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 Stine, Susan Charnley, Lee Cerveny, Bruce G. Marcot, Gordon Reeves, Paul F. Hessburg, Damon Lesmeister, Matthew J. Reilly, Martin G. Raphael, and Raymond J. Davis[1]

> "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."
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> —E.O. Wilson, *Consilience: The Unity of Knowledge* (1988)

Introduction

Long-term monitoring programs and research related to Northwest Forest Plan (NWFP, or Plan) goals, strategies, and outcomes provide an unprecedented opportunity to examine how the scientific basis and socioecological context of the Plan may have changed during the 23 years since its implementation. We also have a prime opportunity to reassess how well the goals and strategies of the Plan are positioned to address new issues.

The NWFP was developed in 1993 through a political process involving scientists in an unusual and controversial role: assessing conditions and developing plan options directly for President Bill Clinton to consider with little involvement of senior Forest Service managers. The role of Forest Service scientists in this planning effort is different—scientists are now limited to producing a state-of-the-science report in support of plan revision and management (USDA FS 2012a), and managers will conduct the assessments and develop plan alternatives.

Implementation of the NWFP was followed by monitoring, research, and expectations for learning and adaptive management; however, little formal adaptive management actually occurred, and the program was defunded after a few years. The goals of the NWFP were daunting and set within the policy and ecological context of the time. President Clinton's question to the Forest Ecosystem Management Assessment Team (FEMAT) was "How can we achieve a balanced and comprehensive policy that recognizes the importance of the forest and timber to the economy and jobs in this region, and how can we preserve our precious old-growth forests, which are part of our national heritage and that, once destroyed, can never be replaced?" (FEMAT 1993). The 1982 planning rule guided land management planning on National Forest System lands, emphasizing conservation based in part on maintaining population viability of native species.

Although many conservation concerns have not changed, new science and challenges have emerged. For example, since the Plan was developed in the early 1990s, the invasive barred owl (*Strix varia*) has become a major threat to populations of the northern spotted owl (*S. occidentalis caurina*) (chapter 4), the number of Endangered Species Act (ESA)-listed fish species has gone from 3 to more than 20, and the frequency and extent of wildfires in dry forest portions of the Plan area have increased substantially in response to climate warming (chapter 2) (Reilly et al. 2017a, Westerling et al. 2006).

[1] **Thomas A. Spies** and **Gordon Reeves** are senior scientists, and **Damon 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 Stine** was director of partnerships and collaboration (retired), U.S. Department of Agriculture, Forest Service, 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 St., Suite 400, Portland, OR 97205; **Lee Cerveny** is a research social scientist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 400 North 34th Street, Suite 201, Seattle, WA 98103; **Paul F. Hessburg** is a research landscape ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1133 N Western Ave., Wenatchee, WA 98801; **Matthew J. Reilly** is a postdoctoral 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 Ave. SW, Olympia, WA 98512; and **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 policy context and social dimensions of the NWFP have also changed. For example, the 2012 planning rule (USDA FS 2012a) places more weight on managing for ecological integrity (an ecosystem or coarse-filter approach) and less weight on population viability of individual species (a species or "fine-filter approach) (Schultz et al. 2013) than did the 1982 rule. The Plan's evaluation of societal influences did not address the emergence and expansion of collaborative processes throughout the NWFP region (Skillen 2015), and the FEMAT assessment itself (1994) largely focused on commodity-based economic development and support for maintaining stability of local and regional economies (Charnley 2006a). In addition, many but not all local economies of the region have diversified away from dependence on federal timber, and the forest products industry has largely moved away from using and valuing large logs, favoring instead the use of small-diameter trees (Haynes 2009).

Scientists in the Plan region also now more fully understand that the social and political context of the NWFP had a strong influence on the setting and attaining of the ecological goals of the Plan—opinions and debates about federal forest management in the region were as much about social values and conflict resolution as they were about science (Lange 2016, Spies and Duncan 2009). Given this context, it is important to have realistic expectations for how this science synthesis might contribute to the assessments and subsequent revision of individual forest plans and forest management. Scientific findings alone will not resolve political debates about the use of natural resources. Reducing scientific uncertainty will not necessarily reduce political uncertainty; and politics will always outweigh science because "science does not compel action" (Pielke 2007). However, providing the latest scientific information and reducing scientific uncertainty are expected to lead to better management decisions within the context of social and political constraints.

There is also an increased emphasis on the social dimension of planning today compared to when the NWFP was developed. Federal managers increasingly use collaboratives, stewardship contracts, and local participation in decisionmaking (Leach 2006, Urgenson et al. 2017). The 2012 planning rule also emphasized that plans must provide for "social, economic and ecological sustainability." This increased emphasis on integrating social and ecological aspects of forest planning coincides with the developing science of coupled human and natural systems or "social-ecological systems" (Liu et al. 2007) (fig. 12-1).

This socioecological perspective goes well beyond the ecosystem management framework that guided development of the NWFP by accounting for interactions between social and ecological systems to help deal with system complexity (fig. 12-1), surprises, and unintended outcomes from policies (Spies et al. 2014). For example, the relationship of federal forests to community well-being has changed since initiation of the Plan. Many communities no longer depend on the economic contributions of wood products as they once did (Charnley 2006a). There is growing recognition of the economic benefits of public lands to communities from recreation and tourism (White et al. 2016a) and nontimber forest products (Alexander et al. 2011), and recognition that ecosystems provide many benefits to human communities beyond timber and nontimber resources. Many studies indicate that the impact of humans on the environment in the NWFP area is much broader than the effects of natural resource extraction. Furthermore, it is clear that the timber industry has also experienced changes throughout the NWFP region, many of which are independent of management decisions on federal lands (e.g., fluctuations in national and global markets for wood products, transformations in how forest products companies are structured, and adoption of new technologies for wood processing) (chapter 8). At the same time, researchers and managers better understand connections between the organizational capacity of agencies, mill infrastructure, and business capacity in the private sector (e.g., a skilled workforce) in achieving forest restoration goals (chapter 8).

The fundamental assumption of the NWFP was that the breadth of the biological and socioeconomic strategies would achieve its biodiversity conservation and socioeconomic goals, and that those goals were also compatible with each other. Scientists and managers now have the perspective afforded by 23 years of research, monitoring, and field experience to suggest that these assumptions were

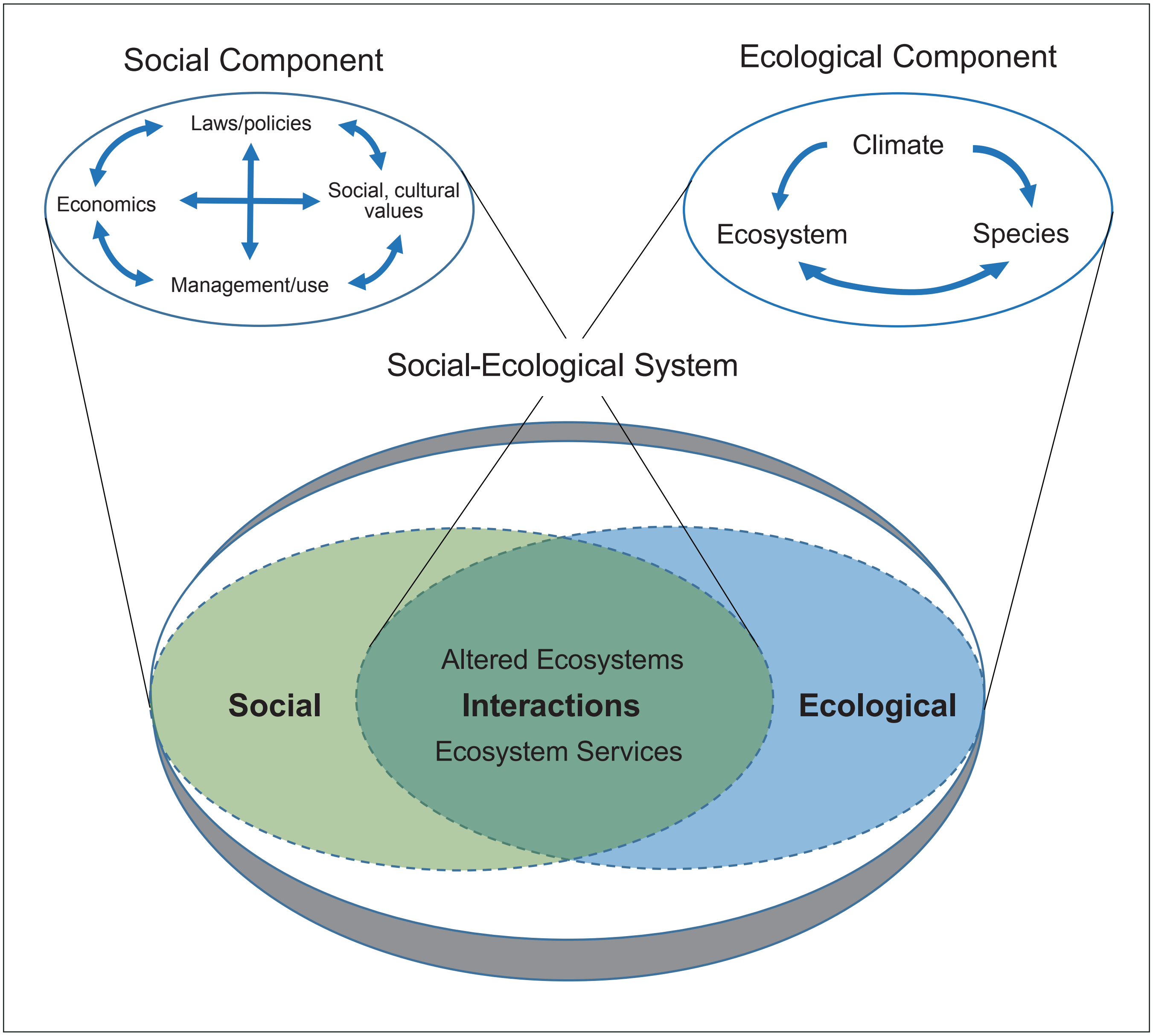

Figure 12-1—Major components and interactions in the Northwest Forest Plan social-ecological system.

only partially correct. In this chapter, we explore these assumptions in depth, using the lens of socialecological systems, and we identify new issues and concerns. We have four major objectives in this chapter:

1. Set the broader context of the NWFP goals and conservation approaches in terms of the science of socialecological systems.
2. Increase awareness of the diversity of ways that humans have influenced forest ecosystems, landscapes, and species of the Pacific Northwest.
3. Characterize how the conservation, restoration, and socioeconomic strategies of the NWFP interact, and how well they meet the original goals and new issues that have arisen since the Plan was established.
4. Identify key scientific uncertainties, research needs, and management considerations.

Guiding Questions

The guiding questions for this chapter are partly based on the questions from the managers (chapter 1), which are addressed more directly in individual chapters, and on cross-cutting questions and issues identified by the authors. The guiding questions for this chapter are:

1. What are the latest findings and perspectives on how global environmental change (including climate, land use, and invasive species changes) is altering forest and aquatic-riparian ecosystems, and their disturbance processes, and how relevant is this science to the NWFP area?
2. What are the latest scientific perspectives on reserve management for species conservation, given new understanding of ecosystem dynamics, and the influences of global environmental change?
3. What are key social components and drivers of the social-ecological systems in the NWFP area?
4. How compatible are the goals and strategies of the NWFP, and how well have the goals been met?
5. How compatible are coarse- and fine-filter approaches that simultaneously guide management for forest ecological resilience and single species viability across the range of disturbance regimes in the NWFP area?
6. What are new concerns within the social-ecological system of the NWFP area, and how well are the original Plan goals and strategies positioned to deal with them?
7. What is known about the tradeoffs of restoration actions across a range of conservation and community socioeconomic well-being goals?
8. What are the current and projected regional-scale issues and challenges associated with the goals of the NWFP?
9. What planning and management approaches are available for dealing with uncertainty in complex-social-ecological systems?
10. What are uncertainties, research needs, and management considerations related to plan revision in the area of the NWFP?

Key Findings

Perspectives on Conservation in an Era of Global Environmental Change

Overview of human influences on Northwest Forest Plan forests and aquatic-riparian ecosystems—The effects of humans on forest ecosystems in the Plan area go well beyond timber management impacts and often originate from Earth system processes outside the region. The impacts of human activity to the global environment have become so pervasive that many scientists are beginning to argue that we are in a new geological epoch called the "Anthropocene" (Crutzen 2006, Steffen et al. 2007). Beginning in the early 1800s, this period of rapid industrialization, population growth, and global trade and transportation led to dramatic increases in atmospheric carbon, land use change, altered disturbance regimes, and introduction of nonnative species. (Carey 2016, Corlett 2015, Creed et al. 2016, Lewis and Maslin 2015, Lugo 2015, Sun and Vose 2016, Wohl 2013).

Americans Indians had managed landscapes in the NWFP area for 10,000 years to create conditions that favored food resources and other cultural values; fire was their most important environmental management tool (Charnley et al. 2007, Robbins 1999, White 1993). However, human activity since development of industrial society in the 19th century has brought many additional large changes to species, forests, streams, and landscapes of the Plan area. Although the ecosystems of the NWFP area are relatively unaltered by recent human activity compared to much of the United States, little if any area of the Plan area could be considered uninfluenced by humans. Forests and landscapes have been altered from pre-Euro-American conditions by human activity including logging, plantation management, building roads and trails, dam and levee construction, and fire exclusion. Even forests and watersheds in designated wilderness areas and in large unroaded areas (Strittholt and DellaSala 2001) have been influenced by humans, climate change, introduced diseases, fire suppression, and other factors (chapter 3) (Hessburg et al. 2016).

Nearly all forests within the NWFP area depend on fire to different degrees. Fire exclusion in dry forests, which occupy 43 percent of the Plan area, has had a profound effect on forest structure and composition, native biodiversity, and resilience to fire and climate change (chapter 3). Although fire activity has increased since the NWFP was implemented, most fire-prone forest landscapes are still running a fire deficit in comparison with conditions prior to the mid to late 1800s when fire frequency declined across the dry-forest zone (chapter 3) (Parks et al. 2015, Reilly et al. 2017a). Burned area is also less than would be expected under the current warming climate (chapter 2), for both moist and dry forests, as a result of fire suppression (chapter 3). The decline or elimination of intentional burning by American Indians is also part of altered disturbance regimes and ecosystems in many areas (chapter 11). The wildland-urban interface is also expanding rapidly in the Plan area. This expansion creates challenges to conservation and management including balancing fire protection and fire restoration goals (Hammer et al. 2007, Paveglio et al. 2009), both of which have implications for biodiversity conservation (McKinney 2002).

Biotic changes are also altering the ecosystems of the NWFP area. The extirpation of top predators and invasions by other species have altered food webs and the trophic structure and dynamics of terrestrial and aquatic ecosystems (Beschta and Ripple 2008, 2009; Wallach et al. 2015) across the region. Invasive species such as the barred owl are having significant effects on the northern spotted owl, and the sudden oak death pathogen (*Phytophthora ramorum*) is altering community structure and fire behavior across large areas of northern California and southern Oregon (Metz et al. 2011). Many of these biotic changes are challenging to deal with in a forest-management context because they are rooted in biological processes (e.g., demography, dispersal, and competition), whose control is often beyond the scope of federal forest land managers.

Finally, climate change is increasingly warming all parts of the NWFP region to levels that may exceed climate conditions experienced in the past 1,000 years (chapter 2). These conditions will continue to alter disturbances, ecological processes, plant and animal community structure, and biotic diversity (chapter 2) (Watts et al. 2016), and they will change the expected outcomes of NWFP conservation strategies (chapters 2, 3, 6, and 7).

In summary, forests, watersheds, and biotic communities in the Plan area have been influenced by native peoples for millennia, while human activities during the past 150 years have not merely altered them but reduced their resilience to natural disturbances. This reality has at least three major implications:

1. Some ecological conditions, even in old-growth forests, that are perceived as "natural" have been influenced by human activity.
2. Restorative actions may be needed to achieve goals for desired species and levels of resilience of forests and aquatic ecosystems to climate change and disturbances.
3. Knowledge of historical ecology can help guide us to the future, but management cannot recreate historical conditions.

Conservation in the Anthropocene

Unprecedented ecological shifts or alterations that have occurred across the globe are also described by an emerging concept of "novel" ecosystems, which describes systems that have "departed entirely and irreversibly from their historical analogs" (Hobbs et al. 2009, 2014; Radeloff et al. 2015). One implication of this perspective is that society may have to accept and manage for some of these novel or "hybrid" (seminatural) states, where it is impractical to change existing conditions. Pressures to maintain the status quo of altered conditions will most likely occur where current conditions provide values (supporting local livelihoods, quality of life, or habitats of desired species) that may not have occurred there historically.[2] This perspective does not mean that maintenance or restoration of native communities or historical dynamics could **not** be a goal—only that many scientists increasingly recognize that restoring and maintaining ecosystem integrity based on the historical range of variation of ecosystem attributes may not be attainable in some places, for ecological or social reasons. Sayer et al.

[2] There is a precedent for this in the National Forest Management Act: "…fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area" (36 Code of Federal Regulations, sec. 219.19, app. 13).

(2013) and Hobbs et al. (2014) recommended using landscape approaches (e.g., spatially based planning over large and heterogeneous areas and long time frames) that recognize the social dimensions of the problem (e.g., see Cissel et al. 1999, Hessburg et al. 2015, 2016) to identify where it is possible to retain or restore native biodiversity, and where acceptance or management for some novel or "hybrid" (seminatural) qualities or ecosystems might be desirable.

