populations are affected by agency regulations associated with NTFP

Rebecca McLain

Figure 10-4—Southeast Asians play a prominent role in the matsutake industry.

harvesting and management practices influencing the distribution and productivity of the species they target, they have been underrepresented in developing regulations and management guidelines for NTFPs on federal forests in the Plan area.

Important issues for managers to be aware of include potential social tensions between commercial gatherers and those primarily interested in recreational, subsistence, and cultural gathering; tenure arrangements governing access to NTPFs; physical safety of harvesters when they are out in the forest; fear of encounters between undocumented workers and immigration and law enforcement officers; challenges associated with illegal harvest activities (e.g., theft); and the right to safe working conditions and fair employment practices for harvesters.

Low recreation participation—

In contrast, recreation visitation by environmental justice populations to national forests in the NWFP area is relatively low (tables 10-3 and 10-4). Nationwide, different racial and ethnic groups exhibit different preferences for types of outdoor recreation activity, although visiting developed sites and viewing and photographing nature are the most popular activities among all groups, including Whites. A main barrier to recreating on national forests for low-income populations is the cost of the trip. Among minorities, distance, cost, lack of transportation, safety concerns, lack of awareness about recreation opportunities, and lack of information in languages other than English are additional barriers.

Table 10-3—Visits to national forests in the Northwest Forest Plan area and nationally by people age 16 and older by household income

Annual household income	Plan area 2006–2010	Plan area 2011–2015	National 2011–2015
		Percent	
Under $25,000	10	12	10
$25,000–$49,000	24	18	18
$50,000–$74,999	25	23	22
$75,000–$99,999	18	20	18
$100,000–$149,999	15	17	16
$150,000 and up	8	11	16

Source: U.S. Forest Service National Visitor Use Monitoring Survey Results—National Summary Report. https://www.fs.fed.us/recreation/programs/nvum/pdf/5082016NationalSummaryReport062217.pdf. (13 December 2017).

Table 10-4—Visits to national forests in the Northwest Forest Plan area and nationally by people age 16 and older by minority group

	Plan area 2006–2010	Plan area 2011–2015	National (2011–2015)
		Percent	
American Indian and Alaska Native	3	3	2
Asian	2	3	2
Black or African American	1	1	1
White	96	95	95
Native Hawaiian and other Pacific Islander	1	1	1
Hispanic or Latino	4	4	6

Source: U.S. Forest Service National Visitor Use Monitoring Survey Results—National Summary Report. https://www.fs.fed.us/recreation/programs/nvum/pdf/5082016NationalSummaryReport062217.pdf. (13 December 2017).

Management Considerations

Improving Working Conditions for the Environmental Workforce

The forestry workforce is increasingly represented by Hispanics or Latinos and other environmental justice populations; thus it is important that federal forest managers address the issue of working conditions for forest workers. Doing so means considering contracting markets and contract oversight, which include bidding on, awarding, and monitoring compliance for projects. Based on the literature, the following actions might help improve working conditions for forest workers.

- The Forest Service and BLM already stipulate in service contracts that contractors must comply with all relevant labor laws. These agencies could enforce the provisions of their own contracts more rigorously.

- Agencies could examine how the features of fire-suppression contracting that are beneficial to workers could be incorporated into other, non-fire contracts (e.g., specific contract requirements and more oversight).
- Agencies could strengthen policies to make labor-law-compliance inspection more consistent, combining these inspections with technical specification inspections, and increasing agency inspector training.
- The competitive low-cost bid process could be changed to reduce contractor incentives for cutting costs, and explicitly incorporate the costs of safety training and daily safety briefings into contract awards.
- Increase the ability of forest communities to capture contracting opportunities on nearby federal forests. Examples include structuring contracts in ways that allow local communities to benefit, e.g., by facilitating local training opportunities or changing contracting guidelines, and addressing obstacles that inhibit local contractor participation.
- Use local restoration contracting service providers for fire suppression to support local forest contracting capacity, and the ability of local contractors to capture contracts during wildfires.

Nontimber Forest Products

The literature offers numerous insights pertaining to issues associated with NTFP gathering and management on federal forest lands in the Pacific Northwest raised by environmental justice populations. They include addressing harvesters' safety concerns associated with NTFP gathering (e.g., encouraging harvesters to wear blaze-orange vests), and examining how policies, including tenure arrangements for NTFP harvesting on federal forests, affect the working conditions and earnings of harvesters. Consideration of how federal forest management activities affect the abundance, distribution, diversity, and quality of economically and culturally important NTFP species also warrants more attention in the planning process.

Minimizing Barriers to Recreation

Minority and low-income populations are currently underrepresented among visitors across the entire National Forest System (fig. 10-5). Management considerations to overcome constraints to recreation participation by these populations on federal forests in the Plan area include:

- Improving information about available recreation opportunities, for example by providing information in multiple languages and working with media outlets that target these populations.

Emily Jane Davis

Figure 10-5—Distance to primitive settings and the cost of recreation, including equipment expenses, are constraints to outdoor recreation participation by low-income and minority populations.

- Improving transportation options to urban national forests.
- Increasing recreation opportunities and facilities that match these users' preferences, such as developing recreation sites that accommodate large groups.
- Finding appropriate ways to address safety concerns associated with visiting federal forests.
- Improving outreach, for example by making people aware of volunteer and employment opportunities on national forests, and developing partnerships and relationships with organizations that promote outdoor experiences for low-income and minority groups.
- Finding ways to alleviate cost barriers to recreation participation.

Nonrecreational Camping and Homelessness

The frequency of homelessness and long-term camping on national forests is increasing. Recognition by agency management of the resource impacts and social effects associated with long-term camping would spotlight concerns raised by law enforcement. Treating homelessness as a chronic and systemic phenomenon in which the agency plays a critical role would potentially lead to greater acceptance of responsibility and action. The Forest Service could develop partnerships with public health agencies, social service agencies, municipal police, and citizen groups to identify safe housing options in local communities for homeless populations to help alleviate undesirable resource impacts and social effects associated with long-term camping.

Wildfire Management

Poverty and minority status are among the social variables that researchers use as indicators of social vulnerability. Socially vulnerable populations tend to be more vulnerable to wildfire than less socially vulnerable populations because they often have fewer resources to invest in wildfire mitigation actions, have lower participation rates in wildfire-mitigation assistance programs, and have less access to wildfire response resources when a fire ignites. These findings suggest that:

- It is important for hazardous fuels reduction treatments to be proportionately distributed in places where low-income and minority populations live near federal forests; such treatments might target these locales because of higher social vulnerability to wildfire.
- Directing outreach and financial and technical assistance to these populations may help them increase fire-safe practices around their homes for greater protection from high-severity fire.

Conclusions

Federal forest managers requested information about trends in the size of environmental justice populations in the NWFP area, and the implications of these trends for federal forest management. Environmental justice populations in the Plan area are growing. Census data reflect the changing demographics of the region, and research from within and outside the Plan area provides insight into how some members of low-income and minority populations interact with federal forests. When thinking about these relationships, it is important to avoid overgeneralizing and creating stereotypes about the values, uses, preferences, and behaviors of specific groups. Inevitably, there will be variation within groups, some of it influenced by gender, age, length of time in the United States, and other factors. The research synthesized here can be used to increase awareness and flag potentially relevant topics for agency staff to examine more closely at the local level.