Recognizing the realities of altered ecosystems in the current era has implications for using the 2012 planning rule (USDA FS 2012a). The rule is based on managing for ecological integrity—ecosystems that "…occur within their "natural range of variation[3] and can withstand and recover from most perturbations." The rule also includes the concept of resilience[4] as related to ecological integrity, in the sense that ecosystems with integrity are resilient and able to recover from disturbances (Bone et al. 2016). Given the pace and scale of environmental change, it may be tempting to assume that history or the historical range of variation are no longer relevant to conservation and management; however, this is not necessarily the case (Higgs et al. 2014, Keane et al. 2009, Safford et al. 2012). In conservation and management, the question is not the fundamental value of history, but how it is used (Keane et al. 2009, Safford et al. 2012). Knowledge of the past can inform management in several ways: (1) history as information for how ecosystems function, or as a reference, (2) enriching cultural connections to the land, and (3) revealing possible futures (Higgs et al. 2014). Using history to set precise reference information and targets may become less important and even have negative consequences (in the case of precise targets) as climate and landscape changes continue, but other types of historical information may become more valuable (Hiers et al. 2016, Higgs et al. 2014). Information about the historical range of variation may be derived from simulation and statistical models and from empirical reconstructions of ecological history and its variations (Hessburg and Povak 2015). Safford et al. (2012) provided several recommendations on the use of history in restoration and conservation including the following:

- Do not ignore history; to understand where an ecosystem is going, you must understand where it has been.
- Do not uncritically set management objectives based on historical conditions and avoid aiming for a single, static target.
- Historical conditions may be a useful short-term or medium-term "waypoint" for management, but they will rarely suffice to prepare an ecosystem for an altered future.
- Plan for the future, but do not forget that the past provides our only empirical glimpse into the range of possible futures.

Our advances in understanding the role of ecological history in a time of global change, notwithstanding the development of guiding principles, clear ecological goals, and metrics, is still a significant challenge and must increasingly consider the social dimensions of environmental problems. Managing for ecological integrity rather than more narrowly for the historical range of variation is considered a more realistic approach, but it is not without its own limitations. Managing for ecological integrity includes significant effort to conserve native biodiversity and promote resilience of species and ecosystems to climate change and invasive species (chapter 3) (Hessburg et al. 2016, Wurtzebach and Schultz 2016). But more importantly, managing for ecological integrity recognizes the importance of ecological processes such as natural disturbance agents that control the dynamics of ecosystems. Managing for ecological integrity and using it to guide monitoring and restoration efforts is a relatively new idea that has yet to be widely applied and evaluated in a land management context (Wurtzebach and Schultz 2016). Ecological integrity also includes managing for ecological resilience, which is the capacity to "reorganize

[3] For our purposes in this chapter, we use "historical range of variability" and consider it synonymous with "natural range of variability." See Romme et al. 2012 for comparisons of the definitions of historical range of variability and natural range of variability.

[4] Resilience is the capacity of a system to absorb disturbance and reorganize (or return to its previous organization) so as to still retain essentially the same function, structure, identity, and feedbacks (see Forest Service Manual Chapter 2020 and see also "socioecological resilience" in the glossary). Broad conceptions of resilience may encompass "resistance" (see glossary), while narrower definitions emphasize the capacity of a system or its constituent entities to respond or regrow after mortality induced by a disturbance event.

while undergoing change so as to essentially maintain the same function, structure, identity, and feedbacks" (Walker et al. 2004). The concept of ecological resilience is increasingly used by the Forest Service, but its use has been ambiguous and open to local interpretation (Bone et al. 2016). "Resilience" can be a useful term and goal only when clarified in terms of "resilience of what, to what?" (Carpenter et al. 2001). A major challenge of managing for ecological integrity or resilience, which are both based on understanding ecological history, is the lack of historical knowledge of ecosystems and their variability in many ecological components and processes. A second challenge is knowing future states: there may be multiple possible alternative states of ecological integrity based on certain realities of climate change, invasive species, and changing social values (Duncan et al. 2010, Romme et al. 2012).

Given changing anthropogenic climate change, land use changes, and changes in societal preferences, it is necessary to acknowledge the critical importance of social systems as both drivers of ecological change and as drivers of policy goals and expectations for forests. The importance of the social system suggests that the concept of resilience or integrity should be broadened to focus on managing for social-ecological resilience to global changes within the inherent capacities of earth life-support systems (Carpenter et al. 2001, Folke 2006). Managing for a broader concept of resilience may be more realistic than managing for a specific range of historical variation (Safford et al. 2012, Stine et al. 2014, Wurtzebach and Schultz 2016) or only a biophysical condition. It means focusing on both ecological and social systems and their interactions, and defining resilience not just in terms of recovery of desired ecological or social conditions (which may not be possible) but also adaptation, transformation, learning, and innovation that may lead to new systems that are better adapted to the current biophysical and social environments. Using social-ecological systems frameworks may provide a pathway toward better recognition of how federal forest management is influenced by the interplay of these two systems and where opportunities and barriers lie to reaching federal land management goals, which typically include both ecological and social outcomes. However, managing specifically with social-ecological resilience in mind is still in an exploratory, conceptual stage (Folke 2006), and it remains to be seen how using this framework could improve the effectiveness of federal management.

Fire exclusion—
Although clearcutting of moist old forests had a major effect on ecosystems in the area of the NWFP, altered fire regimes have also affected species and ecosystems. Fire is a critical ecological process in most of the forests of the Plan area, and this chapter devotes considerable attention to complex and sometimes controversial (see chapter 3) fire-related issues. This emphasis on fire is motivated by several factors: (1) fire is a fundamental process that affects most forest ecosystems, species, and human communities of the region; (2) the scientific understanding of the role of fire in both moist and dry forests has increased significantly since the Plan was developed; (3) the 2012 planning rule emphasized ecological integrity and restoration, which are grounded in disturbance ecology—and fire is generally the most significant and altered disturbance in the region; (4) managers have relatively more influence on fire, through suppression policies and management of vegetation, than do most other disturbance processes (e.g., wind or diseases) in the Plan area, and (5) prescribed fire and fire suppression have become a major component of federal land management efforts in policy and budgets in recent years.

The area of the NWFP encompasses a wide range of forest environments and can be broken into two major forest zones (dry and moist) and four different historical fire regimes (chapter 3; fig. 12-2).

One of the most pervasive anthropogenic effects within the drier forest zone, which makes up almost half of the NWFP area, is a major shift in fire regimes as a consequence of fire exclusion and suppression[5] (chapter 3). Lack of fire in dry forests and moist mixed-conifer forests, which historically experienced frequent to moderately frequent wildfire, altered forest structure and composition, and had cascading ecological effects on ecosystems and species.

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[5] Fire exclusion is the minimizing or removal of wildfire as a keystone ecological process, either indirectly as a result of livestock grazing, roads, railroads, agriculture, and development, or directly via intentional fire suppression and prevention activities. Fire suppression is the act of putting out wildfires.

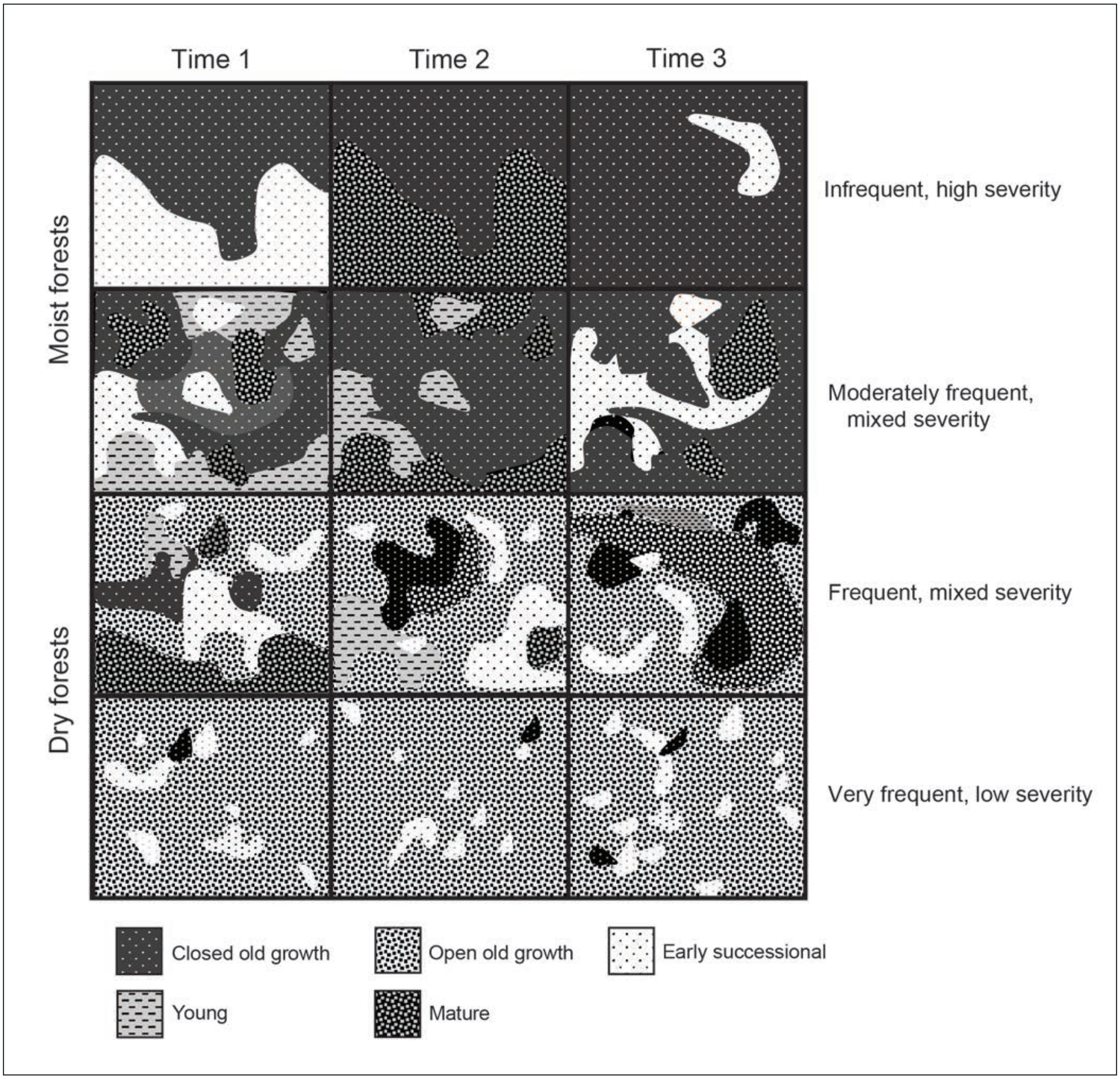

Figure 12-2—Idealized spatial patterns of forest successional stages in the two major forest zones and the four historical disturbance regimes of the Northwest Forest Plan area at three arbitrary points in time. Time 1 and 2 are separated by about 100 years; time 3 is at least 400 years later so that patterns from time 1 and 2 are not evident. See chapter 3 for more information. Illustration adapted from Agee 1998.

These effects include:

- Increased forest density and abundance of shade-tolerant tree species.
- Loss of early-successional, open-canopy young, and open old-growth forest types, and altered successional pathways.
- Increased area of dense, young, multistoried forest vegetation that is used by the northern spotted owl and other late-successional species.
- Decline in habitats for species that use open, fire-frequent forests or early-successional vegetation.
- Less frequent fire, but when fires occur under extreme weather conditions, they can result in uncharacteristically large, high-severity patches of fire.

Larger patches of high-severity fire in this historical regime may have undesirable short- and long-term effects in terms of accelerated upland erosion, loss of forest cover to continuous shrubfields, chronic stream sedimentation, chronically elevated bark beetle populations, and reduction of services from forests of all seral stages (chapter 3). Large patches of high-severity fire in forest ecosystems that historically burned with frequent but low-severity fire can kill many of the large, old, fire-resistant trees that survived fires in the past. Such trees are considered a regionally and globally significant "keystone ecological structure" in a wide range of ecosystem types (Lindenmayer et al. 2014). Extremely large and unusually severe fires also have major social and economic impacts through heavy smoke, evacuations, greenhouse gas emissions, costs of firefighting, lost productivity, and threats to and loss of lives, income, and property. Such social and economic impacts are expected to increase, particularly in the NWFP area, as climate change results in more hazardous fire and smoke conditions (Liu et al. 2016). The landscapes left following extremely large and uncharacteristically severe fires can pose significant management challenges too, as reforestation treatments can be costly and often dangerous in many burned areas. Planting may be needed to avoid persistent loss of forest cover in some areas, yet reintroducing fires while protecting the investment in young, fire-susceptible trees is particularly challenging.

Fire exclusion has also had an effect in moist forests that historically experienced long fire-return intervals. The effects are different than in dry forests, and relate mainly to decreased occurrence of diverse early and mid-successional and nonforest (meadow) vegetation. High levels of fuel accumulation at stand scales and landscape connectivity of fuels are characteristic of moist productive forests that grow for many decades or centuries without fire. However, lack of fire in drier parts of moist forests may lead to more homogeneous stand structures and fuel beds than occurred historically, when infrequent fire created a mosaic of seral stages. The broader ecological implications (e.g., ecosystem function and fire behavior) of these changes are not clear and are in need of further research (Tepley et al. 2013).

Social perspectives on altered forests—
The challenges to managing for ecological integrity, resilience, and desired species in the NWFP area are both ecological and social. In moist forests, where fire was and continues to occur infrequently, uniform plantations, the time required for succession to old growth (centuries), and fragmentation of older forests are key ecological concerns. In dry forests, which historically experienced very frequent and moderately frequent fire-regimes (chapter 3), the ecological constraints on management include the fact that, with build-up of fuels in historical fire frequent regimes, fire often cannot be reintroduced as prescribed fire without first reducing fuels via mechanical means. And, more significantly, climate change and invasive species will continue to alter fire regimes and vegetation dynamics, making these increases in fuels even more consequential.

The social and economic constraints to widespread restoration of fire in fire-frequent ecosystems are large and include agency budgets, limited workforce capacity, air quality regulations, social acceptability of prescribed fire, lack of markets for restoration byproducts, and the risk of losing other values (Charnley et al. 2015; Collins et al. 2010; North et al. 2012, 2015; Ryan et al. 2013) (chapter 8). Public support for restoring fire to the landscape will be required to make progress (North et al. 2015). In addition, the costs of restoring fire through mechanical treatments and prescribed fire are high (Houtman et al. 2013), and to be fully funded by Congress would require significant re-investment in public forest lands at levels beyond current annual wildfire suppression and preparedness funding. For example, the recent Forest Service budget appropriations for hazardous fuels reduction are less than one-fifth what they are for fire suppression (Charnley et al. 2015), and current rates of restoration treatments in many areas of the Western United States are well below what is needed for restoration (North et al. 2012, Reilly et al. 2017a, Spies et al. 2017, Vaillant and Reinhardt 2017). This deficit has led some to call for more use of managed natural ignitions (North et al. 2012). Some initial studies indicate that managed and some unmanaged wildfires have the potential to increase the scale of restoration benefits (Meyer 2015, Reilly et al. 2017b), though the relative benefits and costs of this approach (table 12-1) are not yet fully understood and will likely differ across the fire regimes of the Plan area (chapter 3).

Table 12-1—Summary of possible (known and hypothesized) major tradeoffs (effects) associated with current management activities and original ecological and socioeconomic goals

Management activity	Closed-canopy old-growth structure and function	Northern spotted owls	Marbled murrelets	Other late-successional old-growth species	Aquatic habitats	Timber and nontimber supply	Local economies	Tribal ecocultural resources
Suppression of wildfire	Increases shade-tolerant tree species and canopy cover Protects existing old-growth trees from loss **Reduces open old-growth types and landscape diversity** **Reduces area of diverse early-successional forest** **Reduces resiliency in some fire regimes**	Protects habitat in northern part of range Increases area of nesting and roosting habitat in fire- prone areas **Can increase landscape-scale risk to owl habitat by promoting larger high-severity patches of wildfire** **Can reduce habitat quality in southern part of range where habitat includes smaller patches of early-successional and nonforest vegetation**	Protects habitat	Protects habitat for species that prefer dense multilayered canopies Variable and poorly understood effects	Increases density of trees in riparian areas Can increase shade on streams	Protects forests scheduled for timber harvest Can increase risk of loss of timber resources where forest fuels accumulate Encourages growth of nontimber forest products that favor closed, mature forest conditions	Can provide short-term economic benefit to communities near wildfire Can promote recreation in unburned forests Protects homes and structures	**Reduces quantity and quality of ecocultural resources associated with early-successional forests, nonforest communities, and open old-growth forests**
Variable thinning plantations in uplands and riparian areas	Accelerate development of large trees Increases vegetation heterogeneity, diversity, and understory layers **Can reduce dead wood if trees removed**	Accelerate development of large nest trees and multiple canopy layers May reduce populations of red tree voles, a prey species, in the short term	Accelerates development of crowns with thick limbs **May create habitat for predator species**	Variable effects; some positive and negative short-term and longer term effects	Accelerate large trees Increases vegetation heterogeneity, diversity, and understory layers Effects likely variable with location in stream network **Can reduce dead wood inputs to streams if trees removed** **Can reduce shading and increase stream temperatures**	Can provide wood products and bioenergy and help support local processing infrastructure May favor nontimber forest products (NTFPs) associated with less dense forests **Not sustainable in long run because plantations may become too old or no longer benefit from restoration management**	Creates jobs for local communities	Can enhance ecocultural resources associated with less dense forests

Table 12-1—Summary of possible (known and hypothesized) major tradeoffs (effects) associated with current management activities and original ecological and socioeconomic goals (continued)

Management activity	Closed-canopy old-growth structure and function	Northern spotted owls	Marbled murrelets	Other late-successional old-growth species	Aquatic habitats	Timber and nontimber supply	Local economies	Tribal ecocultural resources
Thinning to restore resilience to fire-suppressed forests	Can help to maintain large, old, fire-resistant trees Can increase old-forest diversity in fire-dependent disturbance regimes Can reduce fire spread rates and reduce sizes of high-severity fire patches	Can protect patches of nesting and roosting habitat from large fires Reduces habitat quality at site level	May reduce loss of large nest trees to wildfire May create habitat for predator species	Same as variable-density thinning	Same as variable-density thinning	Can provide wood for local communities May not be sustainable in long run because restoration may shift toward prescribed fire as stands are repeatedly treated	Creates jobs for local communities Open forests may be preferred by some recreationists Reduces risk of wildfire to wildland-urban interface communities Open, managed forests may not be preferred by some recreationists	Can enhance ecocultural resources associated with less dense forests, including large nut-bearing trees
Prescribed fire	Same as above	Same as above	Unknown	Unknown	Unknown		Can reduce fuel loads and fire risk to local communities Could potentially support local crews dedicated to using managed fire Smoke can cause health and safety concerns	Can enhance eco-cultural resources, including fungi, plants whose germination is enhanced by smoke, and plants affected by insect pests
Early-seral creation in closed-canopy forests over 80 years in matrix to mimic wildfire effects	Can increase habitat diversity and provide habitat for species dependent on open, habitats and dead trees. **Not compatible with dense old-growth forest structure at stand scales** **Cannot fully replace wildfire effects if does not include prescribed fire or occur in older stands**	May not be compatible with habitat in part of the range Can be compatible at landscape scales in southern parts of range	**Not compatible with habitat at any scale**	Likely reduces habitat, but some species may benefit from juxtaposition of old and young habitats	Can increase light to streams and stream productivity Can increase habitat diversity and promote longer term integrity of stream ecosystems **Can decrease shade and increase stream temperatures in some contexts**	Can provide wood products and help support local mill infrastructure Favors NTFPs associated with early-seral forest	Can benefit local economies	Can enhance eco-cultural resources associated with less dense forests, including various understory plants and game animals

Table 12-1—Summary of possible (known and hypothesized) major tradeoffs (effects) associated with current management activities and original ecological and socioeconomic goals (continued)

Management activity	Closed-canopy old-growth structure and function	Northern spotted owls	Marbled murrelets	Other late-successional old-growth species	Aquatic habitats	Timber and nontimber supply	Local economies	Tribal ecocultural resources
Early-seral creation in closed-canopy plantations to mimic wildfire effects	Can increase habitat diversity and provide habitat for species dependent on open habitats and dead trees Does not reduce current area of old growth **Will reduce future amounts of dense old-growth forest structure at stand scales and landscape scales** **Cannot fully replace wildfire effects if does not include prescribed fire or occur in older stands**	**Could have some negative effects on dispersal habitat** May be compatible at landscape scales in southern parts of range	**Does not affect current habitat although it could increase edge and occurrence of nest predators at landscape scale**	Does not likely affect habitat for these species, and some species may benefit from juxtaposition of old and open canopy conditions	Can increase light to streams and stream productivity Can increase habitat diversity and promote longer term integrity of stream ecosystems **Can decrease shade and increase stream temperatures in some contexts**	Can provide wood products and help support local mill infrastructure Favors NTFPs associated with early-seral vegetation	Can benefit local economies	Can enhance ecocultural resources associated with less dense forests, including various understory plants and game animals
Planting after wildfire	Planting of key tree species may benefit forest recovery	Planting of key tree species may benefit longer term recovery of habitat	May benefit long-term recovery of habitat	May benefit long-term recovery of habitat	Planting of key tree species may benefit longer term recovery of habitat	Can benefit long-term recovery of forest resources	Some work for local communities	Recovery of conifer forest may benefit some resources, but recovery of non-conifer species (e.g., hardwood trees and shrubs) are also important concerns, as well as ability to restore frequent fire regime
Salvage after wildfire	**Removal of large dead wood reduces habitat for many wildlife species** **Logging of dead trees can kill regeneration and increase erosion** Removal of small dead trees in fire-excluded forests may reduce impacts on soil if reburn occurs	**Removal of dead trees likely not compatible with habitat**	NA (does not use postfire environments or dead trees)	**Removal of dead wood likely not compatible with habitat for some of these species**	**Removal of dead trees (especially large ones) may work against natural riparan/aquatic recovery processes**	Can provide timber and support local mills	Can provide jobs for local communities	

Table 12-1—Summary of possible (known and hypothesized) major tradeoffs (effects) associated with current management activities and original ecological and socioeconomic goals (continued)

Management activity	Closed-canopy old-growth structure and function	Northern spotted owls	Marbled murrelets	Other late-successional old-growth species	Aquatic habitats	Timber and nontimber supply	Local economies	Tribal ecocultural resources
Road removal	Can reduce spread of invasive species to older forest blocks Can reduce edge effects **Can reduce access for restoration management**	Unknown	May reduce corvid populations that prey on nests	Unknown	Reduces erosion potential Reduces risk of landslides and debris flows Increases fish passages through stream networks	**Can reduce access for timber management and NTFP gathering**	**Can reduce access for recreation and other forest uses** Can improve water quality	Can benefit desired aquatic resources, **but also can limit access to desired ecocultural resources**
Managing wildfire for ecological benefits	Can increase diversity of old-forest types Can increase landscape resilience to future fire **Can destroy old-growth forests and large old trees**	May reduce risk of loss from fire to surviving patches of habitat **Can eliminate habitat**	May reduce risk of loss from fire to surviving patches of habitat **Can eliminate habitat**	Not well known, but likely similar to spotted owl response	Can increase habitat diversity and promote longer term integrity of stream ecosystems **Can decrease shade and increase stream temperatures**	May damage and reduce value of trees that were scheduled for wood production Can reduce fuels and lower risk of loss of unburned forests	Can increase area of habitat for game species and increase hunting use Can reduce future risk of large high-severity fires that threaten local communities	Can promote ecocultural resources by restoring fire and more open structure as above, **but there may also be concerns about effects of large high-severity patches in untended areas on desired resources (e.g., mature oaks)**

NA = not applicable.

Note: Effects in regular type are generally consistent with a goal; effects in boldfaced type are generally not consistent with a goal or have negative effects on other goals not emphasized in the Northwest Forest Plan. Effects may differ with spatial and temporal scale and with geography. The effects are generalized, so they may not apply in all contexts and there may be considerable uncertainty, especially regarding the effects of extreme fires. For detailed discussions of these effects, see individual chapters of this synthesis.

Another social challenge is that some altered conditions of ecosystems in the NWFP area may be desirable to some people, despite being highly departed from historical conditions, and at greater risk to loss from wildfire and drought. For example, the denser forests that have developed in forests with very frequent and moderately frequent fire regimes now support more area of habitat for northern spotted owls and other dense forest species such as goshawks (*Accipiter gentilis*) (chapters 3 and 4) than they did under the historical fire regime. Some groups may favor maintaining some dense stands; for example, the Klamath Tribes expressed a concern for promoting mule deer (*Odocoileus hemionus*) habitat by retaining dense tree patches as deer hiding cover within ponderosa pine (*Pinus ponderosa*) forests that were historically open in their ancestral lands on the Fremont-Winema National Forest (Johnson et al. 2008). Based on discussions with stakeholders who participate in central Oregon forest collaborative groups, we have observed that some stakeholders value the aesthetic and wildlife values of the fire-excluded, multilayered grand fir (*Abies grandis*) and white fir (*A. Concolor*) forests, which appear to fit an idealized old-growth forest based on wetter old-growth types. A study from moist forests (moderately frequent, mixed-severity fire regime) in the western Cascade Range of Oregon indicates that tall, multilayered forests that develop in the absence of fire may buffer climate change effects on the microclimate for wildlife (Frey et al. 2016a, 2016b). It is unknown if that finding applies to fire-excluded dry forests. Finally, such forests may be more desirable to some people simply because they occur without active management (except for suppression), which may be simply mistrusted (e.g., see DellaSala et al. 2013 and "Trust and collaboration" section below).

Although some people see benefits in dense fire-excluded forests, many see the risks (see discussion in Brown 2009). For example, many stakeholders who participate in the central Oregon forest collaboratives mentioned above are concerned about the increased risk of widespread tree mortality resulting from severe fire, drought, and insects, and some see opportunity for economically feasible restoration treatments that would remove established grand fir/white fir established over the past 100 years in favor of fire-tolerant and drought-tolerant tree species.[6]

Invasive species—

Species invasions or range-expansion species native to North America have also affected the native biota of the NWFP region (chapter 6). Invasive species are widespread—more than 50 percent of inventory plots in almost all physiographic provinces of the Plan area contain nonnative plant species (Gray 2008), but most of them do not get much attention. An exception is the barred owl, which is an example of an invasive species (Peterson and Robins 2003) (some have called it a "native invader species") (Carey et al. 2012) that has become a major threat to the viability of northern spotted owl populations (chapter 4). Although the barred owl may be the most prominent example, there are many other examples in the NWFP area of species that may have been exotic or native to the region but are having undesirable effects on other species and ecosystems as a result of landscape and other anthropogenic changes. For example, native corvid (the crow/raven family) populations have expanded as a result of human food waste and human disturbance of vegetation (Marzluff and Neatherlin 2006, Peterson and Colwell 2014), and corvids prey on the nests of marbled murrelets (*Brachyramphus marmoratus*) (chapter 5).

The widespread expansion of true firs into pine forests, where fire has been excluded, could also be termed "native invader" (Carey et al. 2012, Simberloff 2011) species that were once rare or uncommon in a landscape, but now have become so abundant that they are altering community (e.g., through competition) and ecosystem dynamics (disturbance regimes) in undesirable ways. In the case of true firs in dry forests, their expansion has altered forest composition, structure, and fire regimes, and they are difficult to control by virtue of their copious seed rain (Hessburg et al. 2016, Stine et al. 2014), which can lead to rapid recolonization of disturbed areas.

The impact of barred owls on northern spotted owl populations is profound; it is not known if this impact can be reversed or at least stabilized across the spotted

[6] Merschel, A. 2017. Personal communication. Graduate student, Oregon State University, Department of Forest Ecosystems and Society, 321 Richardson Hall, Corvallis, OR 97331.

owl's range through efforts to remove them. An ongoing, large-scale experiment will shed more light on this future (USFWS 2013, Wiens et al. 2016). A proposal to remove an established species to protect another is a major challenge to society from ecological, economic, and ethical perspectives (Carey et al. 2012, Livezey 2010), but it is not unprecedented (e.g., Wilsey et al. 2014). Multiple approaches to northern spotted owl conservation, including large-scale experiments and landscape-scale forest restoration experiments, can provide more learning opportunities and more understanding of ways to promote resilience of the subspecies. In the long run, the northern spotted owl may be locally or completely displaced by the barred owl. From an ecosystem perspective (e.g., productivity, food webs, trophic cascades), the effect of loss of northern spotted owls on the forests and vertebrate communities is unknown, but it is hypothesized that prey species and other competing native predators may experience changes in behavior, abundance, and distribution as a result of predation by the barred owls, which has a broader prey base and occurs at higher densities than the northern spotted owl (Wiens et al. 2014).

Invasive species occur in aquatic and riparian ecosystems as well. Across the Plan area, 63 nonnative species and species groups are identified as regional aquatic-riparian invasive or nuisance species priorities (chapter 7). Of these, 31 (49 percent) species or species groups were designated as "high concern" and inventoried by the NWFP's Aquatic Riparian Effectiveness Monitoring Program (AREMP) in 2016. Nonnative species are not always harmful to native fishes or their habitats, but in many instances they can (1) compete with, prey upon, hybridize with, or infect native species with novel pathogens; (2) greatly alter the structure of food webs; or (3) cause habitat changes that reduce the productivity of desirable aquatic organisms. Climate change will likely influence the expansion of nonnative plant and animal species in the NWFP area, while at the same time either reducing or even extirpating native species (Dale et al. 2001, Garcia et al. 2014, Urban 2015).

Other disturbance agents—

Novel ecological conditions are also a concern where ecosystems are subject to multiple disturbance agents. For example, stands infested by the sudden oak death pathogen have increased potential for high burn severity (chapter 3), while rodenticides used in illegal marijuana cultivation and the spread of barred owls may tax populations of sensitive fishers (*Martes pennanti*) and northern spotted owls, respectively, so that they become more sensitive to other disturbances (Gabriel et al. 2012, 2013) (chapter 6). As an example from aquatic systems, the combination of climate change, severe fire, tree mortality, and floods may increase the potential for debris flows (Cannon and DeGraff 2009) and ensuing debris jams at culverts and bridges. Such flood impacts can threaten life, property, and access; damage expensive infrastructure; and impair stream functions by causing stream bank erosion and channel incision. The challenges to restoring fire and geomorphic disturbances to these ecosystems are daunting. Landscape and social-ecological systems perspectives are needed to meet the broad Forest Service goal (http://www.fs.fed.us/strategicplan) of increasing the resilience of forests and aquatic ecosystems to fire and climate change while meeting the specific late-successional forest goals of the NWFP (Fischer et al. 2016, Hessburg et al. 2015, 2016; Reeves et al. 1995, 2016; Stephens et al. 2013).

Perspectives on Reserves in an Era of Global Environmental Change

Views of the conservation community—

The scientific community's response to the cumulative effects of climate change, land use change, and invasive species has led some to call for new approaches to conservation (Millar et al. 2007, Wiens 2016). Some researchers have affirmed that "tomorrow's landscapes may become so altered by human actions that current management philosophies and policies of managing for healthy ecosystems, wilderness conditions, or historical analogs will no longer be feasible" and will require a new land ethic (Keane et al. 2009). Others have advocated for a new science of conservation rooted in the integrated nature of social-ecological systems (as mentioned above) and designed to promote human well-being as well as biodiversity conservation, particularly where poverty is pervasive, through judicious and sustainable use of ecosystems rather than strict preservation (Kareiva and Marvier 2012). In the conservation ethics literature, the contrast is often made between humanism, emphasizing the importance of productive human use of natural resources, and biocentrism, emphasizing a primary goal of maintaining ecological integrity (Stanley 1995). These new perspectives have received pushback from some conservation biologists. For example, Miller et al. (2014) and Doak et al. (2014) argued that conservation centering on human values, now often organized using the framework of ecosystem services, is an "ideology" that (1) is not new (e.g., it reflects ideas advocated by Gifford Pinchot a century ago), and (2) does not address the root causes of lost biodiversity, which they described as "unabated consumption and increasing human populations." Instead, they emphasized preservation of biodiversity through large networks of protected lands arranged to foster connectivity and some sense of permanence. They devoted little attention, however, to what such protection means in disturbance-dependent and highly dynamic systems with a strong history of human impacts, or in systems in which invasive species are widespread, or where permanence of certain vegetation, habitat conditions, or biotic communities is simply unattainable.

These debates notwithstanding, nature reserves (also termed "protected areas") including wilderness areas, remain key components of conservation strategies and forest planning around the world (Simončič et al. 2015, Watson et al. 2014). E.O. Wilson, in his book *Half-Earth, Our Planet's Fight for Life* (Wilson 2016), challenged society to set aside half of the Earth's lands and seas to conserve biodiversity in reserves equivalent to World Heritage sites. Other scientists have echoed a similar call in advocating for an extensive reserve network focused on riparian areas across the United States (Fremier et al. 2015). Although we are a long way from these goals (e.g., 10 percent of U.S. land is in a protected area (Aycrigg et al. 2013), the area of wildland reserves or protected areas is growing (Götmark 2013) and have made essential contributions to maintaining populations of threatened species, or have slowed their rate of loss. In the NWFP area, reserves[7] on federal lands constitute about 80 percent of the federal forest area and 28 percent of the total forest area on public and private forest lands (chapter 3). Conservation biologists have argued that protected areas are necessary but not sufficient to meet conservation objectives (Margules and Pressey 2000, Noss et al. 1997, Rayner et al. 2014). Governance and management of reserves are as important as the designation of the reserve on a map. For example, ineffective governance of protected areas in many countries has not kept out detrimental land uses such as development, intensive logging for timber, degradation from invasive species, and illegal hunting (Watson et al. 2014). In addition, reserves may need active management to meet biodiversity goals (Lemieux et al. 2011, Lindenmayer et al. 2000) or to meet needs of local communities that are compatible with biodiversity goals (Watson et al. 2014). Pressey et al. (2007) suggested that appropriate actions within or outside reserves may include "control of invasive species, management of disturbance regimes, quarantine against disease, restrictions on harvesting, and restoration." In summary, the literature provides overwhelming support for the idea that reserves have an essential role to play in conservation (e.g., slowing rates of losses of native biodiversity), if they are effectively managed (Watson et al. 2014).

Many types of reserves—

Globally, there are many types of reserves, depending on a variety of existing conditions and long-term intentions. For example, the International Union for the Conservation of Nature (IUCN) defines seven categories that encapsulate the variety of purposes and specific contexts for a reserve (Spies 2006) (chapter 3). These range from category 1a, "strict nature reserve," which still allows some light human uses, to category 6, which allows sustainable use of natural resources, such as agroforestry. Biosphere reserves defined by the IUCN can include "core areas" or **sanctum sanctorum** which are open only to those with special scientific permits, and are bordered or surrounded by buffer zones with various allowances for ingression and resource use and extraction (e.g., Cumming et al. 2015, Peine 1998, Taylor 2004). These categories of reserve designs differ depending on the amount of human activity and use that is considered compatible with the primary conservation objectives of the reserve (Lausche and Burhenne-Guilmin 2011), although many of the IUCN reserve design architectures, including the core/buffer design, are not implemented as such in the United States.

[7] Designated wilderness areas account for about 42 percent of federal reserves, not including riparian reserves, and encompass roughly 7.1 million ac (including some national parks like Olympic and Mount Rainier National Parks).