Emergent issues for which research is ongoing include the presence of temporary residents—including homeless populations—on national forests, many of whom are likely low income; and connections between wildfire management and environmental justice. Important information gaps remain, however. There is virtually no research or monitoring data that concern the specific impacts of the NWFP on low-income or minority populations apart from American Indian tribes. Also sparse is literature regarding the broader impacts of forest management activities on environmental justice populations. Apart from recreation, little information is available about noneconomic relationships between environmental justice populations and federal forests. Research to better understand the variation within minority groups regarding their interactions with federal forests in particular places is also lacking, for example, how low-income or minority status intersects with subgroup characteristics (i.e., gender, age, religion) to influence forest values, uses, and management impacts. Growth in environmental justice populations throughout the NWFP area calls for reassessing earlier findings, and ongoing research into how these populations relate to federal forests and are affected by federal forest management.

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Roasting salmon over an open fire.
Photo by Jon Ivy Coquille Indian Tribe.

Chapter 11: Tribal Ecocultural Resources and Engagement

Jonathan Long, Frank K. Lake, Kathy Lynn, and Carson Viles[1]

Main Points

- Implementation of the Northwest Forest Plan (NWFP, or Plan) has emphasized consultation and cooperation with tribes, but when written, the Plan itself did not consider tribal management practices or explicitly seek to promote many resources valued by tribes.
- Many valued tribal resources are found in early-seral forests, meadows, and open woodlands. Fire suppression and reductions in traditional, active management practices have caused resource quality and quantity to decline, with negative effects on tribal well-being.
- Opportunities exist for working with tribes to restore key resources, and such strategies are consistent with emerging directions in forest management.

Introduction

The ecosystems within the NWFP area support an array of resources used by tribes for food, medicine, and materials. These resources also support sacred sites, tribal sense of place, and cultural identity. Implementation of the NWFP has emphasized the importance of consulting and cooperating with tribes. The 10-, 15-, and 20-year NWFP monitoring reports specifically considered the effectiveness of consultation with tribes. The monitoring reports also devoted increasing attention to tribal access to forest resources and places that are important for cultural, subsistence, or economic reasons, particularly those protected by treaty rights held by federally recognized tribes. However, the Plan did not consider proactive efforts to foster resources valued by tribes beyond old forests and salmonids. In commissioning the NWFP science synthesis, Forest Service resource managers asked us if active management would be needed to provide the cultural resources valued by tribes, including first foods such as salmon, elk, huckleberries, and camas. We summarize key findings and management considerations from chapter 11 below.

[1] **Jonathan Long** is an ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1731 Research Park Drive, Davis, CA 95618; **Frank K. Lake** is an ecologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 3644 Avtech Parkway, Redding, CA 96002; **Kathy Lynn** is a faculty researcher and **Carson Viles** is a research assistant, University of Oregon, Environmental Studies Program, 5223 University of Oregon, Eugene, OR 97405.

Key Findings

Tribes remain generally concerned about the availability and condition of eco-cultural resources and places of special interest on federal lands. Both social and biophysical factors have limited tribes from obtaining desired resources from public lands. The issue extends beyond access or permission to harvest resources to whether resources are available in sufficient quality and quantity for harvest. Consequently, tribes and researchers have focused on the productivity of ecosystems, particularly for resources such as nut-producing trees, understory plants for food and fiber, game animals such as elk and deer, and fish, especially salmonids and other anadromous species such as sturgeon, candlefish, and lamprey (fig. 11-1). Tribes have long emphasized that they actively used fire and other practices to maintain the productivity of many of these resources.

Frank K. Lake

Figure 11-1—Lamprey, candlefish, and night smelt harvested by Yurok Tribe members on a basket tray made from sandbar willow (*Salix exigua*), March 2014.

Disruption of Traditional Tribal Practices Negatively Affects Tribal Well-Being

Historical tribal practices included plant harvesting, tilling, weeding, moving plant propagules, and burning. The disruption of those traditional practices has perpetuated a cycle of degradation of valued resources and tribal well-being that started with displacement of tribes from their ancestral lands:

1. Confinement to reservations followed by land allotment and termination has limited tribes' ability to practice land-tending traditions such as burning.
2. Resource quality and quantity have declined, with many areas no longer suitable for harvesting desired foods, basketry materials, medicines, and other cultural resources.
3. Community members have experienced poor health and well-being, particularly because food and economic insecurities are associated with reductions of traditional resources and practices.
4. Intergenerational transmission of traditional ecological knowledge has been impeded as elders have fewer opportunities to practice the traditions and teach them to youth, as well as reduced incentive to do so.
5. Lands have become feral and inhospitable "wilderness" from a tribal perspective.
6. People's understanding of reference conditions has become distorted as experience with past conditions is replaced by exposure to present degraded conditions.

These combined effects deter tribal members from maintaining or reestablishing traditional practices. Other stressors, including climate change, invasive species, species extirpations, and changes in land use exacerbate this cycle by reducing the availability of ecocultural resources and constraining access by tribal members.

Active Management to Restore Fire While Conserving Large Trees Is Needed for a Diverse, Reliable Supply of Ecocultural Resources

Active management, including use of fire and complementary thinning and fuel reduction treatments, can help restore a variety of communities that sustain tribal ecocultural resources. The NWFP did not emphasize the ecological importance of fire and the influence of American Indians prior to Euro-American colonization. Many ecosystems within the Plan area, from inland areas characterized by frequent fire to coastal areas characterized by infrequent fire regimes, were influenced by American Indian use of fire. Although the historical breadth and depth of fire use by American Indians has been subject to debate, as have the historical frequency and extent of fire in general, research has concluded that the effects of indigenous burning would have been particularly pronounced around historical tribal settlements, trade and travel routes, and harvesting and hunting areas. As tribes were displaced, the frequency of fire in many of these places throughout the region was reduced.

Such influence was particularly important in ecological transition areas, or "ecotones," between forests, woodlands, grasslands, and wetlands. Many species of special importance to tribes are associated with early-successional communities, forest openings, and more persistent nonforest communities such as meadows and wetlands that support vibrant small woody and herbaceous plant communities. These were often favored harvesting sites. Highly desired resources that depend on frequent disturbances include trees and shrubs that produce edible nuts and fruits, geophytes (such as camas) that produce edible roots, fungi that produce edible mushrooms, and forbs and grasses that produce nutritious seeds and forage for deer and elk. In addition to resources found in early-seral or open environments, valued resources come from woodlands and forests dominated by old trees that are better able to survive fire than smaller trees. Exclusion of fire has led to forest encroachment and densification in woodlands, meadows, riparian areas, prairies, and other vegetation communities.

Although restoration of nonforest vegetative communities is important, tribes also place special value on large, old trees of both hardwood species and conifers. Large western redcedar trees, for example, are important for carving canoes and totem poles. Some wildlife species of special tribal value, including marten and pileated woodpecker, are associated with older forests, large decadent or dead trees, and dense tree canopies.

Actively restoring and maintaining historical fire regimes through forest thinning and greater intentional use of fire would reduce the risk of uncharacteristically severe wildfires and improve the productivity and availability of many tribal ecocultural resources. Such treatments are particularly important to restore systems altered by historical timber harvest, fire suppression, and novel influences such as sudden oak death. Promoting a diversity of fire effects across large landscape areas is an important strategy to help ensure long-term sustainability and availability of ecocultural resources for tribes. This availability, in turn, supports important socioeconomic benefits such as food security and work opportunities. Tribes maintain that active management could expand the pool of resources to benefit human beings and a multitude of wildlife species.