In general, reserves are defined in terms of objectives and management actions that are needed or allowed, and in terms of actions that cannot be allowed in order to achieve primary conservation objectives, that is, by specifying human activities that are permitted or excluded. As a result, reserves exhibit a hierarchy of conservation goals, as demonstrated in the NWFP area, in which conservation of functional older forest and northern spotted owl habitat are the top priorities in late-successional reserves (LSRs), at least in the wetter provinces. In the drier provinces, according to the latest U.S. Fish and Wildlife Service recovery plan for the northern spotted owl, restoration becomes an "overlapping goal" with northern spotted owl habitat that must be reconciled (USFWS 2011). In addition, the 2012 planning rule emphasizes managing forests for ecological integrity and resilience to climate change, a goal that is not mentioned in the standards and guidelines for the LSRs (USDA and USDI 1994b). Thus, reserves as they have been conceived and implemented globally and regionally exist along a continuum of uses and management approaches, based on goals and cultural context.

Social controversies around reserves—
Although reserves are a cornerstone of conservation biology, they exist in a larger social context in which they may not be viewed so favorably. The idea of a nature "reserve" is a cultural construct associated with Euro-American notions of humans as distinct from nature (Cronon 1996) (see chapter 11). Rules governing permissible activities in protected areas or reserves differ across the globe (Simončič et al. 2014) and can be controversial (Brockington and Wilkie 2015). Reserves, with strict rules concerning management or resource extraction, have been criticized for threatening livelihoods by denying access to resources, and for not recognizing that nature changes as a result of disturbance and succession (Bengtsson et al. 2003); tribes, in particular, have expressed such concerns about NWFP reserves (see chapter 11). Often, the costs of reserves are experienced by local people, while benefits disproportionately accrue to people some distance away (Brockington et al. 2008). Controversies about reserves have several dimensions:

1. They are often written into the founding stories of a nation or culture (e.g., old-growth forests in the Pacific Northwest (Spies and Duncan 2009) and therefore touch deep emotions.
2. The local effects on people can be beneficial (e.g., amenity values) (Hjerpe et al. 2017, Holmes et al. 2016) or negative (e.g., reserves that restrict access to commodities or subsistence goods and can increase poverty in rural areas (Adams 2004, West et al. 2006).
3. The goals for nature in the reserves can be ambiguous or difficult to achieve given that nature is multidimensional, dynamic, and often influenced directly or indirectly by human activity.
4. Achieving biodiversity goals often requires management, especially given effects of past land use change, invasive species, and climate change, which can be controversial if stakeholders hold different values for reserves.
5. Reserves, which typically occupy a small part of most landscapes, are not sufficient by themselves to provide for biodiversity (Franklin and Lindemayer 2009).
6. They are flash points for politics of conservation related to land use and national and regional debates about values expressed through different interest groups (Brockington and Wilkie 2015).

Reserves in dynamic ecosystems—
Some conservation biologists and legal experts (e.g., see Craig 2010) recognize the problem of conserving biodiversity in fixed reserves, where vegetation structure and composition, disturbances, climatic influences, and plant and animal communities are highly dynamic. Approaches to reserves in dynamic systems fall along a gradient in terms of size and objectives. At one end of this gradient are relatively small fine-filter or coarse-filter (e.g., static vegetation states) reserves that some (Alagador et al. 2014, Bengtsson et al. 2003, Bisson et al. 2003, Lemieux et al. 2011) suggest could be moved in response to changing environmental conditions (e.g., disturbance, invasive species, climate change). Some of the late-successional reserves (LSRs) in the Plan area are small and would fit into this category in terms of size and objective. At the other end of the gradient are large (coarse-filter) reserves that are managed to accommodate dynamic ecosystem processes (e.g., disturbance and succession) (Bengtsson et al. 2003,

Pickett and Thompson 1978). Some of the large LSRs may meet this size criterion relative to fire sizes (chapter 3), but are primarily focused on maintaining or increasing one successional state—dense old-growth forests. The first type of reserve approach—in which new protected areas are established and old ones decommissioned in response to changing environmental conditions—has received little formal evaluation, and we are not aware of any publications that document where a reserve was decommissioned and replaced with a new one or an alternative approach in the United States. However, dynamic habitat conservation approaches (which do not use the term "reserve") are being used for two endangered forest species in fire-prone forests: the red-cockaded woodpecker (*Picoides borealis*), which depends on fire to maintain old-growth pine (*Pinus* sp.) forests of the Southeastern United States, and the Kirtland's warbler (*Dendroica kirtlandii*), which depends on dense young jack pine (*Pinus banksiana*) forests that regenerate following wildfire or logging in Michigan (Moore and Conroy 2006, Spaulding and Rothstein 2009). These cases indicate that alternatives to fixed no-management reserves for conservation of listed species of fire-prone landscapes exist, but examples do not exist for old-growth forests and northern spotted owls.

A simulation study in Quebec (Rayfield et al. 2008) evaluated static and dynamic habitat reserve strategies for American marten (*Martes americana*), a species that uses mature coniferous forests. The results indicated that the dynamic reserve strategy supported more high-quality habitat over a 200-year simulation than did static reserves. The locations of new reserves were constrained by fragmented forest patterns created through logging and wildfires in surrounding non-reserve areas. These findings have two major implications: (1) if reserves are focused on just one successional stage or habitat for a single species, they may not be effective in the long run in fire-prone landscapes; (2) if dynamic conservation strategies are to be successful in the long term, the surrounding nonreserved areas must be managed in a way such that habitat replacement options for target species are available when reserved areas are no longer functioning as intended. They also highlight the importance of investing in and supporting private lands conservation to enable possible future replacement options associated with private lands, and to provide habitat functions for species that are not restricted to reserves, or other species that were not the focus of the reserve.

In contrast to the above species-centric reserves or conservation areas, large reserves based on dynamic coarse-filter objectives (e.g., ecosystem patterns and processes) will more likely meet conservation goals than fixed-area reserves for particular species or vegetation conditions. Large protected areas (e.g., larger than 25,000 ac) (more than 100 of the existing LSRs are larger than 25,000 ac) could better support the full range of natural disturbances within their boundaries than could small reserves (see chapter 3 for evaluation of the dynamics of LSRs as a function of their size). In such cases, it may be more possible to capture inherent ecosystems dynamics—natural and intentional management disturbances used to change the vegetation in ways that match the biophysical and topographic template and contribute to overall successional diversity and resilience. Management may still be needed to achieve specific goals (e.g., creation of fire-resistant forest structures and heterogeneous fuel beds) and could promote resilience of some components of ecosystems components to climate change, drought, and fire.

Challenges to management of small and large reserves are significant. For small reserves with a narrow species or vegetation state objectives, moving reserves dynamically to deal with climate change, disturbance, and other changes may be more effective at maintaining biodiversity than fixed reserves (Bengtsson et al. 2003). However, a dynamic reserve in which adjustments to standards, guidelines, and reserve boundaries would be more difficult to implement, monitor, and govern than one in which reserves are fixed in perpetuity in location and management guidelines. Moving reserves would likely require an ongoing and robust decisionmaking process that involved diverse stakeholders and a high level of trust. In large reserves, with both ecosystem and species goals, there would likely be less need or motivation to move reserve boundaries because there would be fewer options for reserve placement in the larger landscape and because overall vegetation conditions in large reserves would be less likely to change as a result of disturbances.

The management of large reserves for ecological integrity and species goals would require development of standards and guidelines for dealing with natural disturbance events and restoration activities intended to restore ecological processes (e.g., fire and hydrological disturbances) while providing for any other goals (e.g., particular species or vegetation states). In addition, standards and guidelines would need to be flexible enough to deal with unforeseen future issues, such as invasive species or climate change effects that might require different types of intervention to meet ecological goals. Changes to reserve boundaries or to standards and guidelines in both large and small reserves would also involve consideration of environmental justice and equity, especially for people living and working near the reserve.

Although the idea of dynamic reserves, or reserves for dynamic ecosystems, may be relatively new in the literature (e.g., Harrison et al. 2008), the literature also lacks studies of the conservation of late-successional forests (i.e., dense older forests) in reserves within dynamic fire-prone ecosystems, which is the situation in the dry forests of the NWFP area. The NWFP was meant to be adaptive, and changes to reserve standards and guidelines might be considered given climate change, fire occurrence, invasive species, and species movements or other relatively new ecological concerns. See "Reserves" on p. 952 for more discussion of NWFP reserves and challenges of implementing reserves in dynamic ecosystems.

Key Social Components of the Social-Ecological Systems of the Northwest Forest Plan Area

Ecosystem services—

The ecosystem services concept, largely developed since the NWFP was initiated, recognizes that forests and other natural systems support many benefits to human communities beyond timber and water supply that were emphasized at the creation of national forests. The recognition of these diverse benefits is not new (Kline et al. 2013); however, efforts to explicitly recognize them within a broader "ecosystem services" framework is somewhat new, and in the process of being incorporated into federal forest management (Brandt et al. 2014; Bruins et al. 2017; Deal et al. 2017a, 2017b; Long et al. 2014; Moore et al. 2017; Penaluna et al. 2017; Smith et al. 2011). Categories of ecosystem services recognized by the Millennium Ecosystem Assessment are **provisioning services** (e.g., food and fiber), **supporting services** (e.g., pollination, soil formation, and nutrient cycling), **regulating services** (e.g., carbon sequestration and water purification), and **cultural services** (e.g., spiritual, symbolic, educational, heritage, and recreational services) (Wallace 2007). Many resource management systems in the United States took such services for granted until relatively recently, as the limits and vulnerabilities of ecosystems in supporting these benefits have become more apparent. However, ecosystem valuation is often difficult owing to the lack of markets for many collective goods. Forest managers often have difficulty assigning value to many features of the forests they manage in ways that appropriately inform decisionmaking (Smith et al. 2011). Kline et al. (2013) indicated that full development of ecosystem services frameworks for public lands will be constrained by lack of ecological data for planning units and economic capacity in terms of models and staffing. They argue that, given these limitations, efforts to apply ecosystem services concepts should include qualitative methods that can be used with stakeholders even without more detailed quantitative information.

Critics of the ecosystem service concept have argued that it has constrained thought and conservation of nature by focusing on "monetization and financialization of nature" that actually devalues nature by ignoring other values that cannot be monetized, and it creates "make-believe markets" that are not effective in conserving nature (Silvertown 2015). These other values include aesthetic, spiritual values and intrinsic values that might come under the title of "cultural services" but are not suited to an instrumental thinking approach (Batavia and Nelson 2017, Cooper et al. 2016, Winthrop 2014). Others have responded by saying that the ecosystem services concept has value beyond market and monetization, can take many forms (Schröter and van Oudenhoven 2016, Wilson and Law 2016), and is strongly rooted in intrinsic values that include spiritual fulfillment and sacred natural sites. Chapter 11 briefly discusses some of these issues, while Winthrop (2014) reflects on tribal contexts in proposing "culturally reflexive stewardship" as a useful framework for understanding motivations for conservation based upon knowledge of local ecosystems, a world view that humans are a part of nature, and cultural practices that reflect residence and use over many generations.

Deal et al. (2017b) suggested that the Forest Service is well positioned to make ecosystem services the "central and unifying concept in federal land management." A 2015 presidential memorandum (OMB 2015) directed all federal agencies to develop and institutionalize policies to promote consideration of ecosystem services in planning, investments, and regulatory policy (table 12-2). However, it has been challenging for the Forest Service to describe and value all the potential ecosystem services that public lands provide. No published full accounting of ecosystem services has been conducted for the NWFP area, but some localized efforts have been made (Deal et al. 2017a, 2017b; Kline et al. 2016; Smith et al. 2011,) (see also chapter 9), and a framework as has been proposed (Deal et al. 2017b). This framework includes describing the ecosystem services provided by forest landscapes, examining the potential tradeoffs among services associated with proposed management activities, and attracting and building partnerships with stakeholders who benefit from particular services that the forest provides. According to Deal et al. (2017a), the common needs for advancing ecosystem services as a central framework for the Forest Service include:

- Building staff capacity for the concept and application of ecosystem services.
- Creating and publishing ecosystem service resource and reference materials.
- Aligning agency staffing, funding, and program structures with ecosystem service priorities.
- Integrating and managing data.
- Identifying inventory metrics; defining outcome-based performance indicators; and organizing and linking data.
- Valuing and mapping ecosystem services using current tools and methodologies.
- Communication.
- Policy including leadership support of using ecosystem services as part of a governance framework.

A review of several project-level applications of ecosystem services in Oregon found that place-based applications can highlight the connections between ecosystem conditions and public benefits (Deal et al. 2017b). The review hypothesized that using this approach could help transform the agency into a more effective and relevant organization and will strengthen public investment in Forest Service activities. Key ecosystem services provided by federal forests in the Plan area include water, recreation, wildlife and plant habitat, wood products, and carbon sequestration. The contribution of Forest Service lands to water yield in streams differs regionally and is especially significant in streams that originate in the western Cascade Range and northern California (fig. 12-3). The water supply from many watersheds in the Plan area originates on national forests (Watts et al. 2016), and water from undisturbed old-growth forests can be especially high in quality as a result of high nutrient retention and low erosion (Franklin and Spies 1991). Streamflow in summer, which is typically quite low, is nevertheless higher from old-growth forest watersheds in the western Oregon Cascades than in watersheds dominated by maturing forest plantations (Perry and Jones 2016). Forested streamside buffers have been shown to protect water quality in many parts of the world (Sweeney and Newbold 2014).

The carbon sequestration potential of old-growth forest ecosystems in the NWFP area has received special attention (DellaSala et al. 2015, Hudiburg et al. 2009, Kline et al. 2016, Smith et al. 2013, Wilson et al. 2013). When the forests and soils of this region develop for long periods (hundreds of years) without natural or human disturbances, they can store some of the highest levels of carbon of any region in the United States and the world (fig. 12-4).

The expanded understanding of ecosystem services also reveals that synergies and tradeoffs can occur between and among biocentric and anthropocentric values (Hunter et al. 2014, Kline et al. 2016). For example, certain conservation approaches (e.g., protecting old growth and restoring watersheds) may have the added benefits of increasing carbon sequestration and water quality and providing economic benefits in the form of scenic quality/aesthetics, recreation, or restoration jobs (Brandt et al.

Table 12-2—U.S. natural resource legislation with examples of federal agency responses and applications of ecosystem services for agencies

Legislation	Intent of legislation	Examples of U.S. federal agency responses
Multiple Use–Sustained Yield Act (1960)	Promote sustainable management of natural resources to meet the growing needs of an increasing population and expanding economy	U.S. Forest Service (USFS) and Bureau of Land Management (BLM) directed to manage timber, range, water, recreation and wildlife with equal importance
National Environmental Policy Act (1969)	Encourage harmony between people and the environment, enrich the understanding of the ecological systems and natural resources important to the Nation, and establish a Council on Environmental Quality	Any federal, state, or local project that involves federal funding, work performed by the federal government, or permits issued by a federal agency must take a multidisciplinary approach to decisionmaking, including consideration of alternatives
Federal Land Policy and Management Act (1976) and National Forest Management Act	Establish policy of inventory and planning in accordance with the Multiple-Use Sustainable Yield Act	USFS and BLM develop land management plans in collaboration with the public to determine appropriate multiple uses, develop strategies for resource management and protection, and establish systems for inventory and monitoring to evaluate the status of resources and management effectiveness
National Forest System Land Management Planning Rule 2012	Regulation developed by the USFS to implement planning required by the National Forest Management Act	Rule explicitly requires USFS managers to address ecosystem services in planning to ensure that forests have the capacity to provide people and communities with a range of social, economic, and ecological benefits for the present and into the future. Staff across the agency develop and apply tools to address ecosystem services in land-management efforts.
Presidential Memorandum: Incorporating Ecosystem Services into Federal Decision-Making (OMB2015)	Directs federal agencies to incorporate natural infrastructure and ecosystem services into decision frameworks	National Oceanic and Atmospheric Administration uses ecosystem service valuation to assess benefits of dam removal and coastal rehabilitation, among other projects
		Natural Resources Conservation Service applies ecosystem service quantification tools to its programs, including watershed rehabilitation and flood mitigation
		U.S. Fish and Wildlife Service incorporates consideration of ecosystem services into wildlife refuge management
		Environmental Protection Agency makes ecosystem services the focus of determining adversity to public welfare in review of air quality standards
		BLM and U.S. Geological Survey collaboratively assess alternative methods and quantification tools for evaluating ecosystem services through a case study in the San Pedro River watershed

Source: Deal et al. 2017b.