Tribes have experienced diminished well-being as species of special importance have been extirpated. Consequently, reintroduction of ecocultural keystone species, in conjunction with restoration of their habitat, is also important for sustaining tribal material uses, cultural values, biological diversity, and ecological processes.

Ecocultural resources have also declined as dams, diversions, roads, and other developments have altered flood regimes and created barriers to fish passage. Strategies for restoring aquatic systems have emphasized the importance of restoring fire and flooding regimes, as well as remediating forest road systems that impede natural passage of organisms, wood, water, and sediment. However, roads are also important for maintaining tribal access to resources and intergenerational transmission of knowledge.

A particularly important research need is for collaborative, integrative studies that evaluate benefits to tribes from active, restorative management or the lack of such treatments, both in terms of the ecological response and socioeconomic benefits that result from those responses. Some studies of sensitive wildlife species acknowledge that restoration may benefit special status wildlife species, many of which are predators, by enhancing populations of prey. However, conservation under the NWFP has often followed a more precautionary approach and avoided intervening in the habitats of declining species and designated late-successional and riparian reserves.

In general, strategies to promote tribal ecocultural resources are consistent with emerging directions in forest management, including reestablishing more natural disturbance regimes and landscape heterogeneity using adaptive management and restoration forestry. Such strategies can be integrated with measures to protect large, old trees, cultural sites, and other ecocultural resources that are potentially sensitive to treatments and vulnerable to severe disturbances.

Access to Valued Resources

Considerable attention has been given to the legal and bureaucratic dimensions of access, such as fees and barriers to obtaining resources on public lands. For example, NWFP monitoring reports and other publications have noted obstacles to harvesting large cedar logs on public lands, as well as cultivation and harvest of beargrass (fig. 11-2), willows, and other plants in reserve areas. Revisions to agency policies that recognize tribal rights to gather forest products for traditional and cultural purposes without fees have ameliorated some of these conflicts.

Competition for resources with non-Indians remains a longstanding issue, with specific examples including commercial harvesting of huckleberries, matsutake mushrooms, floral greens, and other forest products. Research suggests that for

Frank K. Lake

Figure 11-2—LaVerne Glaze holding harvested beargrass, July 2005. Some American Indians use beargrass for weaving baskets and other traditional purposes.

some of these resources, non-Indian commercial harvesters may have greater incentives to overharvest than tribal members who follow traditional practices. Establishment of gathering areas on public lands that are reserved for tribal use (fig. 11-3) appears to have been an effective solution to this challenge, although managing roads and regulating access by non-Indian recreational users will continue to require site-specific considerations.

Leslie Seaton

Figure 11-3—Handshake Agreement sign in Indian Heaven Wilderness, Gifford Pinchot National Forest, Washington. This sign commemorates a historic example of federal-tribal collaboration dating back to 1932, when the Forest Service agreed to reserve an area of huckleberry patches on the national forest for exclusive gathering by the Yakama Nation.

Strategies for Engaging Tribes in Forest Planning and Management

Tribes are concerned not only with ensuring that lands are actively tended, but also that they have opportunities to help shape and conduct those efforts directly. Research has highlighted the social importance of American Indians being able to practice and maintain stewardship traditions on ancestral lands, rather than deferring such management to nontribal employees or contractors. Tribal engagement, including formal consultation and longer term partnerships, is important for achieving land management objectives in the 2012 forest planning rule, upholding tribal rights and federal responsibilities, and recognizing the value of tribal ecocultural resources. Collaborative engagement with tribes in planning, researching, implementing, and monitoring treatments can foster adaptive capacity of both tribes and partnering institutions.

Management Considerations

- Restoring diverse seral and grassland communities across the landscape as well as natural disturbance processes, hydrological connectivity, and species that have been extirpated is important for sustaining ecocultural resources and associated tribal well-being.
- Active management that is informed by traditional ecological knowledge can promote the quantity and quality of many important cultural resources while supporting other ecological goals, including conservation of large trees. Such management is a greater need in drier ecosystems that evolved with more frequent fire, but it is also important for culturally important areas within wetter ecosystem types.
- Promoting the quality, abundance, and availability of ecocultural resources is important to tribes beyond ensuring viability of species and access to resources.
- Understanding specific reasons for decline in resource use is important when developing strategies to benefit tribal communities. A lack of current harvesting activity does not necessarily indicate a lack of interest or demand.
- Many tribes desire opportunities to maintain traditional tending practices, including burning (fig. 11-4), as a means of sustaining and passing down traditional knowledge.

Frank K. Lake

Figure 11-4—Klamath River Training Exchange prescribed burn on a privately owned area for experimental research and tribal gathering of tanoak nuts and other forest products near Orleans, California, October 2015.

- Partnerships with tribes can build upon the foundations in the Tribal Forest Protection Act and other laws and policies that provide for explicit tribal engagement and cooperative management.
- Designation of special tribal stewardship areas can be a useful strategy to formalize cooperative management over particular areas of special importance to tribes and to achieve social and ecological objectives of both tribes and federal land management agencies.
- Native knowledge can provide insight about the effects and tradeoffs associated with management actions, and the lack of active management, on important ecological and sociocultural dynamics.

Conclusions

Scientific publications have recognized the important influence American Indians have had on ecosystems in the Pacific Northwest. Research has also increasingly considered the dependence of tribal communities on well-functioning and diverse forest and nonforest ecosystems in the region. Forest management plans can support tribal values by integrating findings from biophysical and social sciences regarding historical range of variation and influence of native peoples, along with priorities and traditional ecological knowledge from tribes. This knowledge may be documented in publications or passed down as oral traditions.

Active forest management offers compelling opportunities for reconciling ecological and social concerns. Several collaborative projects in the region highlight how tribes have guided active management within stewardship areas on public lands to promote ecocultural resources. Intensively managed areas could serve as nuclei to support broader landscape restoration by restoring frequent fire regimes, heterogeneous plant communities, and groves of large trees.

The concepts and principles of adaptive management and restoration forestry are generally consistent with efforts to promote tribal interests. However, particular attention to tribal engagement, including formal consultation as well as broader partnerships, will be important to ensure that development and implementation of strategies will uphold tribal rights, federal responsibilities, and the critical importance of ancestral lands to tribes.

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Field tour with the Lakeview Forest Landscape Collaborative in the Fremont-Winema National Forest. Photo by Tom Spies, USDA Forest Service.

Chapter 12: Integrating Ecological and Social Science to Inform Land Management in the Area of the Northwest Forest Plan

Thomas A. Spies, Jonathan W. Long, Peter A. Stine, Susan Charnley, Lee Cerveny, Bruce G. Marcot, Gordon H. Reeves, Paul F. Hessburg, Damon B. Lesmeister, Matthew J. Reilly, Martin G. Raphael, and Raymond J. Davis[1]

Main Points

- The interconnections between social and ecological systems have become clearer since the Northwest Forest Plan (NWFP, or Plan) was adopted. Meeting ecological restoration goals requires social license to conduct management, as well as agency capacity, a skilled local workforce and wood processing infrastructure, and markets for restoration products. Meeting goals for timber to support local communities, in turn, depends on restoration or management for ecological goals.
- Conserving species is challenging in the face of threats that transcend ownership boundaries and lie beyond the control of federal land managers. This reality should temper expectations for federal land management plans but could also motivate efforts to engage in cross-boundary conservation.
- Effective management of federal lands within the NWFP area depends on recognizing regional variation in ecosystems and human communities. Management actions to promote resilience and conserve species are best achieved when ecological differences in environment and disturbance regimes are taken into account. Community economies in the NWFP area have diverged since the Plan was implemented. Efforts to support local communities will be most effective when they recognize differences in the economies that support those communities.

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[1] **Thomas A. Spies** is a senior scientist emeritus, **Gordon H. Reeves** is a senior scientist, and **Damon B. Lesmeister** is a research wildlife biologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3200 SW Jefferson Way, Corvallis, OR 97331; **Jonathan W. Long** is an ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1731 Research Park Drive, Davis, CA 95618; **Peter A. Stine** was director of partnerships and collaboration (retired), Pacific Southwest Research Station, 1731 Research Park Drive, Davis, CA 95618; **Susan Charnley** is a research social scientist and **Bruce G. Marcot** is a research wildlife biologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 620 SW Main Street, Suite 502, Portland, OR 97205; **Lee Cerveny** is a research social scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 400 N. 34th Street, Suite 201, Seattle, WA 98103; **Paul F. Hessburg** is a research landscape ecologist, Pacific Northwest Research Station, 1133 NW Western Avenue, Wenatchee, WA 98801; **Matthew J. Reilly** is a post-doctoral researcher, Humboldt State University, Department of Biological Sciences, 1 Harpst Street, Arcata, CA 95521; **Martin G. Raphael** is a senior scientist (retired), U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 3625 93rd Avenue SW, Olympia, WA 98512; **Raymond J. Davis** is a wildlife biologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, 3200 SW Jefferson Way, Corvallis, OR 97331.

- The benefits of forests to society extend beyond timber. The ecosystem services concept was largely developed after the NWFP was written. The 2012 planning rule now emphasizes use of the ecosystem service framework to better align agency management with the range of values associated with federal forests. However, applications of this framework are still in the early stages, and research-management partnerships are needed to make progress.
- All management choices involve some social and ecological tradeoffs related to the goals of the NWFP. Management goals are most likely to be met when both ecological and social elements are considered and integrated. Science can reveal the tradeoffs, but managers will have to decide whether or how to address them.

Introduction

The goals of the Northwest Forest Plan for federal forests are imbedded within a diverse, dynamic, and complex social-ecological system (fig. 12-1) that has changed significantly since the Plan was implemented in 1994. In the past two decades, the capacity of the Forest Service and the forest industry to conduct restoration efforts across landscapes has declined significantly as budgets for managing resources have diminished and mills that could process the products of restoration have closed. Public values have shifted from resource production toward resource protection. The Forest Service is increasing emphasis on ecosystem services (in addition to multiple uses) as a way to communicate the diverse values of federal forests and increase public support for forest stewardship.

A major change in biodiversity conservation policy occurred for the Forest Service in the form of the 2012 planning rule, which shifted conservation emphasis toward whole ecosystem approaches and away from population viability of numerous individual species. The new rule recognizes that individual species approaches will still be needed for a few species.

New conservation concerns also have emerged, including a major threat to populations of the northern spotted owl (*Strix occidentalis caurina*) by the nonnative barred owl (*Strix varia*), which has been expanding its range. Fire suppression and fire exclusion are leading to two undesirable outcomes: (1) larger patches of high-severity fire in dry forest zones where fuels have accumulated, and (2) less diverse early-seral (post-wildfire) vegetation in drier parts of moist forest zones. Exotic invasive species are increasing in several taxonomic groups across the region and affecting native biotic communities and ecosystem processes. Finally, climate

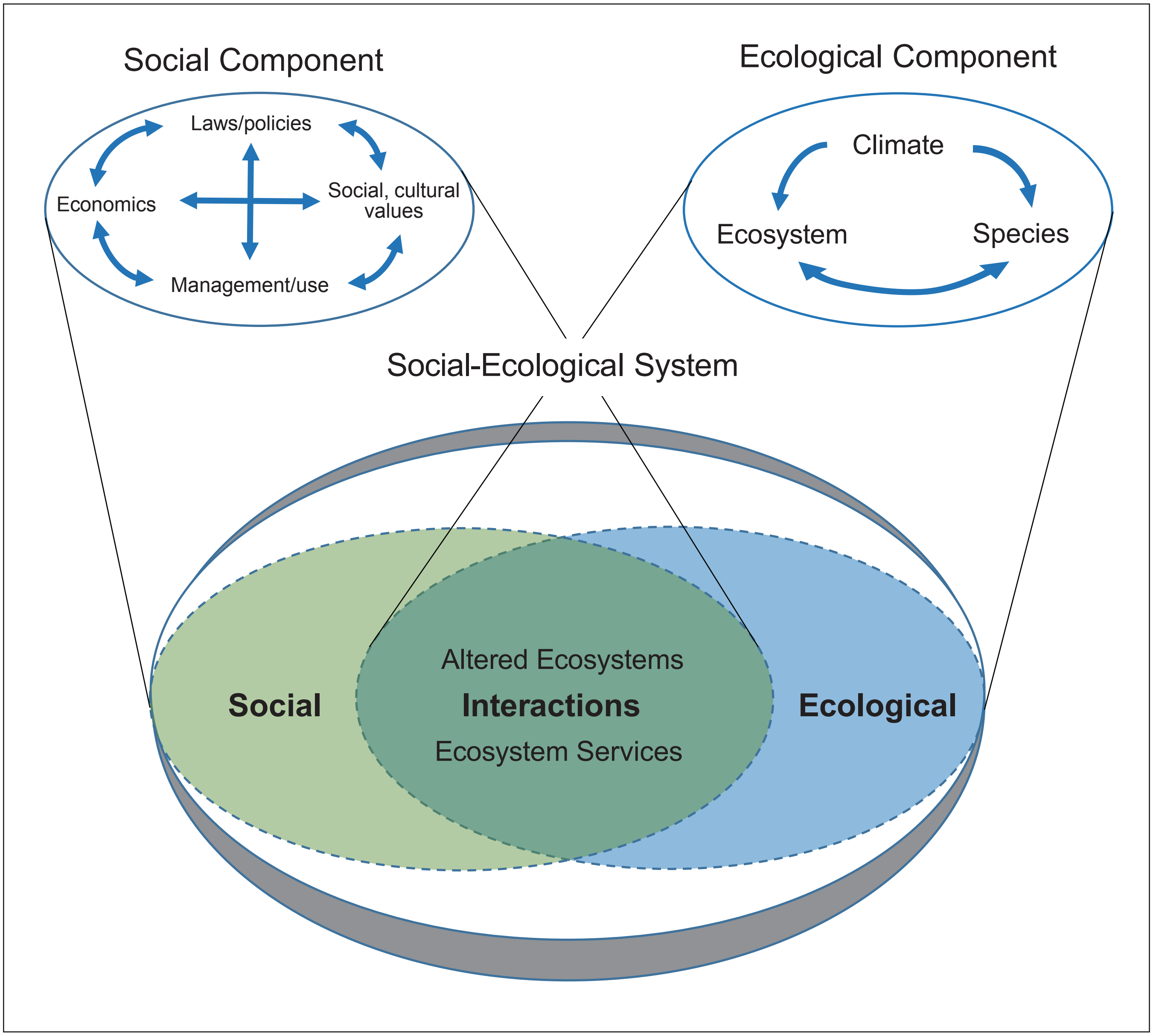

Figure 12-1—The social-ecological system in which the Northwest Forest Plan is imbedded.

change, which is already having some ecological effects, is expected to have a large but variable impact on species and ecosystems.