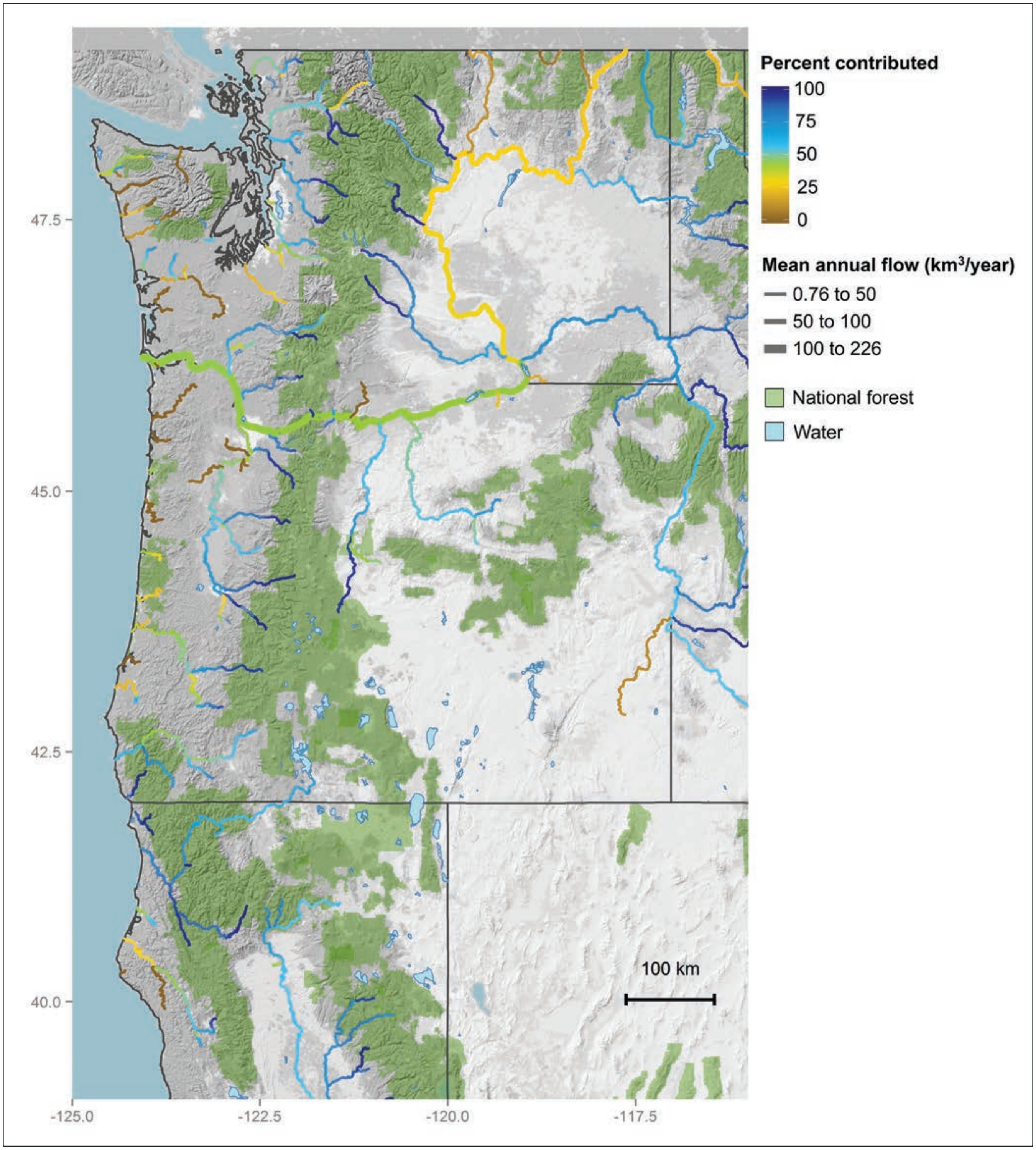

Figure 12-3—Percentage of annual streamflow from U.S. Forest Service lands in Washington, Oregon, and northern California. Data from Luce et al. 2017 (https://www.fs.usda.gov/rds/archive/Product/RDS-2017-0046/.) and https://www.fs.fed.us/rmrs/national-forest-contributions-streamflow-pacific-northwest-region-region-6.

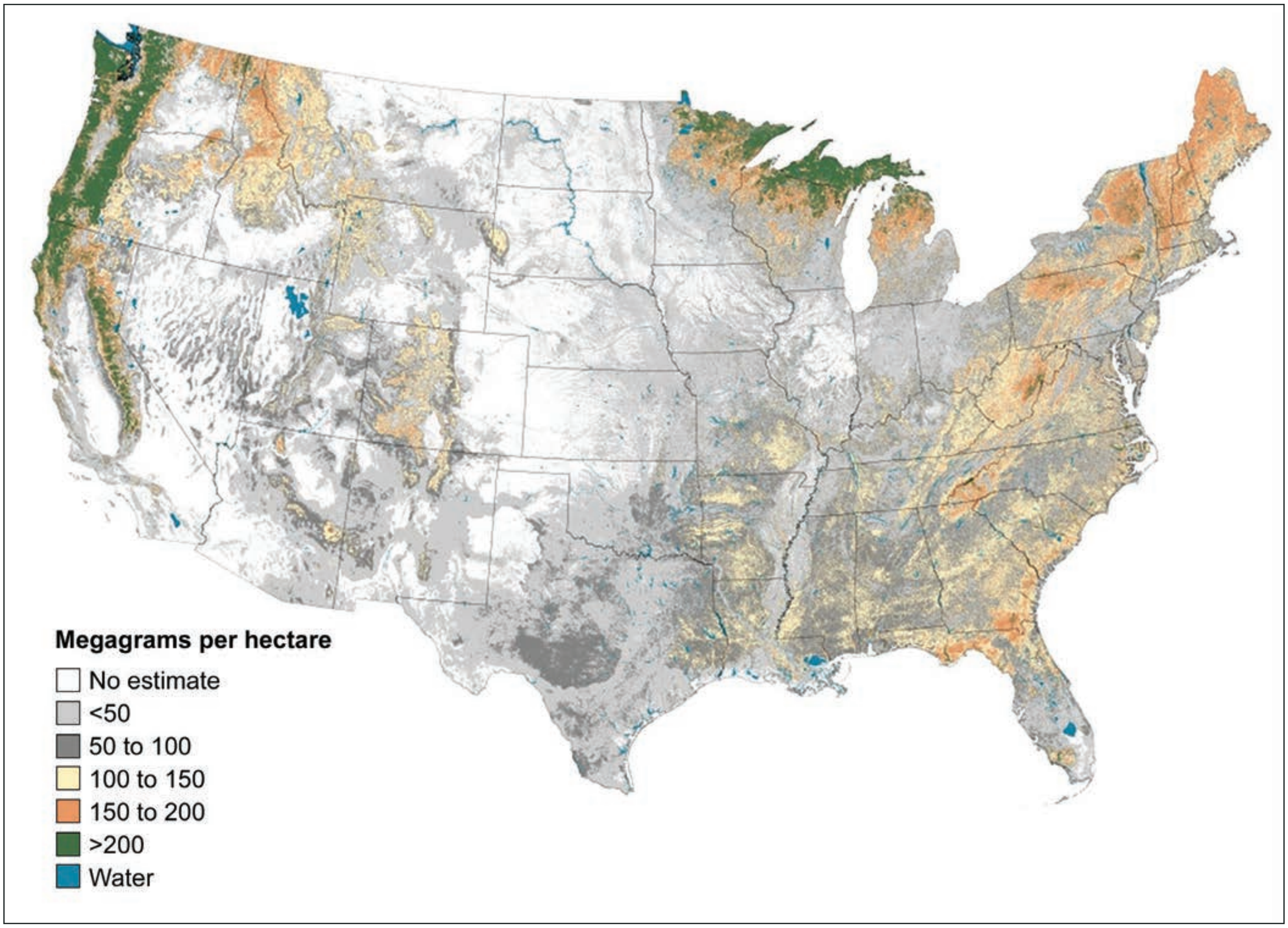

Figure 12-4—Total forest ecosystem carbon density in the United States, 2000–2009. Includes above- and belowground live trees, downed dead wood, forest floor, soil organic carbon, standing dead trees, and understory above- and belowground pools. From Wilson et al. 2013.

2014). In some cases, recreation and restoration benefits may help to offset job losses associated with declines in timber production. However, the economic systems and accounting for federal lands do not yet fully consider the values of carbon sequestration and water supply, and newer economies based on amenity values may not make up for job losses associated with protection of late-successional old-growth habitats and other economic factors in the timber industry (Charnley 2006a) (chapter 8). These variable effects and measures make it difficult to generalize about the ecosystem service impacts of the NWFP or conservation approaches in general. In addition, market forces external to NWFP communities and wood products manufacturing have also transformed since the NWFP was implemented, making it difficult to tease apart the role of federal lands management from other drivers of economic change in influencing community socioeconomic well-being.

Despite its limitations, many scientists consider the ecosystem services framework useful for managing the broad array of benefits that forests provide to people (Deal et al. 2017a, 2017b). Although there are challenges in operationalizing and measuring the entire set of ecosystem services outlined by the Millennium Assessment, the framework gives managers a more diverse set of possible objectives, including managing forests and rangelands for water, pollination potential, carbon, firewood/fuel, cultural heritage, spirituality, solitude, scenery, and many other values.

Institutional capacity—

A key interaction in the social-ecological system lies between the desire to restore forest dynamics and create more resilient forests and the limited capacity of human communities and federal agencies for active management. Although forest management on federal lands was often seen in the past (and still is by some) as a threat to native biodiversity, it is now seen by many ecologists and managers as critical to restoration and conservation of terrestrial ecosystems (Johnson and Swanson 2009). Interestingly, this view is not widely held for aquatic ecosystems (chapter 7). In the past, revenues from timber harvest often subsidized forest management, yet those revenues have declined with reductions in harvesting (chapter 8). Trends of declining agency budgets, increased fire suppression costs, and reduced agency staffing pose challenges to achieving forest management objectives such as ecological restoration, reducing wildfire risk to human communities, promoting habitat for wildlife (chapter 8), and providing diverse opportunities and settings for recreation (chapter 9). Federal agencies lacked the institutional capacity (staff with the required skills, financial resources, management flexibility, and incentives) to fully implement the NWFP's ecosystem management goals (Charnley 2006a). Efforts to maintain species and habitats and restore desired ecological conditions (e.g., old growth) and processes (e.g., succession fire and natural flows) require funding, forest management capacity (e.g., workforce and wood products infrastructure), and public support. The budgets for restoration and the annual rates of treatment are well below what is needed to restore fire to the historical levels found in frequent-fire landscapes (North et al. 2012, Reilly et al. 2017b, Spies et al. 2017). Limited budget and agency capacity has led to innovative approaches to accomplishing restoration, such as stewardship contracting and partnerships with nongovernmental organizations or other government agencies (chapter 8). However, wood processing mills needed to support forest restoration are closing in some regions (especially in less-productive dry forests), where timber supply from both private and public lands is insufficient to keep them in business (chapter 8).

The NWFP represented a dramatic shift in social priorities, from commodity production toward biodiversity conservation, which has been part of a larger national process that has been called "green drift" (Klyza and Sousa 2010) in environmental policymaking in the United States. However, the idea that "working forest landscapes" or "anchor forests" (multi-ownership landscapes that support sustainable timber and biomass production) can provide conservation values, funding for restoration, and support for rural communities has also gained much traction in recent years (Charnley et al. 2014, Corrao and Andringa 2017). Nevertheless, working forest landscapes are subject to the same concerns that have been raised about the balance between conservation and incorporation of human needs—how to reconcile different world views and values. This tension can only be resolved through social processes including public engagement and collaborative efforts that take into account social, ecological, and economic considerations and legislative actions (chapter 9).

Trust and collaboration—

Trust among federal land management agencies and the public is key to restoration and landscape-scale management for multiple goals, but trust is often lacking and difficult to cultivate (chapter 9). Trust among interested parties is essential for developing adaptive management strategies that can nimbly and effectively respond to changing climate, species, disturbances, human values, and markets. Trust can be lost in many ways on federal lands, especially when local-level agreements or collaborative processes are overridden by national-level political decisions (Daniels and Walker 1995), or when local decisions are seen as circumventing federal laws or policies. Researchers and practitioners have characterized public trust as integral to effective natural resources decisionmaking and implementation (Davenport et al. 2007, Pretty and Ward 2001, Shindler and Cramer 1999, Wondolleck and Yaffee 2000). Meanwhile, distrust can be a precursor for natural resource conflict (Nie 2003). Trust and distrust are not inversely related, but rather, trust is multidimensional and can coexist with distrust. Moreover, trust is contextual (depending on the setting or issue) and dynamic (changing based on each encounter or experience) (Lewicki et al. 1998). Trust in natural resource institutions stems from creating trust in both processes and outcomes, whereas interpersonal trust depends on promoting trusting relationships between the public and agency personnel. For natural resource agencies, some factors shown to constrain the development of trust include unclear communication, limited public involvement opportunities, historical resentments, conflicting values, lack of progress in meeting objectives, lack of community awareness, and high turnover of personnel (Davenport et al. 2007). Trust among conflicting parties in resource management can be elusive, but it can be positively influenced through transparency, having clear processes, stated objectives, clarity of roles, and commitment to engagement (see chapter 9). A desire to build or expand trust is an important motivator for collaboration and conflict resolution (Wondolleck and Yaffee 2000), but "common ground will be elusive in conflicts involving fundamental value differences" (Wondolleck 2009). Frequent turnover among local forest management staff has been cited as a constraint on productive collaborations, particularly within tribal communities (see chapter 11).

Current efforts to enhance trust and generate social learning around restoration and other efforts to meet NWFP and other ecological goals are focused on collaboration among multiple agencies, and stakeholders around projects at various scales, from the watershed level to entire landscapes (chapter 9). Collaboration is touted as a means to achieve ecological goals as well as social benefits, which include conflict resolution, trust, and improved decisionmaking (Wondolleck and Yaffee 2000). Many of these collaborations are occurring in the fire-prone regions of the Western United States, and they are supported by funding related to forest restoration and fire-risk reduction programs. The Collaborative Forest Landscape Restoration Program is having some success in encouraging stakeholders to work together to help plan and implement forest restoration treatments, particularly in dry forests at the landscape scale (Butler et al. 2015, Urgenson et al. 2017).

Two well-established collaboratives fall within or immediately adjacent to the NWFP area: the Deschutes Forest Collaborative in central Oregon and Tapash Forest Sustainable Collaborative in eastern Washington. The Western Klamath Restoration Partnership is another example that builds upon years of collaboration in northern California. In addition to large-scale collaboration, there has been a proliferation of community-based collaborative groups in the Plan area that are engaged in National Environmental Policy Act planning, stewardship contracting, and multiparty monitoring, on both sides of the Cascades (Davis et al. 2015a) and in northern California. Other types of collaboratives in the NWFP area have formed around specific resource concerns, such as California Fire-Safe Councils (Everett and Fuller 2011) and the U.S. Fire Learning Networks (Butler and Goldstein 2010).

Collaborative processes are viewed by natural resource agencies as an effective way to engage stakeholders, provide an opportunity for dialogue and deliberation, and build trust and foster relations among groups that historically have worked in opposition (Butler et al. 2015, Urgenson et al. 2017). For example, the threat of high-severity wildfire in forests of the NWFP area that historically burned frequently may be a "common enemy" that can enable environmental and timber groups to work together with the Forest Service to advance restoration projects on the ground (Urgenson et al. 2017). This approach has emerged in some places such as the Western Klamath Restoration Project on the Klamath and Six Rivers National Forests in northwestern California, where a broad partnership of interests, including tribal communities (chapter 11) are coalescing around landscape-level restoration efforts rooted in returning fire to the system. Efforts like this will potentially be a model in some forest types for making meaningful progress on large-scale forest restoration. Collaboration appears promising, and studies to date have identified positive outcomes associated with social interactional concepts such as trust, social capital, learning, and process (Davis et al. 2017). There has been less emphasis on evaluating outcomes such as improved social and ecological conditions. The tremendous investment in collaborative processes may yield enhanced trust and improved ecological and social conditions. Although the landscape collaborative program in the United States has provided better community engagement in decisionmaking, the long-term benefits of the program have not yet been documented (Butler et al. 2015).

Forest collaboratives have been designed to distinguish the roles of agency staff as decisionmakers who consider input from stakeholder collaborators, rather than devolving decisionmaking to local communities or coopting the process to meet predetermined objectives (Butler 2013) (fig. 12-5). In other words, collaboratives are not engaged in true power sharing, because ultimately the federal agency's line officer makes the final decision. Agency participation in collaborative efforts often takes place at an "arm's length" with agency participants playing the role of "technical advisor" and often not holding roles as voting members of collaborative groups (Butler 2013). In fact, agency (Forest Service) participants in collaborative groups are more often motivated by the need to build social trust, whereas non-agency participants are motivated by the desire to achieve social and ecological outcomes (Davis et al. 2017). Greater decentralization of authority has arisen through co-management or community-based natural resource management efforts, particularly outside of the United States; however, there have been relatively few examples of such efforts in which both resource utilization and biodiversity conservation goals have been achieved (Kellert et al. 2000). Strong legal foundations, institutions, and investments in monitoring may have contributed to these successes, as demonstrated in some examples of tribes and state governments conserving salmon in the Pacific Northwest (Kellert et al. 2000) (chapter 11).

Team Hymas

Figure 12-5—The Forest Service has built upon precedents such as the Handshake Agreement of 1932 by establishing areas that are specially managed to support resources important to tribes within ancestral lands that are now national forests. Many of these approaches embody principles of cooperative management that go beyond collaboration, yet maintain the agency's decisionmaking authority. An area in the Sawtooth Berry Fields was reserved in 1932 by a handshake agreement between Yakama Indian Chief William Yallup and Gifford Pinchot National Forest Supervisor J.R. Bruckart for use by Indians.

Tribal perspectives—

Chapter 11, which addresses American Indian tribal values, vividly describes the integrated social and ecological values of ecosystems in the NWFP area. Tribes value a vast diversity of animals and plants for utilitarian values that include the use of timber, as well as intangible cultural values. The perspectives held by native peoples of the Pacific Northwest, informed by thousands of years of place-based experience, help to internalize many of the tradeoffs between use and preservation, as well as provide a long-term, broad spatial perspective about system dynamics. For example, many tribes want to sustain the legacy of old trees and associated biological diversity while also promoting the productivity and diversity of early-successional communities, nonforest communities, and hardwood communities, and also generating timber and nontimber forest products (fig. 12-6). To achieve such multifaceted goals, some tribes have developed innovative forest management plans that many consider to be fulfilling the promise of the NWFP for addressing both social and ecological goals (e.g., Baker 2003, Hatcher et al. 2017, Johnson et al. 2008). Chapter 11 highlights the critical role of fire in dry and some moist forest types for maintaining desired ecosystem conditions.

Thomas Dunklin

Figure 12-6—Clarence Hostler gathering matsutake mushrooms under tanoak trees on the Six Rivers National Forest, near Orleans, California, November 2013.

What Have We Learned About the Components of the Northwest Forest Plan and Their Compatibilities?