On the other hand, the NWFP monitoring program indicates that progress is being made toward meeting several of the original long-term goals of the Plan. It is maintaining vegetation conditions that support northern spotted owls and marbled murrelets (*Brachyramphus marmoratus)*, protecting large blocks of dense old-growth forests, providing habitat for aquatic and riparian-associated organisms, and reducing the loss of mature and old forests to logging. Other goals have not been met, such as providing for a predictable timber harvest to support rural communities, desired levels of road decommissioning, and adaptive management and learning through effectiveness and validation monitoring of old-forest species and biodiversity. Finally, congressional legislation that provided alternative formulas for payments to counties most affected by the NWPF to mitigate the financial impacts of reduced timber harvesting were realized in the short to mid term, but their long-term viability remains uncertain.

The NWFP was founded on a scientific approach that combines research, monitoring, and adaptive management, but it is ultimately a political document. Given social and ecological changes that have occurred over the past 24 years, managers may want to consider revising their approaches to management in the NWFP region to better meet the original goals as well as new goals and challenges.

Chapter 12 of the NWFP science synthesis addresses cross-cutting questions and evolving issues that require multifaceted answers drawn from both ecological and social research. These questions stem from the nexus of the conservation, restoration, and socioeconomic strategies of the NWFP, addressing how well they met their intended goal, and identifying new issues that have arisen since the Plan was established. Here we highlight key findings and management considerations.

Key Findings

Social and Ecological Interactions

For much of the 20th century, timber production was the central means by which federal forests in the NWFP area contributed to the socioeconomic well-being of communities (fig. 12-2). Although timber production remains important today in some Plan-area communities, the economies of many communities have shifted or diversified over the past two decades. Rural communities are not all alike, the NWFP affected communities differently, and the social and economic bases of many traditionally forest-dependent communities have changed. Providing for a diverse set of community benefits from public lands may be the best way to support communities in their efforts to diversify economically and contribute to building community resilience to future changes in federal forest management and policy.

The ability to sustain ecosystem services, conserve species, and promote ecosystem resilience to climate change and fire is highly dependent on socioeconomic factors. Declines in wood processing infrastructure throughout the Plan area have made vegetation management less economical. This has created a financial barrier to fully accomplishing forest restoration. With declining agency capacity, it will be difficult if not impossible to maximize all these objectives; prioritization will be needed. Production of wood from private lands is important for maintaining local

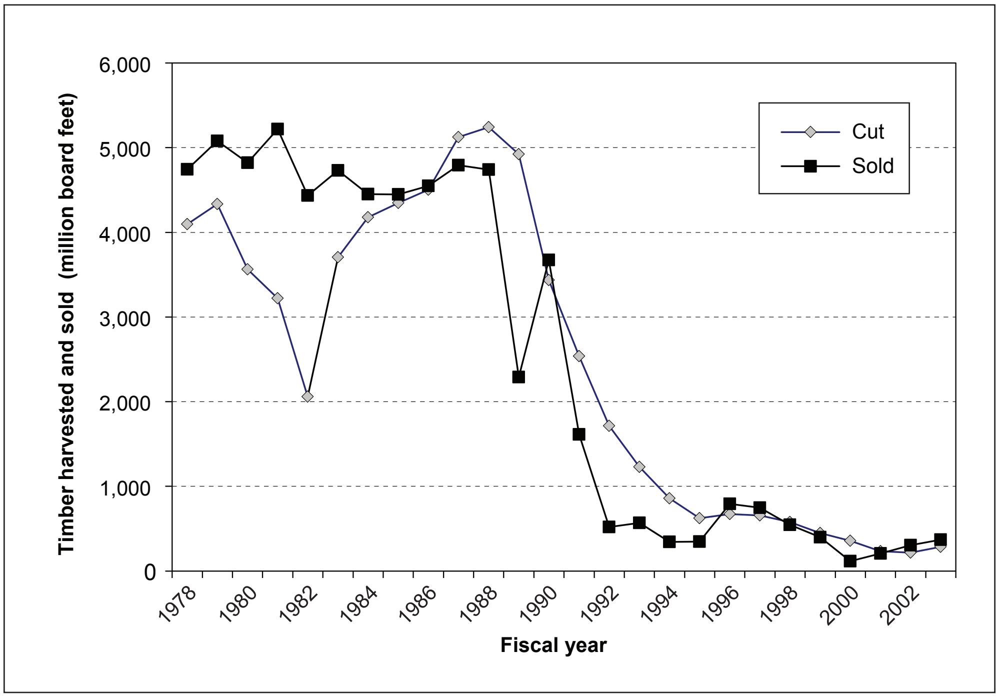

Figure 12-2—Volume of timber sold and harvested from Forest Service units in the Northwest Forest Plan area, 1970s–2002 (Charnley 2006a).

wood-processing industries. In many cases, the feasibility of restoration projects on federal lands depends on this industry infrastructure to produce and support markets for wood products and a skilled workforce to carry out the projects.

Working collaboratively to meet ecological goals—

Collaborative groups may be part of the solution to increasing trust and social license for forest management. However, collaborative processes are a relatively recent phenomenon and continued learning and adaptive management will be needed to determine the best way forward. Efforts to collaborate with neighboring landowners in planning and implementing management activities for landscape-level treatments can help increase forest resilience to climate change, invasive species, and wildfire, and help provide desired ecosystem services (e.g., fish habitat) in mixed-ownership landscapes. Any strategies to promote resilience to climate change and disturbances will need to recognize complex ecological and social system dynamics operating across land ownerships. Tensions that arise from competing values can be resolved only through social processes that include transparent accountability for all involved.

Engaging with tribes to promote tribal ecocultural resources, in part to uphold the federal trust responsibility, would also likely align with other objectives for ecological restoration.

Developing capacity to use managed wildfire as a tool—
Although major disturbances such as large wildfires can be undesirable and costly, they can also promote desired conditions and reestablish key ecosystem processes and species across more land than can be accomplished through prescribed fire or mechanical treatments. Institutional and social systems may need to evolve to take advantage of such opportunities; for example, by designing postfire management interventions based upon long-term restoration goals as well as more short-term considerations such as safety and timber salvage. Institutional capacity to take advantage of these opportunities is severely limited by an agencywide decline in staffing, a decades-long history of budget cuts in non-wildfire areas, a lack of infrastructure for processing of forest products, and monetary resource shifts toward fighting wildfires rather than restoring forests.

Conservation of Species and Ecosystems

The current outlook for widespread persistence of northern spotted owls is not good. It appears unlikely that spotted owls can persist without significant reduction in barred owl populations. Without the implementation of the NWFP (e.g., if the pace of old-growth logging from the 1970s and 1980s had continued for 23 years), spotted owl populations would likely have already become moribund. Forests capable of supporting interconnected populations of spotted owls have increased or stayed relatively stable at the Plan scale. However, the rapid pace of change in climate and fire regimes suggests that recent trends may not continue, especially in dry, fire-frequent forests.

Under the original NWFP goals, an emphasis on multilayered old-growth forest conservation was critical, given its importance to the viability of populations of spotted owls. However, the 2012 planning rule broadens and changes the focus on conservation; it emphasizes ecological integrity and resilience (ecosystem goals that were not part of the NWFP goals), and deemphasizing species-viability approaches. This means that conserving biodiversity in this region is more than about conserving dense old-growth forests for spotted owls and other species—other seral stages also are valuable, including open, fire-dependent old growth; diverse early- and mid-successional post-wildfire vegetation; wetlands; fire-dependent oak-dominated forest patches and woodlands; and shrublands and grasslands.

The contribution of federal lands to the conservation and recovery of fish, northern spotted owls, and marbled murrelet populations listed under the Endangered Species Act continues to be essential, but it is likely insufficient to reach the comprehensive goals of the NWFP, or the newer goals of the 2012 planning rule.

Collaborative efforts combined with incentives could help to increase conservation on nonfederal lands, but further research is needed to evaluate the impact of particular approaches within the NWFP context.

With congressional reserves, late-successional reserves (LSRs), riparian reserves, and administratively withdrawn areas occupying more than 80 percent of the Forest Service and Bureau of Land Management land base in the Plan area, and little cutting of old growth occurring, rates of additional fragmentation of older forests from management activities on federal lands will be very low. Landscape-level change will be dominated by succession in plantation and mid-seral forests, and an increasing area of disturbance from wildfire. Concerns over fragmentation of old-growth forests from logging have shifted toward concerns about climate change effects and access of species to climate refugia. However, the effects of past fragmentation on the biota likely have not disappeared—there may be lags in the response of some species to past landscape changes. The widespread effects of roads on species and ecosystem processes also remain a conservation concern, especially those that constrain full floodplain functioning or directly contribute high sediment loads to streams. The small amount of logging in most nonreserved northern spotted owl habitat and in mature and old-growth forests over the past 15 years of NWFP implementation does not reflect the original provisions of the Plan as written, but it does mean that the major historical threat to biodiversity (commercial logging of old-growth forests) has been greatly reduced on federal lands. This outcome may have been a result of the Survey and Manage program, which was administratively burdensome, and changes in the social acceptability of cutting old growth in the matrix.

Drier areas within the moist forest zone had historically more frequent and more mixed-severity fire than was previously appreciated. This means that fire suppression in some moist-zone forests has likely reduced the amount of structurally diverse early-seral vegetation that would have developed over the past several decades relative to the historical disturbance regime under a warming climate. Fire suppression has also likely reduced the diversity of older forest structural and compositional conditions and landscape diversity of seral stages.

A major challenge to management for resilience to fire and climate change exists in historically frequent-fire landscapes of northern California, southern Oregon, and the eastern Cascade Range of Oregon and Washington. Although fires in these areas have been increasing in recent years, they are still much less frequent than historically. However, some recent fires have created larger patches of high-severity fire compared to the historical regime, likely as a result of increased fuel accumulation and continuity. Fire exclusion has increased the area of dense forests and nesting habitat for northern spotted owls, compared to their historical amounts. Landscapes including large LSRs, in which little or no restoration or management to restore fire and successional dynamics occurs, likely will not provide for resilient forest ecosystems in the face of climate change and increasing fire.

Scientists are becoming more aware that selective active management within reserves is needed to conserve biodiversity in fire-frequent landscapes, where human activities have excluded fire and have decreased resilience of forests to fire, insects, disease, and drought. Invasive species such as the barred owl and the sudden oak death pathogen are also motivators for interventions within reserves.

Tradeoffs Associated With Management

All management choices involve some social and ecological tradeoffs related to the goals of the NWFP. For example:

- Variable-density thinning can accelerate the development of large live trees and habitat diversity that will benefit northern spotted owls and other species in the future, and produce wood products for the market. However, within the range of the murrelet, these actions may have a short-term negative impact on habitat quality by creating diverse understory species that benefit murrelet nest predators. These thinning treatments also can reduce amounts of dead wood that provide habitat to other species.
- Thinning and restoring fire to fire-dependent forests will increase habitat for species that use more open older forests and increase forest resilience to fire and drought while creating restoration jobs and reducing wildfire risk in the wildland-urban interface, but these actions can reduce habitat quality for species that use dense older forests.
- Variable-density thinning in uniform plantations in riparian zones can restore vegetation heterogeneity that was characteristic of these zones under historical disturbance regimes and can promote growth of very large conifers; however, it can temporarily reduce shading of streams and production of dead wood relative to no management.
- Maintaining road systems to conduct landscape-scale restoration and support recreation will negatively affect some species and ecosystem processes. Many of the potential negative impacts can be ameliorated through landscape-scale planning and using best practices for decisionmaking.

In the long run, thinning in plantations and young forests less than 80 years old in LSRs to promote old-growth forest development will not sustain wood production for local communities. There is no new science that specifically indicates that timber management using retention silviculture in forests more than 80 years old in the matrix is inconsistent with the original goals of the NWFP. However, this source of timber may not be available if managers need to protect additional older forest in the matrix to mitigate threats to the northern spotted owl from the barred owl or avoid logging (even with alternative silviculture) of large, old trees to address social concerns. Given these possibilities, the most viable approach to long-term timber production and meeting some early-successional biodiversity goals might be an approach that creates openings in some of the plantations in the matrix. This strategy would be most effective in more productive moist forests where older plantations contain commercially valuable trees.

Monitoring and Adaptive Management

Although much has been learned in 24 years, large uncertainties remain in terms of scientific knowledge and drivers of social and ecological systems, many of which remain outside the control of federal land managers. Risk management is a widely recognized process for dealing with threats to goals, and managers may want to consider formalizing risk management in forest planning. Development, evaluation, and testing of new, highly integrated conservation strategies is encouraged to deal with uncertainties and knowledge gaps related to fire, climate change, invasive species, tradeoffs between ecosystem and species goals, and tradeoffs between ecological and social components. These forest and social systems will undoubtedly change in coming decades in ways that we have not anticipated. Continuation of research, monitoring, public engagement, and adaptive management can facilitate adaptation of forest plans and management to future change.

Management Considerations

The Socioeconomic System Has Changed Since the 1990s

Timber harvesting is no longer the only focal federal management concern from a socioeconomic standpoint. Wildfire management has risen to become an important concern for communities, especially as the number of people living near and recreating in forests has increased. Recreation has also become a significant driver or economic activity in many forest communities and will likely increase in the future. The effects of recreation on biodiversity are poorly studied.

The supply of timber harvested from federal forests has drastically declined and has not reached the level that was expected under the Plan. Efforts to use alternative management strategies have general public support (in contrast to lack of support for clearcutting), and expanded use of restoration treatments (e.g., ecological forestry) could increase the volume of timber produced over recent levels and contribute to local wood markets. Agencies could consider structuring restoration contracts in ways that make them more accessible to local communities.

Rural communities are not all alike and approaches to garnering ecosystem services (including timber) and adaptation to wildfire may want to consider tailoring management plans and communication efforts to the community type. Major community types include (1) formal suburban, (2) high amenity/high resource, (3) rural lifestyle, and (4) working landscape/resource dependent.

The forests of the NWFP area provide many ecosystems services in addition to wood. Carbon sequestration, nontimber forest products, water supply, and recreation are among some of the most valuable of these services (fig. 12-3). Greater consideration of ecosystem services as a framing element of Forest Service plans and management may be a way to focus on forest values that are in sync with the current and changing society. Ecosystem service frameworks on federal lands may also promote more public support for agency programs, though that remains an untested hypothesis.

Places and the meanings that society attributes to them have real implications for forest management. Managers can take advantage of the positive power of place and cultural ecosystem services to engage with the public in forest stewardship projects.