Coarse- and fine-filter approaches to conservation— Both coarse- and fine-filter strategies for conserving biodiversity (Hunter 2005, Noss 1987) are a part of the NWFP and the 2012 planning rule, and the relative importance of the two appears to have shifted toward coarse-filter approaches under the current planning rule. Earlier scientific debate on the pros and cons of single species (e.g., fine-filter) vs. ecosystem (coarse-filter) approaches to management (Casazza et al. 2016, Simberloff 1998, White et al. 2013) have been replaced by recognition that these approaches are complementary, and both are a valuable part of conservation strategies (chapter 6) (DellaSala et al. 2015, Hunter 2005, Noon et al. 2009, Reilly and Spies 2015, Simberloff 1998, Tingley et al. 2014). Meso-filter approaches (e.g., habitat elements like snags and large old trees) also have been included in a conservation approach hierarchy (Hunter 2005). The challenge now, and the source of some debate, is to find an appropriate level or balance of coarse-, meso-, and fine-filter approaches (Schultz et al. 2013). If a plan is weighted too much toward single species, or a particular successional stage, the strategy may succeed “in protecting a few of the actors at the expense of the majority of the cast” (Tingley et al. 2014). If weighted too much to the overarching ecosystem goals, the “stage” may be conserved but the “star actors may not show up” (Tingley et al. 2014).

Although the NWFP was based on coarse- and fine-filter strategies, the “star actor,” i.e., providing enough suitable habitat to sustain northern spotted owl populations, had a very large influence on the Plan. The approach of using the northern spotted owl as a surrogate or umbrella for old-forest ecosystems developed “unintentionally,” driven mainly by the need to meet the mandates of the ESA and other federal policies (Meslow 1993). The emphasis on the northern spotted owl carried through the development of the Plan, despite the fact that the NWFP was intended to be an “ecosystem management” plan. The single-species focus had unintended consequences for other biodiversity conservation and for management of resilience to fire and climate change across an ecologically diverse region. For example, in dry forests within the range of the northern spotted owl, large portions of the forest conditions that support this species are the result of 100 or more years of fire exclusion that has altered forest ecosystems and their resilience to drought and fire (chapter 3). The emphasis on the fine-filter aspect of the Plan—focusing on the northern spotted owl—challenges the Plan’s ability to meet other ecosystem goals under the 2012 planning rule, including ecosystem integrity and resilience to climate change and other stressors.

The congruence of coarse- and fine-filter goals and management approaches varies by disturbance regime (chapter 3). The most congruence between managing for historical range of variation or ecological resilience (i.e., a coarse-filter approach based on ecosystem dynamics) and for species that use dense older forests is in moist forests, where fire was infrequent (frequencies of 200 to >1,000 years), and forests would often grow for centuries without major disturbance. However, in regimes where fire was frequent or very frequent (less than 50 years) and landscapes were dominated by open-canopy forests, it is challenging to manage for both a coarse-filter approach based on landscape-scale ecological integrity, and the fine-filter approach of the NWFP based on maintaining or increasing the area of dense older forests. That is not to say that the two goals cannot be integrated in dry forests, only that the current NWFP strategy in dry forests does not guide management toward ecological integrity, which would emphasize management for the ecosystem-regulating role of fire.

Congruence between the two approaches (ecological integrity and coarse filter based on prioritizing dense, multilayered forests) is intermediate in moderately frequent to somewhat infrequent fire regimes (50 to 200 years) of the drier part of the moist forests where fire exclusion has had somewhat less effect. Here, historical fire regimes created a highly dynamic mosaic of high-, moderate-, and low-severity fire and higher diversity of early, mid- and late-successional stages than in the infrequent fire regime areas (fig. 12-2) (chapter 3). The relative abundances and spatial patterns of different forest states in the fire regimes of the NWFP area create inherently different biodiversity and ecosystem process conditions in the NWFP region. This ecological and geographic variability means that weighting the plan too much in favor of a single successional stage (e.g., dense older forest) will not likely succeed in maintaining a broader set of goals related to ecological integrity or resilience to climate change and drought.

Northern spotted owl—

The northern spotted owl was listed as threatened under the ESA in 1990. Despite extensive efforts of federal agencies to protect northern spotted owls, conserve remaining habitat, and set aside areas as future habitat, populations have continued to decline (chapter 4). When the NWFP was implemented, northern spotted owl populations were predicted to continue declining for as long as 50 years owing to lingering impacts of previous habitat loss before populations would recover while sufficient area of younger forests grew into conditions that supported the owl (chapter 4). Unknown at the time were the effects that competitive pressure by barred owls would have on spotted owl populations, which have further compounded the challenges faced by northern spotted owls and accelerated their rate of population decline. Without the protections afforded by the NWFP and ESA, northern spotted owl populations would likely have experienced even steeper declines (chapter 4). Clearly, efforts to recover the subspecies are facing multiple challenges related to both habitat management and the barred owl invasion (USFWS 2011). With the continued population expansion of the barred owl within the range of spotted owls, the long-term prospects for spotted owls are not good and remain uncertain.

Although structural definitions of old-growth forests and northern spotted owl habitat are similar in many ways, they are not synonymous (Davis et al. 2016), and strategies to conserve them may differ (fig. 12-7). Additionally, northern spotted owls do not function as an umbrella for **all** or even most other species within the full range of vegetation conditions in the NWFP area (Burnett and Roberts 2015, Carroll et al. 2010), a fact that was recognized at the time of the development of the NWFP and which led to the development of the Aquatic Conservation Strategy (ACS) and additional species protections in the form of the Survey and Manage program (chapter 6) (Carroll 2010, Molina et al. 2006, Raphael and Marcot 1994, Thomas et al. 2006).

Marbled murrelet—

The marbled murrelet has habitat needs that overlap those of the northern spotted owl and that are compatible with many definitions of old-growth forests (fig. 12-7). Thus, plans and strategies that focus on northern spotted owls and old-growth forests are likely to benefit to a large degree the marbled murrelet within its range. However, there are some distinctive habitat differences between marbled murrelets and northern spotted owls that require special conservation considerations (chapter 5). The most obvious difference is that the murrelet is a diving seabird whose foraging habitat is in the coastal marine environment, thus marine conditions must be considered in murrelet habitat needs. Murrelet nesting habitat occurs in coastal forests that typically experienced infrequent, high-severity fire regimes. Within that environment, marbled murrelets preferentially select larger, more contiguous patches of forest throughout their range and tend to avoid edge habitats where risk of nest depredation is greater (Raphael et al. 2015) (chapter 5); therefore, unlike for the northern spotted owl, proximity of early-seral forest is undesirable because it can increase abundance of birds that prey on murrelet nests. Extensive efforts to restore fire-resilient open old-growth forests in the somewhat infrequent to moderately frequent, mixed-severity regimes in the range of the murrelet may reduce habitat quality by increasing the exposure of nests to predators.

Aquatic ecosystems—

Goals of aquatic ecosystems partly overlap with characteristics of old-growth forests, and with habitats for northern spotted owls and marbled murrelets (fig. 12-7). For example, large dead trees and shading from dense patches of streamside conifer forests contribute to habitat quality in stream channels and cool stream temperatures that support salmonid populations (chapter 7). In coastal areas, tall, multilayered conifer canopies can intercept fog and deliver more moisture to streams than can shorter dense forests, mitigating some of the effects of climate change (chapter 7). However, the absence of disturbance for extended periods can result in the decrease in suitable substrates, reducing habitat quality (Reeves et al. 1995) (chapter 7). Riparian and stream environments are also dependent on geomorphic and

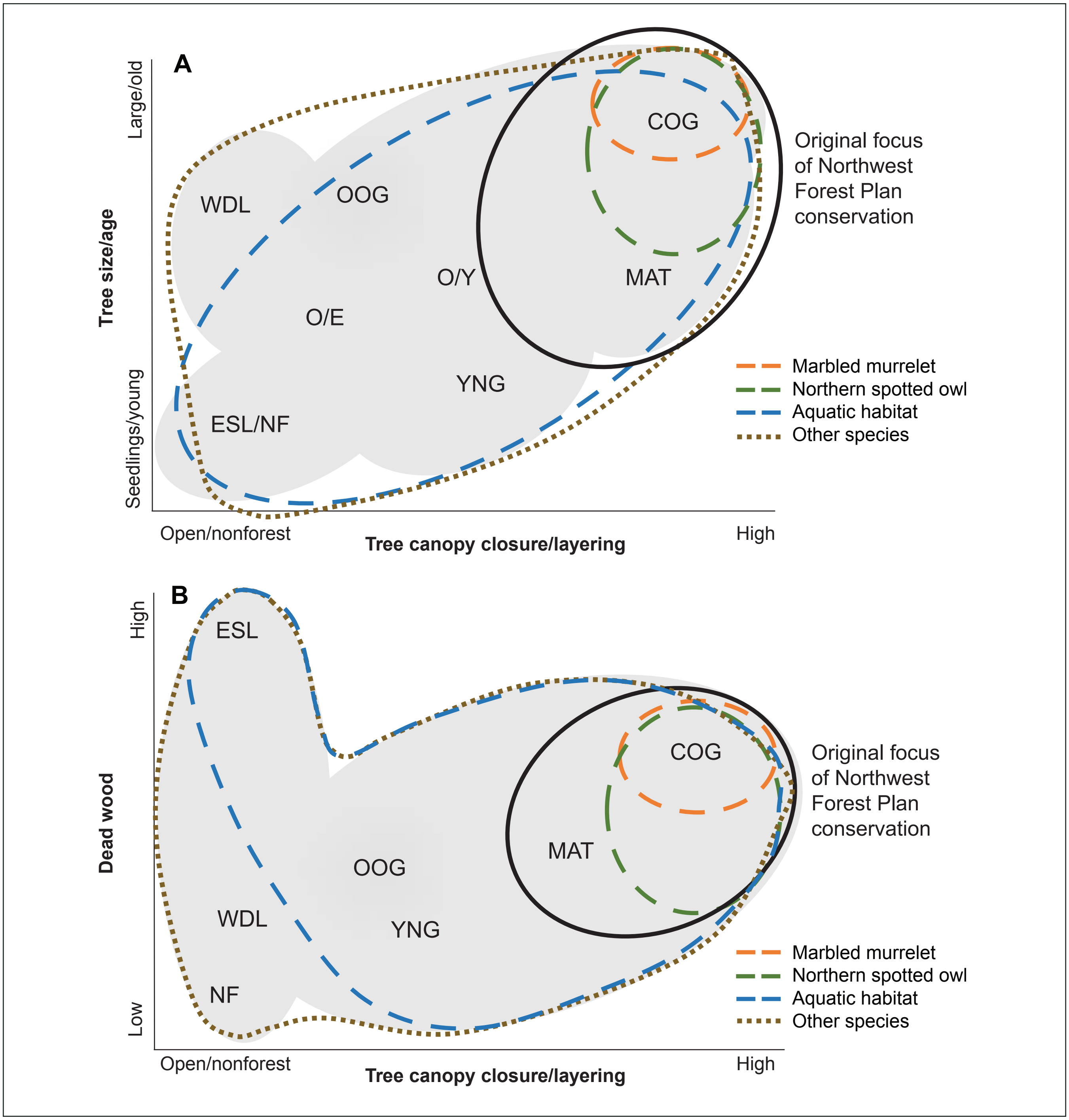

Figure 12-7—Distribution of habitat (dotted line ellipses) in relation to (A) tree canopy closure and tree size and (B) tree canopy closure and dead wood for different biodiversity components in the area of the Northwest Forest Plan. Northern spotted owl habitat refers to forests that are suitable for nesting and roosting. Gray ellipses refer to selected vegetation structure classes: COG—closed-canopy old growth; OOG—open-canopy old growth; YNG—young forest; MAT—mature forest; O/E—early successional with old live trees; O/Y—young forest with old trees; WDL—woodland; ESL/NF—early-seral/nonforest (shrubland, grassland). Conserving and restoring aquatic ecosystems requires a range of vegetation states, including older forest through time, but is not restricted to old growth (chapter 7). Many terrestrial species, including some tribal ecocultural resources, require early-successional and nonforest vegetation. Similarly, salmonid community assemblages differ between recently disturbed streams and undisturbed streams in old-growth forests.

hydrological disturbances that make many riparian areas a mosaic of older conifers, younger conifers, hardwoods, and shrubfields. This mosaic and the disturbance and successional dynamics that drive it means that the range of variation in riparian vegetation habitats may include conditions that do not qualify as old-growth forests (e.g., a lack of old conifer trees) or meet the habitat needs for northern spotted owls and marbled murrelets (fig. 12-8).

Fires burning through riparian areas and surrounding uplands may have reduced some stream qualities in the short term, but these events often improve conditions as large dead trees fall into streams, and as postfire floods, landslides, and debris torrents reorganize streams into more complex habitats (chapter 7) (Bisson et al. 2003). The absence of fire results in the lack of large influxes of sediments and wood, the basic building blocks of habitat for native fish, to the valley floors (Bisson et al. 2003, Flitcroft et al. 2016, Reeves et al. 1995) (chapter 7). Active management will continue to be used to reduce fuels and vegetation that make the forests susceptible to uncharacteristically large and severe wildfires. Such management often strives to prevent disturbances to streams, which can reduce or eliminate the occurrence of periodic disturbances that deliver sediment to the valley bottoms and stream channels. The lack of these disturbances and sediment can have serious unintended consequences to riparian-dependent wildlife and aquatic organisms (chapter 7).

Disturbances such as floods, landslides, and debris flows, which are essential for aquatic ecosystem functions, can be affected by roads that alter disturbance flow pathways and disconnect streams from uplands (Jones et al. 2000). These changes can reduce the resilience of these

Tom Spies

Figure 12-8—Mosaic of vegetation and substrate conditions along the North Fork of the Elk River, which occurs in an unlogged and largely unroaded watershed on the Rogue-Siskiyou National Forest in coastal Oregon.

ecosystems to these natural disturbance events. Decommissioning of roads can also improve passage for fish and other species and help reconnect streams and floodplains and improve water quality. Not all roads are the same, however, in terms of their ecological effects, and knowledge of how road networks are distributed relative to geomorphic processes can aid in the design of more effective road systems and restoration of watershed processes.

The potential of federal lands to contribute to the recovery of listed fish, particularly Pacific salmon, in many parts of the NWFP area is likely more limited than was recognized when the ACS was developed (chapter 7). The primary reason for this difference is that, in many situations, federal lands have a limited capacity to provide high-quality habitat for some of the listed fish. Federally managed lands are generally located in the middle to upper portions of watersheds, which tend to have steeper gradients and more confined valleys and floodplains, making them inherently less productive for some fish (Burnett et al. 2007, Lunetta et al. 1997, Reeves et al. 2016). Federal lands may, however, be major sources of wood, sediment (Reeves et al. 2016), and water (Brown and Froemke 2010, 2012) for downstream nonfederal lands, and will be important for the potential recovery of most populations. Nevertheless, their contribution to recovery may in many cases be insufficient without parallel contributions from nonfederal land ownerships elsewhere in the basin (Grantham et al. 2017).

Other species of late-successional and old-growth forest— The Survey and Manage program (chapter 6) identified and listed many fungi, lichens, bryophytes, invertebrates, and other species groups that were deemed to require specific surveying to help ensure their conservation under the NWFP. Although the NWFP protects 80 percent of the remaining old-growth forest in the region, this amount of old growth may represent only about 15 percent of the historical amounts of old growth that occurred in the moist forests across all lands in the NWFP area (chapter 3). The Survey and Manage program helped reduce the number of species on the list that were originally ranked as having low potential for persistence. The program also helped evaluate other species for potential addition to the lists and to make adjustments to surveys and site protection as needed for conservation of those species. Reduction in survey status or removal from the Survey and Manage species lists resulted from efforts to locate species during "predisturbance surveys" before harvests or other management activities. Since the 2006 synthesis (Haynes et al. 2006), no species have been added to the Survey and Manage species list; any additions would occur through a renewed annual species review process, and none was added the last three times the review process took place in 2001, 2002, and 2003.

The approach of the Survey and Manage program represented a fine-filter strategy applied to hundreds of species, which created a nearly impossible administrative and financial challenge to land management agencies (Molina 2006). This approach may not be consistent with the goal of having "a few species of special concern" under the new planning rule, although the rule also calls for creating lists of "species of conservation concern." At present, we recognize that alternative strategies to applying a fine-filter approach to large numbers of species include a meso-filter approach that is based on functional groups and habitat elements (chapter 6). As levels of intensive timber management from late-successional and old-growth forests continue to be low, as has been the case in recent years (fig. 12-9), and all such forests are excluded from timber management, the original motivation for the program—logging of unreserved older forest in the matrix (Molina et al. 2006)—would seem to have weakened. Most of the logging that has occurred under the NWFP appears to have been associated with restoration in plantations in moist forests and fuel reduction activities in dry fire-excluded late-successional and old-growth forests. The situation in dry forests raises the question of how to reconcile the goals of dense-forest species with those of ecological integrity and species that use more open fire-dependent forests? Fire exclusion has dramatically altered the habitats of both types of native species in these regimes (chapter 3) (Dodson et al. 2008; Keane et al. 2002, 2009); however, effects on biodiversity have received little empirical study in the NWFP area (Lehmkuhl et al. 2007), and broader evaluations of other dimensions of biodiversity (e.g., population genetics, food webs, and ecological functions) have generally not been made.

Forest carnivores, particularly those associated with old forest conditions, were not a primary focus of the original

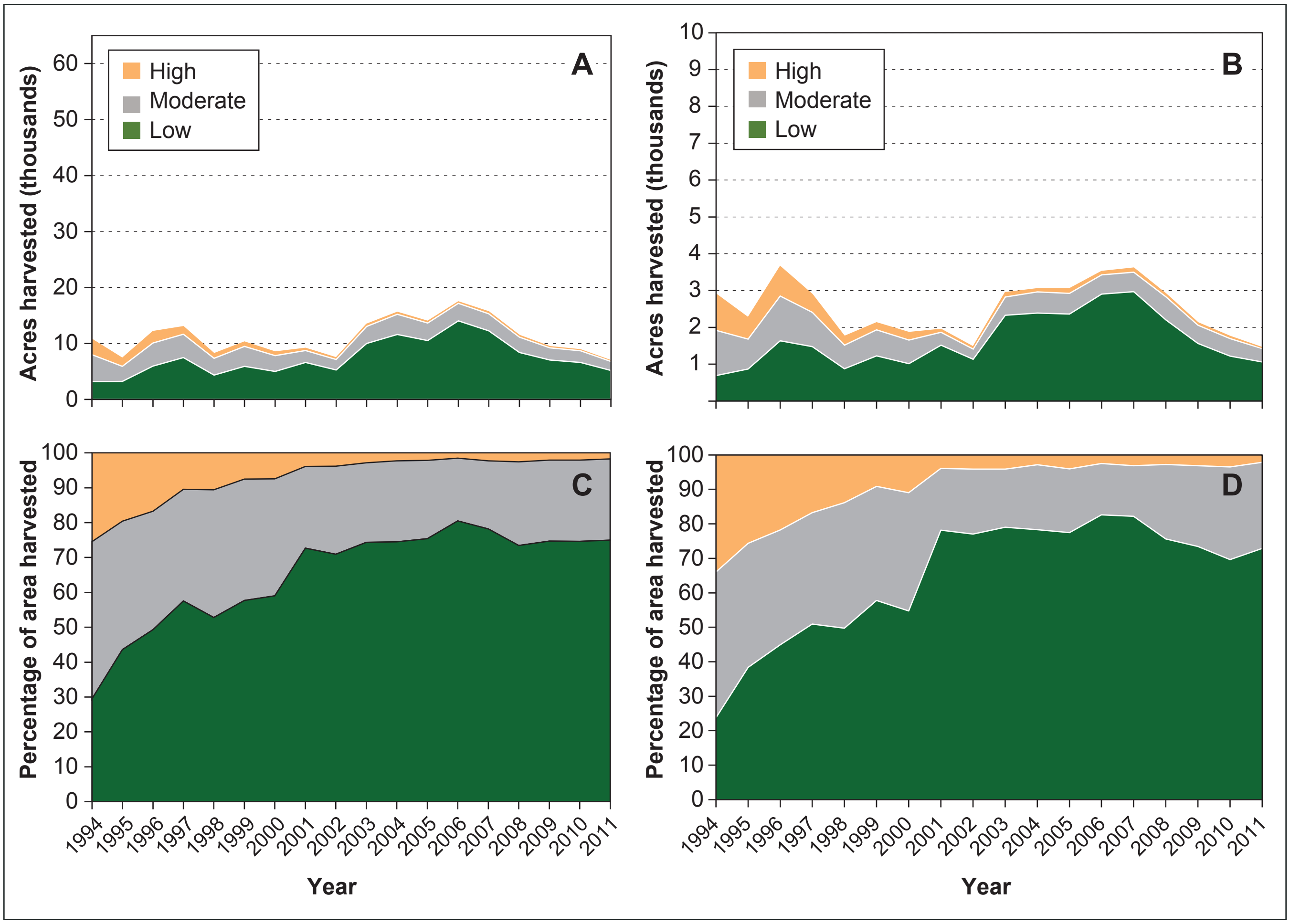

Figure 12-9—Trends in area of (A) old-growth structure index (OGSI) 80 harvested and (B) OGSI 200 harvested by intensity class (low, medium, and high) and percentage of harvest of (C) OGSI 80 and (D) OGSI 200 by intensity class on all federal lands between 1994 and 2011. OGSI is an index of stand structure based on live and dead tree characteristics that can be used to map the degree of old-growth development across a landscape as an alternative to classifications that simply define forests as old-growth or not. OGSI 80 and OGSI 200 represent the index at 80 and 200 years, respectively. Low = 0 to 33 percent loss of vegetation cover (all life forms); moderate = 33 to 66 percent loss, high = >66 percent loss. Note difference in scale between acres harvested in OGSI 80 and OGSI 200. Based on analysis of annual thematic mapper satellite imagery. Data are from Davis et al. 2015b. See Davis et al. 2015b for more information about OSGI.

NWFP. Fishers, marten, and lynx (*Lynx canadensis)* were addressed in the Forest Ecosystem Management Assessment Team report (FEMAT 1993) to a limited degree, with suggestions for conservation actions including closure to trapping of marten on federal land, evaluation of the effects of poisoning porcupines (*Erethizon dorsatum*), completion and implementation of habitat capability models for fishers and martens in California, and conducting more thorough surveys for both marten and fisher. Concern for the status of these species and for the wolverine (*Gulo gulo*) (which uses higher elevation, alpine, and subalpine habitats) has increased significantly in the past 23 years, and recent findings have identified new populations, new threats, and even new taxonomic species (see chapter 6). The Forest Service has increased measures to conserve habitat for these species, particularly in northwest California, where an extant population of fisher remains at risk. Increases in populations of carnivores would potentially have benefits to these ecosystems that cascade through trophic levels (Beschta and Ripple 2009), but the broader ecological effects of the further reduction or loss of these carnivores or their return in the NWFP area are not well understood.

Old-growth forest ecosystems—

The goal of the NWFP was to create "a functional, interactive, late-successional and old-growth ecosystem" (USDA and USDI 1994b: 6). As mentioned above, the congruence of the old-growth forest with the other conservation goals varies by location within the NWFP region, and by the definitions of old growth, and objectives. In general, the NWFP goals, which are yet to be fully achieved (e.g., in terms of area) (chapter 3) (Davis et al. 2015b), will provide a foundation for reaching many of the biodiversity goals of moist forests. But these goals are not consistent with managing for native biodiversity of dry forests and will not lead to long-term resilience of those ecosystems to wildfires and drought, or the broad diversity of successional and fuel patterns that support the natural fire regime (chapter 3) (fig. 12-7). Moreover, meeting NWFP goals has consequences for other components of forest biodiversity (e.g., early-seral species) not considered in the original NWFP (chapter 3) (Hessburg et al. 2016), especially those dependent on fire of different frequencies and severities, including aquatic ecosystems (chapter 7). In addition, new studies and increased recognition of the historical role of moderately frequent fire in drier parts of the moist forest zone, suggest that the Plan goal of conserving biodiversity associated with older forests may need to be revisited even in these relatively moist forests (chapter 3). Management for ecological integrity in this fire regime likely would seek to have a range of old-forest structural types (e.g., with and without tree age cohorts created by partial stand-replacement fires) and other successional conditions across landscapes. Fire in the moist forest zone sustains old forests and other successional stages, and contributes to hillslope processes (e.g., landslides and debris flows) that are fundamental to creating diverse and essential fish habitats (see below).

Reserves—

Late-successional forest and riparian reserves were major and controversial components of the NWFP. Based on the monitoring results and the original goals of the NWFP, the reserve strategy can be considered a success from the standpoint of halting old-growth logging (Davis et al. 2015b, 2016; Raphael et al. 2015). In addition, although late-successional and old-growth forests have continued to decline across the NWFP area owing to wildfire and logging (in the first few years of the NWFP), trends are in line with the Plan's expectation of losses (Davis et al. 2015b, 2016), but new concerns have emerged about fire and climate change. Similarly, clearcutting of riparian forests on federal lands has also come to a halt, contributing to improvements in watershed health (chapter 7).

Although trends in the amount of dense old growth are in line with expectations at a regional scale, there are reasons for concern (chapter 3). First, as mentioned above, maintaining or increasing current amounts of dense older forests in the dry forest zone is not consistent with managing for ecological integrity, as defined under the 2012 planning rule. Second, the Plan did not consider climate change effects that are already significant in dry forests (chapters 2 and 3). Managing for large areas of dense older forest (e.g., current LSR design) will not promote resilience to fire and drought, both of which are increasing under climate change. We explore these concerns in more depth below.

The standards and guidelines for the reserves specifically called out a need for active management to restore ecological diversity to plantations in both moist and dry forest types. Restoration activity has occurred in plantations in LSRs in moist forests, where innovative approaches to thinning have been developed and widely applied (chapter 3). The standards and guidelines for dry, fire-frequent forests (east of the Cascades and in the Oregon and California Klamath provinces) were different (USDA and USDI 1994b). There, the focus of management was on accelerating older forest development in younger forests and reducing risk of loss to high-severity fire in older forests. This concern was the impetus for designating some LSRs under the NWFP as "managed LSRs," in which silvicultural treatments were permitted to reduce risk of loss of stands around some northern spotted owl activity centers. However, the area of this type of LSR was small (about 102,000 ac) compared to the millions of acres of LSRs in dry forests (USDA and USDI 1994a). It is not clear how much restoration activity has actually occurred in older forests in LSR's or in riparian reserves in fire-prone forests because the implementation monitoring program was not continued. However, indications are that between

1993 and 2012 (20 years) less than 2 percent of older forest (OGSI 80) in the dry forest zone had treatments (Davis et al. 2015b) that would reduce total canopy cover, and surface and ladder fuels and risk of loss of older forest to large high-severity fires.

The issue of the need for restoration management also applies to riparian reserves, where relatively few restoration treatments have occurred (chapter 7). Primary reasons for the limited amount of restoration activity include (1) differing perspectives about the characterization of reference conditions, conservation, and management; (2) concerns about the potential effects of mechanical treatments on stream temperature and wood recruitment; (3) concerns about rare and little-known organisms (Reeves 2006); and (4) lack of trust in managers to undertake actions primarily for ecological benefits (chapter 7).

The LSR strategy of the NWFP was not designed or implemented in a way that promotes or restores ecological integrity or resilience in frequent or moderately frequent fire regimes (Spies et al. 2006, 2012). The initial identification of LSRs used a triage-based methodology that identified remaining concentrations of dense older forests after a history of fire suppression and aggressive harvesting. These areas were intended to provide habitat for northern spotted owls with adequate size and spacing of late-successional and old-growth forests to support the owl's recolonization. But this delineation was done without consideration for topographic and environmental setting and historical fire regimes of the forests. The standards and guidelines for silviculture in fire-prone forests (USDA and USDI 1994b) place many restrictions on restoration in dry forests in LSRs, and emphasize stand-level treatments to accelerate development of late-successional (i.e., dense multilayered) forests in younger forests that do not "degenerate suitable [northern spotted] owl habitat." They also suggest that treatment in older forests "may be considered" where they "will clearly result" in reduced risks. The standards and guidelines also lack a landscape perspective for fire and dry forest dynamics (e.g., see Hessburg et al. 2015, 2016; Stine et al. 2014) that is now understood to be critical to achieving a mix of ecological goals in fire-prone landscapes. The main reason for the low level of restoration in older forests in LSRs mentioned above may be lack of social license including the threat of litigation (Charnley et al. 2015), which occurs much more frequently in the Forest Service's Pacific Northwest Region (Oregon and Washington) than any other region in the country (Miner et al. 2014). Other reasons may include valuing multistoried forests, the burden of protocols under the Survey and Manage Program, lack of trust in managers (Olsen et al. 2012), the perception of some that mixed-conifer forests do not need restoration (Urgenson et al. 2017), or that reserves mean no-touch areas. Nevertheless, a review of the literature conducted for the 10-year socioeconomic monitoring report, combined with interviews held with forest managers and community members in four case-study locations across the NWFP area, found that most people (84 percent) believe that active forest management is needed to maintain forest health, as long as it does not include harvesting old-growth or clearcutting (Charnley and Donoghue 2006). Most interviewees did not believe that enough active management had occurred during the first decade of the Plan, expressing concerns about fire, insects, and disease.

If the broader goal of managers is to build resilience to fire and climate change across fire-prone landscapes, our evaluation of recent science indicates that the current NWFP conservation strategy (e.g., LSRs, matrix, survey and manage species) in fire-prone forests would not increase ecological integrity or resilience of terrestrial and aquatic ecosystems in these landscapes (chapter 3). This is because the current approaches focus on maintaining current levels or even increasing the amount of dense older forest. Although some treatments are permitted in older forests to reduce risk of loss of northern spotted owl habitat to wildfire, insects and disease, the current strategy does not appear to have a goal of landscape-level resilience to fire and climate change as indicated under the 2012 planning rule. Landscape-level strategies that restore fire as an ecological process based on topography, vegetation heterogeneity, successional dynamics, fire behavior, and other factors would be more in line with the latest scientific thinking (Cissel et al. 1999, Hessburg et al. 2015). Such an approach would also be more in line with the most recent northern spotted owl recovery plan (USFWS 2011, 2012), which provides broad guidelines for navigating diverse ecological goals in these regions and states:

> …we recommend that dynamic, disturbance-prone forests of the eastern Cascades, California Cascades and Klamath Provinces should be actively managed in a way that reconciles the overlapping goals of spotted owl conservation, responding to climate change and restoring dry forest ecological structure, composition and processes, including wildfire and other disturbances… . Vegetation management of fire-prone forests can retain spotted owl habitat on the landscape by altering fire behavior and severity and, if carefully and strategically applied, it could be part of a larger disturbance management regime for landscapes that attempts to reintegrate the relationship between forest vegetation and disturbance regimes, while also anticipating likely shifts in future ecosystem processes due to climate… .

Modeling studies suggest that landscape approaches could reduce conflicts between restoration of fire-excluded ponderosa pine forests and conservation of the Mexican spotted owl (*Strix occidentalis lucida*) in Arizona (Prather et al. 2008); meanwhile, for the Sierra Nevada of California, Stephens et al. (2017) suggested that more comprehensive restoration treatments were needed to reduce wildfire risk to California spotted owls. Within the NWFP area, Spies et al. (2017) and Ager et al. (2017) modeled landscape scenarios in the eastern Cascade Range of Oregon and found that most of the existing area of spotted owl habitat could be maintained for 50 years despite the occurrence of wildfire (at recent rates) and restoration activities designed to create open, more resilient forests. Projected losses of owl habitat from wildfire were significantly more than from relatively limited restoration activities, but these losses were made up for by gains in habitat from growth and succession of small-diameter or relatively open forests. The value of examining both losses to fire and succession together has also been highlighted in a study by Reilly et al. (2017b), who found that in the eastern Cascades of Washington, Oregon, and California, losses of closed-canopy forests to high-severity fire between 1985 and 2010 were mostly balanced by gains from succession, though higher elevation forests showed significant declines and LSRs showed a small net decline in old, closed-canopy forests. These studies suggests that landscape-scale assessments of northern spotted owl habitat dynamics and fire need to take into account the age and structure distribution of all forests in a landscape and account for potential increases in northern owl habitat from succession. These trends may not hold in the future, however. Ager et al. (2017) found that if the rate of wildfire were to increase 2 to 3 times over current rates (e.g., moving from fire-return intervals of 250 years to 100 and 63 years, respectively), as some climate change studies suggest could happen (chapter 2), then the amount of northern spotted owl nesting and roosting habitat across the Deschutes National Forest could decrease by 25 to 40 percent in 30 years. Climate change projections also suggest decreased tree growth in the future (Restaino et al. 2016), which may affect the rate at which forest structure can regrow following fire.

The only explicit strategy that implements this vision for high-frequency fire forests is the Okanogan-Wenatchee National Forest Restoration Strategy (USDA FS 2012b). This strategy places a priority on restoring fire as an ecological process while maintaining adequate areas of spotted owl habitat that will shift across the landscape as fire and successional processes operate. Dynamic landscape approaches to reserves (as described above) or habitat conservation would have some similarities with recovery plans used for other listed bird species that find habitat in dynamic fire-prone landscapes (e.g., Kirkland's warbler and red-cockaded woodpecker). However, the habitats of these species are threatened by fire suppression rather than being promoted by it in the case of the northern spotted owl. The literature indicates that a dynamic landscape approach could still fit the broader definition of a "reserve" (e.g., exclusion of industrial level logging).

The current LSR-Matrix approach for dry zone forests does not appear to have or meet goals related to ecosystem integrity and management for resilience to climate change and fire. Managers may want to consider reevaluating and redesigning the NWFP conservation strategy for dry forests based on new scientific knowledge of climate change effects, knowledge of restoration strategies for dry forest landscapes (Hessburg et al. 2016), and the new 2012 planning rule, which emphasizes ecosystem approaches to conserving biodiversity. The science and experience with proposed changes to the NWFP conservation strategies indicate that design and implementation of such approaches would be facilitated by a transparent and inclusive decision-making processes (Olsen et al. 2012).

There may also be ecological benefits for alternative approaches for terrestrial and aquatic goals in dry parts of the moist zone forests (Cissel et al. 1999, Reeves et al. 1995). Management based on the historical disturbance regimes can benefit aquatic habitats (Reeves et al. 1995) in these fire regimes. For example, Cissel et al. (1999) found ecological benefits from changing the spatial distribution of reserves and standards and guidelines for LSRs and the matrix to better approximate the mixed-severity fire regime dynamics of the western Cascades of Oregon. Experiments were started in older stands to evaluate the management alternatives that included using timber harvest and prescribed fire as surrogates for partial stand-replacement fire. However, the effort was abandoned because stakeholders were skeptical of cutting older trees in the matrix lands, and they lacked trust in the agency to implement such approaches to achieve restoration goals (Olsen et al. 2012).

Thomas et al. (2006) suggested changing the NWFP allocations to protect all remaining older forest, whether located in reserves or the matrix. The U.S. Fish and Wildlife Service critical habitat designation recommends conserving spotted owl sites (recovery action 10) and protecting high-quality habitat (recovery action 32) whether it occurred in LSRs or the matrix (USFWS 2011, 2012). The science suggests that these actions will have ecological and social benefits, but there will be tradeoffs associated with timber production and needs of species that use other successional stages, although none of those species has been identified as threatened, endangered, or at risk because of conversion of their habitat to late-successional or old-growth forest conditions.