Environmental justice populations are growing, and Hispanic and Latino workers are an increasing part of the forestry workforce. Agencies can affect working conditions for these populations through changes in contract markets and oversight.

The quality of a resource management decision is strongly dependent on the quality of processes that lead to it. Best practice guidelines for these processes (e.g., collaboration) include philosophy of empowerment, equity, inclusiveness, engaging stakeholders early, open communication, and iterative or frequent engagement. Collaborative groups can be part of the solution for increasing trust and social license for management.

Nongovernmental organizations and other agencies may help managers meet their social and ecological goals. Engagement with tribes to promote tribal ecocultural resources, in part as a means of upholding the federal trust responsibility, would likely also align with other objectives for ecological restoration, while also providing additional tools and resources for accomplishing those objectives.

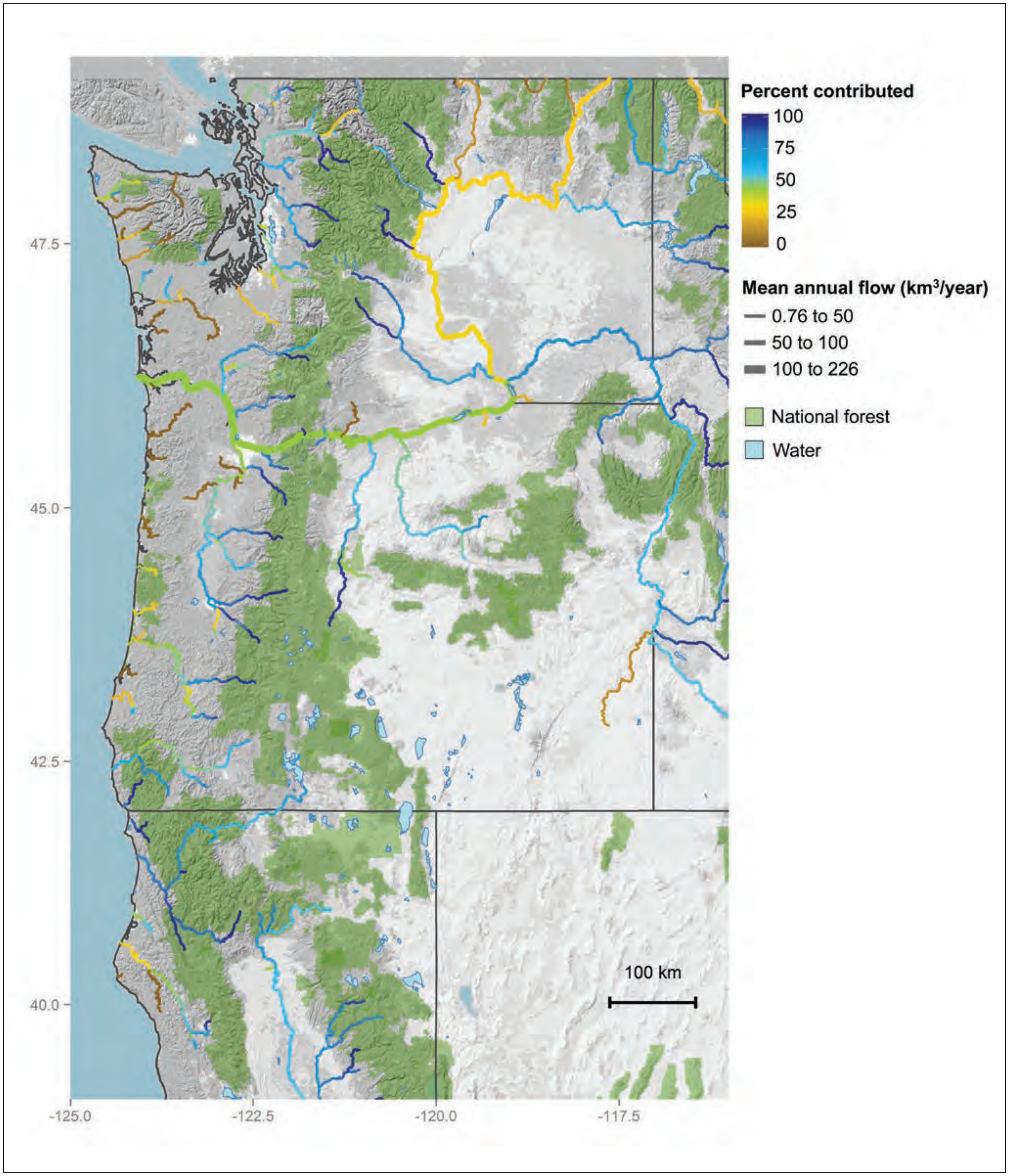

Figure 12-3—Contributions of forest service lands to streamflow, an important ecosystem service, in the Northwest Forest Plan area.

Balancing Whole Ecosystem Goals With Goals Associated With Dense Older Forests

Actions can be taken to move these ecosystems, forests, landscapes and populations of species toward more desirable conditions that are better aligned with current policies, climates, and social values. The challenge will be to determine how to prioritize restoration and address ecological and socioeconomic tradeoffs.

Ecological history can be a valuable guide for restoration, but land managers, in reality, cannot restore ecosystems to any particular historical period or condition. However, they can learn from the historical dynamics and forest patterns to develop bet-hedging strategies against large wildfires, invasive species, and climate warming. Ecological and social history demonstrates that change is inherent in these forests, and we are in a period of rapid change with uncertain outcomes.

The 2012 planning rule sets a new context and focus for ecosystem management under the NWFP: ecological integrity based on maintaining and restoring disturbance and other ecological processes and the conditions that support them. This focus is broader than the coarse-filter approach of the NWFP, which emphasized one successional stage: dense, multilayered old growth. This means that managers and society will need to decide how to balance whole ecosystem goals and goals associated with dense older forests and the species that use them for habitat. The compatibility of these different goals will vary with spatial and temporal scale and ecological region.

Several features of the NWFP provide a good starting place for addressing conservation in an era of climate change and invasive species:

1. A large extent of ecological reserves.
2. Regional connectivity of older forest conditions across all land allocations and elevational gradients.
3. Recognition of the need for restoration and active management.

However, the standards and guidelines are not well suited for restoring fire as an ecological process that could improve resilience of forests to climate change, and we lack knowledge of how the current Plan relates to climate refugia for at-risk species. Managers may want to consider reassessing the Plan under different climate change scenarios and making changes that improve the outlook for meeting conservation and socioeconomic goals.

Forest Management Varies Regionally

Moist forests—

The goals, standards, and guidelines for moist forest LSRs with infrequent fire appear to provide a relatively good match for maintaining and restoring ecological integrity and resilience as defined under the new planning rule, especially in the face of climate change and invasive species. Focusing restoration (such as variable-density thinning) in LSRs with moist forest plantations makes sense from a conservation perspective, and can provide jobs and economic returns. However, there will be tradeoffs with some ecological goals that could require mitigation efforts. For example, snags and down wood may need to be created to produce desired amounts of dead wood.

Fire suppression has affected vegetation in moist forests, especially in the drier part of the zone where historical fires were more frequent, mixed-severity effects were more common, and seral stage patchworks were more varied. Some level of fire suppression will always be needed in these forests. However, restoring fire or using fire surrogates (e.g., variable-density thinning) are important strategies for managers to consider to promote early-successional forests and diversity in plantations and forests more than 80 years old in the matrix. Managing for diverse early-seral stages would require developing landscape-scale prescriptions to ensure that old-growth goals were not compromised.

Given the social pressure to avoid logging older trees, producing wood from existing plantations in matrix lands may be a win-win opportunity for promoting biodiversity associated with early-seral ecosystems and providing economic returns to support local communities.

Dry forests—

The goals, standards, and guidelines for LSRs in dry forests that prioritize conservation of existing dense older forests appear to be inconsistent with management for ecological integrity and resilience to climate change and fire, as defined under the new planning rule. Dense late-successional and older forests would have been relatively uncommon in most dry forests, and their current higher abundance is largely a result of fire exclusion.

Management actions that promote resilience in fire-prone forest landscapes both within and outside of LSRs include promoting the growth of large, fire-resistant trees through thinning; reducing the vertical and horizontal continuity and volume of forest fuels (fig. 12-4), restoring the patchwork of open- and closed-

Susan Charnley

Figure 12-4—Thinning to restore forest resilience to wildland fire.

canopy forests; and tailoring these conditions to topography. Active management, including restoring fire processes, can also benefit many tribal values. Landscape-level strategies such as working with native diseases and insects to promote heterogeneity and considering the needs of focal species are needed to meet diverse ecological and social goals for these dynamic landscapes in the face of increasing wildfire and drought.

The Challenges of Conserving Individual Species

Northern spotted owl—

Continued success at conservation of northern spotted owls under the NWFP rests on understanding how to minimize the impacts of barred owls and on how to manage dry- and moist-zone forests in ways that meet overlapping species and ecosystems goals.

Marbled murrelet—

The current design of the NWFP appears to be valid for recovery of populations of marbled murrelets. However, threats from nest predation by jays and crows, conditions in the marine environment, and climate change introduce uncertainties into expectations for habitat and population trends.

Other species in older forests—

Information gleaned from surveys conducted during the early phase of the NWFP enabled the removal of many species from Survey and Manage program lists. Given the lack of surveying and monitoring of other species, it is now difficult to address the conservation status of those species that remain on the lists. Decline in harvest of old growth is expected to lower risk to these remaining species. Knowledge about species associated with early-seral vegetation and fire-dependent communities is not well developed.

Importance of Restoration in Aquatic and Riparian Ecosystems

The Aquatic Conservation Strategy has contributed to improvements in riparian and stream ecosystems. However, contributions from streams and forests on nonfederal lands are still important to achieving NWFP conservation goals, especially under climate change, which may shift species distributions. Transboundary collaborative groups can help restore watersheds and fire regimes, especially when supported by innovative arrangements to share funding, resources, information, or liability.

Management in riparian reserves can be justified to increase compositional and structural variability and diversity of successional pathways in areas where uniform conifer plantations dominate riparian areas. Creating snags and felling trees with root wads can mitigate undesirable effects of management on dead wood. Justification for using the second site-potential tree-height to set the width of riparian reserves is not strongly supported for microclimate functions, but other functions (e.g., landscape connectivity) could be compromised if reserve boundaries were reduced.

Under current goals, a restoration strategy will need to ameliorate damage from past human actions to restore degraded systems or at least increase their resilience to climate change and fire. Areas ripe for consideration include culverts that are likely to fail in priority watershed areas, some dams and diversion used for irrigation water withdrawal, and identifying areas that would benefit from intensive thinning and use of fire.

Rethinking Reserves

The science is clear that reserves are a critical component of conservation. The science also suggests that active management may be needed and that reserve design should periodically be reevaluated and revised to address new goals or threats. Changes could include revising standards and guidelines, expanding reserves, increasing connectivity of reserves, shifting locations of small reserves, or using dynamic landscape approaches based on disturbance ecology to guide management. Ideally, meeting ecosystem goals for reserves would require reserve areas that are large enough to support fire and other key natural disturbance processes. Using disturbance-based management approaches to conservation (as opposed to focusing on a single seral stage or species) is likely to require a robust social component to increase transparency, public understanding, and trust in managers.

Conclusions

The NWFP is a science-based plan to conserve terrestrial and aquatic species (especially the northern spotted owl) and ecosystems associated with older dense conifer forests, and to produce a sustainable supply of timber. The Plan has conserved old forests and their associated species but has not produced the levels of timber that were expected. The policy, social, and ecological context for the NWFP has changed since the Plan was implemented nearly 25 years ago. A significant change occurred with the 2012 planning rule, which shifted the planning and management emphasis toward ecosystem approaches (e.g., ecological integrity) and away from focusing on the viability of many single species (with exceptions for a few species that are not well suited to ecosystem approaches).

New conservation concerns have also arisen, including a major threat to northern spotted owl populations from expanding populations of the nonnative barred owl, effects of fire suppression on forest succession and fire behavior in dry forests, and lack of development of diverse, early-seral vegetation in moist forests. Invasive species and climate change are also now recognized as significant threats to conservation of native ecosystems and species.

The connections between social and ecological systems have also become clearer. For example, declining agency budgets, lack of markets for restoration products, and mill closures reduce capacity to meet ecological restoration goals. The 2012 planning rule now emphasizes use of an ecosystem service framework to better align agency management with the range of values associated with federal forests. Rural communities are not all alike; many with economies formerly based on federal timber have shifted to amenity-based economies based on recreation on federal lands. For those economies that still depend on federal timber, restoration management, (e.g., ecological forestry) can contribute to local and regional timber supply but will not fully replace the federal timber that was produced prior to the NWFP.

Active management is important to meeting ecological and socioeconomic goals, but social license for active management can be difficult to find. Collaboration efforts can be an important tool for increasing trust in managers and support for restoration. However, collaboration is not a panacea for increasing rates of restoration, and the effects of collaboration on landscape outcomes are not well understood.

The NWFP was intended to be adaptive and responsive to new ecological and social knowledge and issues, but formal adaptive management efforts were not sustained. Despite this shortcoming, much has been learned through research, monitoring, and experience in implementation of the Plan. Given the policy, social, and ecological changes that have occurred, managers may want to consider revising the Plan to address several issues, including:

1. Increased threat to the northern spotted owl from the barred owl.
2. Decreased resilience of forests to fire and climate change in the dry forest region.
3. Declines in vegetation diversity (e.g., diverse early-seral and other vegetation stages) in drier parts of the moist forest region.
4. Potential for using patch cutting in plantations in the matrix to produce a more sustainable flow of timber and create early-successional vegetation.
5. Declining forestry infrastructure (e.g., workforce and mills) and capacity to do active management for ecological and social goals.
6. Recognizing that human communities in the Plan area are diverse and need to be supported in different ways.
7. Using the variety of ecosystem services from public lands to assist communities in their efforts to diversify economically.

Large uncertainties remain related to the ability of plans and management to meet old and new agency goals, including conservation of old-forest species, management for ecological integrity, use of ecosystem services, and benefits and sustainability of collaboration. Risk management, adaptive management, and monitoring are considered the best ways to deal with complex social and ecological systems whose futures are difficult to predict, or to affect through policy and land management actions alone.

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Pacific Northwest Research Station

Website	http://www.fs.fed.us/pnw/
Telephone	(503) 808–2592
Publication requests	(503) 808–2138
FAX	(503) 808–2130
E-mail	pnw_pnwpubs@fs.fed.us
Mailing address	Publications Distribution Pacific Northwest Research Station P.O. Box 3890 Portland, OR 97208–3890

U.S. Department of Agriculture
Pacific Northwest Research Station
1220 SW 3rd Ave.
P.O. Box 3890
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