The NWFP was intended to adapt to new knowledge and changes in the environment (USDA and USDI 1994b), which is consistent with the idea that conservation should be adaptive and iterative (Carroll et. al. 2010, Walters 1986), but this goal has not been fully achieved for various reasons (see below). Although lines are drawn on maps, and standards and guidelines are developed for reserves and other land allocations, findings from conservation and ecosystem sciences suggest that these should not be seen as immutable. Ecological and social science research, adaptive management experiments at landscape scales, and monitoring are critical to learning and meeting the conservation goals of the NWFP. These tools are also critical to addressing other species and habitat concerns, along with other human values across the wide range of forest environments within the range of the northern spotted owl.

Socioeconomic goals—

The NWFP had four main socioeconomic goals (Charnley 2006b): (1) produce a predictable and sustainable level of timber and nontimber resources, (2) maintain the stability of local and regional economies on a predictable, long-term basis, (3) assist with long-term economic development and diversification in communities most affected by cutbacks in timber harvesting to minimize the adverse impacts associated with job loss (USDA and USDI 1994b), and (4) promote interagency collaboration and agency and citizen collaboration in forest management (Tuchmann et al. 1996). Regarding the first goal, 20 years of monitoring data indicate that the probable sale quantity of timber identified by the Plan was never met, meaning that timber sales have not been predictable or at the level envisioned (chapter 8). The probable sale quantity established by the Plan was based on a number of assumptions: (1) harvesting unreserved older forest in the matrix with novel silviculture would contribute roughly 90 percent of the volume during the first three to five decades of the Plan, (2) about half of the harvest during the first decade would come from forests more than 200 years old, and (3) the main harvest method would be regeneration harvest, using retention harvesting approaches (chapter 3) rather than clearcutting (Charnley 2006a). The area of regeneration harvest in OGSI 80 and OGSI 200 (fig. 12-9) was 1,000 to 2,000 ac annually in the first 5 years of the Plan, but it declined to near zero by 2000 and has stayed very low since then. Most of the harvest since 2000 has been in the form of thinning and partial canopy removal (figs. 12-9C and 12-9D), which generate less volume than intensive (regeneration) harvest. The early levels of regeneration harvest may have also included sales awarded before the Plan was implemented.

Appeals and litigation over timber sales that included large, older trees, and lack of public support for clearcutting and old-growth harvesting, were major factors preventing the agencies from cutting OGSI 80 and OGSI 200 to meet probable sale quantity (Charnley 2006a, Thomas et al. 2006). The need to protect more habitat for the northern spotted owl (given the threat from the barred owl), and the need to protect late-seral habitat for other species associated with older forest also limited harvest in mature and old-growth forests (chapter 6).

Thus, the main source of timber supply shifted from the intended ecological retention harvesting from older unreserved forests in the matrix in the first few years of the Plan to restoration thinning of smaller trees from plantations and forests less than 80 years old in LSRs and the matrix. Timber as a byproduct of thinning in plantations and restoration in dry older forests is compatible with several conservation goals as discussed above, and it is less controversial. However, such thinning in LSRs cannot be sustained, because in 10 to 20 years most of the plantations will have been thinned once, and most of them in the moist provinces will become too old (80 years) to be treated again according to the record of decision (USDA and USDI 1994b) (chapter 8). Likewise, the thinning and restoration of resilience in fire-prone older forests may not produce a sustainable supply of wood as restoration eventually shifts from mechanical removal of understory trees to using wildfire and prescribed fire to maintain resilience (Spies et al. 2007). The sale of wood products generated may not offset the costs of treatments.

One way that restoration might provide for more economically viable and longer term production of wood from federal lands is through the use of ecological forestry[8] approaches (Franklin and Johnson 2012) to create diverse early-successional habitats (chapter 3). Such habitats are created naturally by wildfires and other natural disturbance agents, but in most areas in the NWFP region these fires are suppressed to protect a variety of human and forest values (see chapter 3). Fire exclusion means that diverse early-seral conditions will develop from fire at lower rates than would have occurred historically. Restoration treatments (mechanical and prescribed fire) could be used to create diverse early-seral vegetation to help achieve biodiversity goals in contexts in which they do not conflict with goals for older forests. Such actions would typically remove some larger trees and could thereby provide timber for local economies, while helping to fund removal of small trees and biomass. Franklin and Johnson (2012) suggested that such actions be focused on existing plantations, outside of LSRs and in places where other late-successional goals are not compromised. This type of management could provide a niche for federal timber production that is something of a win-win for a diverse set of ecological and socioeconomic goals. In addition, the fact that federal timber cannot be exported could also provide a supply of timber for local mills that would not have to compete with export markets that are currently strong.

Ecological forestry principles could also be used in riparian forests to restore the diverse forest structure and composition that occurred under historical disturbance regimes. Since development of the ACS, there has been support in the scientific literature for discretion in setting site-specific activities (Kuglerová et al. 2014, Lee et al. 2004, Richardson et al. 2012), which can be economically beneficial (Tiwari et al. 2016). Greater flexibility in the management of riparian areas would depend on the "context" of the area of interest (Kondolf et al. 2006, Montgomery 2004) and the primary management objective for the specific area (Burnett and Miller 2007). However, development of such an approach has been limited because of the reliance on "off-the-shelf" and one-size-fits-all concepts and designs, rather than on an understanding of specific features and capabilities of the location of interest (Kondolf et al. 2003, Naiman et al. 2012). A mix of approaches could be undertaken, recognizing ecological and other goals such as timber harvest, especially if applied over larger spatial scales (Burnett and Miller 2007, Miller and Burnett 2008, Olson and Rugger 2007), and if consideration is given to the distribution of populations of concern and connectivity among them

[8] Ecological forestry uses silviculture based on knowledge of natural disturbance regimes and succession to manage forests for ecological goals or a mixture of ecological and socioeconomic goals. See chapter 3 for more information.

(Olson and Burnett 2009, Olson and Kluber 2014, Olson et al. 2007). Reeves et al. (2016) provided an example of such an approach and showed that small adjustments in the amount of area in which active management may occur results in substantial increases in wood production while still meeting ecological goals.

We now have a new understanding of the relations between federal forest management and community socioeconomic well-being (chapter 8) that helps us understand the ability of the NWFP to achieve goal 2 (maintain stability of local and regional economies). For example, private forests currently contribute the vast majority of logs processed by mills in the Plan area. Greater timber harvest on federal forests would increase the number of logs available to mills and likely create additional work opportunities for loggers, at least in the short term. Generally, increased federal harvest would reduce the prices paid for logs by mills, which in turn would make wood products producers better off, while making private landowners worse off because their logs will be worth less. However, there are exceptions where mills need to maintain capacity for processing but timber resources are in limited supply, including in forest regions with few mills. In these cases, increased federal harvests can help keep mills from closing, benefiting both wood products producers and private landowners.

Federal forest management can contribute to community well-being in other ways, through the production of a variety of commodities, natural amenity values, other ecosystem services, and employment opportunities, but it cannot ensure the stability of local communities and economies (chapter 8). Not only is community well-being a product of multiple influences at multiple scales; social systems, like ecological systems, are dynamic. Today a more relevant question for managers is how federal forest management can contribute to community sustainability and increase community resilience in the face of social and environmental change. Social, economic, and ecological sustainability are linked, and community resilience contributes to resilient social-ecological systems.

Regarding long-term economic development and diversification (socioeconomic goal 3), the Northwest Economic Adjustment Initiative and Jobs in the Woods programs had mixed results (see chapters 8 and 11). However, alternate formulas for payments to counties embedded in the Secure Rural Schools Act have made important economic contributions to NWFP-area counties and communities, although the future of these payments remains uncertain because the Secure Rural Schools Act expired in 2017.

As to the fourth goal—increased collaboration in forest management—the NWFP was perceived by many people who were interviewed as part of the socioeconomic monitoring program during the first decade of the Plan as moving forest management decisionmaking from the local to the regional level (Charnley 2006b). Since that time, however, the number of forest collaborative groups has grown in the Plan area (from 8 to 25), and the agencies have emphasized the importance of local-level collaboration as a way of doing business (chapter 9).

One way of reducing tradeoffs between the social and biodiversity goals of the NWFP would be to increase activities that contribute to community well-being while fostering the engagement of local communities in conservation. One clear example is to continue attempts to create quality jobs that employ local community residents in ecosystem restoration, research, monitoring, fire suppression, and other activities that contribute to forest stewardship (Charnley 2006a. Although such jobs are unlikely to replace the number of jobs lost over the past few decades in the wood products industry, and may not pay as well, they nevertheless can make a significant economic contribution in local communities and be a source of economic diversification.

Adaptive management and monitoring—

The NWFP was founded on the concept of adaptive management and learning, based on monitoring, adaptive management areas (AMAs), and other forms of reactive, active, and passive adaptive management. Adaptive management, social learning, and landscape-level experiments are key components of increasing social-ecological resilience (Tompkins and Adger 2004). Strategies to promote this type of resilience would include engagement of collaborative groups in management experiments, demonstration projects, and landscape restoration projects. Social networks may be able to help spread adaptive forest management ideas and practices to deal with fire and climate change in the area of the NWFP (Fischer and Jasny 2017, Jacobs and Cramer 2017).

Bormann et al. (2006) provided an indepth evaluation of the adaptive management and regional monitoring program for the NWFP; here we highlight a few key findings. First, the adaptive management program as embodied in the AMAs was generally not successful, as funding for the AMAs declined after 1998, and adaptive management protocols were not widely integrated into agency missions at local scales. However, some successes in active adaptive management did occur. For example, the Central Cascades AMA was the location of efforts to develop and implement alternative landscape-scale approaches to meeting NWFP goals based on mixed-severity fire regimes (Cissel et al. 1999). Other AMAs may have implemented valuable experiments, but we could not find published or unpublished reports that document these actions. Four obstacles to adaptive management in the NWFP area were identified by Bormann et al. 2006: (1) perceived or real latitude to try different approaches on AMAs was too limited; (2) adaptive management was perceived as only a public participation process and there was a lack of consensus on implementing ideas on the ground; (3) precautionary, risk-averse approaches dominated and eventually overshadowed efforts to learn by doing, limiting the ability to increase understanding of systems; and (4) sufficient resources for management activities and the attending followup monitoring and research were not available. The lack of adaptive management activity and restoration activity in general may be a consequence of the fact that federal forest management increasingly takes place in a "vetocratic" setting in which non-Forest Service stakeholders reduce the decision space of managers and make the agency less autonomous than it was previously (Maier and Abrams 2018). According to Maier and Abrams (2018), this situation developed as a way for managers to reduce likelihood of litigation and to provide funding for nontimber objectives that is tied to collaboration.

It also should be noted that the Plan was not implemented as written, as managers responded to various social, economic, and administrative constraints. The implementation of the Plan has occurred through a more reactive or passive adaptive management approach based on resource limitations, social influences, and different interpretations at the ground level. The changes made in implementation of the NWFP include avoiding timber production from older forests in the matrix, ending of surveying for rare species, limited restoration activities in LSRs in fire-prone forests and riparian zones, and, of course, adaptive management itself. Because the NWFP has not been formally changed, it can be confusing to discuss the "Plan" without qualifying whether one is referring to the NWFP as written or as applied.

Obstacles to learning and adaptive management and maintaining an effective monitoring program are not easily overcome (Bormann et al. 2006). Some key principles for more effective adaptive management and monitoring include (1) engaging multi-agency regional executives in guiding learning, (2) involving regulatory agencies, (3) accommodating reasonable disagreement among stakeholders, (4) committing to quality, standardized record keeping by managers, (5) developing long-term funding strategies and maintaining a critical mass of agency expertise, (6) reinterpreting the burden of proof and the precautionary principle so that passive management is not the default and different management approaches can be applied, and (7) allowing for scientifically credible and relevant management experiments to take place even if they do not have total social license.

Although the adaptive management component of the NWFP fell quite short of expectations, the effectiveness monitoring program has been a relative success as evidenced by the valuable and insightful information obtained by 20 years of monitoring of old-growth forest, northern spotted owls, marbled murrelets, aquatic systems, socioeconomic conditions, and tribal relations. Monitoring moved the implementation of the Plan from opinion to evidence-based decisionmaking, helped institutionalize some adaptive management at regional scales, provided evidence of measurement error and variance in key Plan indicators, and demonstrated that agencies can work together effectively.

Plan Goals and Strategies in Relation to New Concerns

Since the development of the NWFP in the early 1990s, several new conservation concerns and issues have emerged that are directly related to meeting its original goals. Perhaps the most significant new concern is the spread of the invasive barred owl and its strong effect on populations of northern spotted owls, as noted above. Here we highlight two other major concerns: (1) the exclusion of wildfire as a keystone ecological process in many NWFP-area forest ecosystems and (2) the role of climate change in profoundly affecting species, wildfire size and severity, and reducing the resilience of dense forests that have accumulated in dry forest zones in the absence of fire.

Fire exclusion and successional diversity—
We have already discussed at length the effects of fire exclusion on forest structure and composition and resilience of dry forests to fire and drought. Here we focus on a somewhat different aspect of that problem, the loss of other successional stages (which contribute to resilience) that are dependent on both low- and high-severity fire. Although not part of the original focus of conservation in the NWFP area, fire-dependent vegetation states are ecologically interdependent with dense old-growth forest in the sense that policies that promote these conditions (e.g., fire suppression) will reduce other vegetation types (Spies et al. 2006). Chapter 3 highlights the ecological significance of open, fire-dependent old-growth forests, including providing habitat for species such as the white-headed woodpecker (*Picoides albolarvatus*), a species that is on Bureau of Land Management (BLM) and Forest Service sensitive species lists for Oregon and Washington as a result of loss of open ponderosa pine forests to logging, and fire exclusion (Buchanan et al. 2003, Mellen-McLean et al. 2013).

Another fire-dependent state is early-successional vegetation (which can also arise from other disturbance agents). The lack of diverse early-successional ecosystems[9] has also become a major conservation concern (DellaSala et al. 2014, Franklin and Johnson 2012, Hessburg et al. 2016, Reilly and Spies 2015, Swanson et al. 2011). Many plant and animal species, including state-listed species, specialize in these early-successional conditions (Swanson et al. 2011, 2014). Some components of these ecosystems can persist for many decades (e.g., snags, dead wood, and open canopies) (Reilly and Spies 2015), but certain conditions within them (snag decay stages and environments for establishment of annual plants) are ephemeral, lasting just a few years. Whereas older forests can take centuries to develop, early-seral vegetation may be initiated in a few hours from a disturbance event and then further develop over many decades before tree canopy closure (chapter 3) (Raphael et al., in press). Maintaining occurrence of these episodic and dynamic ecosystems depends upon relatively frequent disturbance (of either natural or human origin) distributed across large landscapes (Reilly and Spies 2015). Clearcutting on private lands can produce open-canopy conditions that support some early-seral plant and animals species but lack dead and down wood, and active control of herbs, grasses, and shrubs to favor tree establishment and growth greatly limit the ecological diversity and function of clearcuts as surrogates for early-seral ecosystems (Spies et al. 2007, Swanson et al. 2011. Thus, early-successional stages, especially structurally and compositionally diverse ones, are important sources of biological diversity in the NWFP area, but their biodiversity has not been monitored or studied as well as later successional stages.

Despite increasing wildfire activity over the past 25 years, the occurrence of high-severity fire across all NWFP fire regimes has been low: rotations of 1,628 to 2,398 years in moist forest fire regimes and 333 to 690 years in dry forest fire regimes (chapter 3). Although area burned has increased with drought in the past 25 years in the area of the NWFP (chapter 2) (Reilly et al. 2017a), the amount of high-severity fire in moist forest may still be within the full historical range (over the past few thousand years) given the large amount of historical climate and fire variability in the region (chapter 3) (Reilly et al. 2017a, Walsh et al. 2015). However, when climate is taken into account, the recent (past 25 years) amount of high-severity fire and early-seral vegetation

[9] These are ecosystems dominated by shrubs, herbs, and grasses that have little or no tree canopy. They develop after stand-replacing disturbances (see chapter 3) and often contain dead legacies of the previous forest. Site conditions are such that they have the potential to develop into closed-canopy forests that can eventually develop into old-growth forests.

in moist forest regimes is probably low given that we are currently experiencing a warming climate. In addition, we know that more than 6,000 lightning-caused fires have been suppressed in moist forests during the past 20 years (chapter 3) within the Plan area. Thus, it is likely that the amount of early-seral post-wildfire vegetation within moist forest regimes is deficient relative to the historical range of variation, especially for the drier parts of the moist forests. In the historical very frequent fire regimes of the dry forests, large patches of high-severity fire that create early-successional vegetation would not have been common, and early-seral conditions would have occurred as a fine-grained mosaic within a matrix of open older forest (fig. 12-2).

Although early-seral post-wildfire vegetation on sites capable of growing forests appeared to be historically uncommon in most areas of high-frequency, low-severity fire (chapter 3), large patches of nonforest areas, such as savannas, grasslands, shrublands, and even some wetlands would have been relatively common and maintained by fire (chapter 3). These nonforest environments, which have been decreasing in many dry forest landscapes (Hessburg et al. 2007, Skinner 1995), are known to support unique biodiversity based on global-scale studies (Veldman et al. 2015) and may be more reduced than dense old-growth forests in the Pacific Northwest region. However, relatively little attention has been paid to the conservation needs of these nonforest and low-tree-density vegetation types in the literature from the NWFP region.

Climate change—

The effects of climate change have become a major concern and focus of research since the NWFP was developed and implemented (chapter 2). The effects and magnitude of climate change are still uncertain and will differ among species, ecosystem processes, and geographic area. In general, climate change adaptation goals can be congruent or compatible with many of the original goals and strategies of the NWFP, including large reserves in which commodity management and roads are excluded or minimized (Spies et al. 2010a). However, the degree of congruence varies with geography and spatial and temporal scale. For example, efforts to reduce tree density within forest stands and to increase resilience to drought conflict with development of dense, multilayer forest habitat at stand or patch scales (e.g., less than 100 ac). Early-seral vegetation created by wildfire or through restoration management could provide opportunity to plant or naturally establish more drought-resistant genotypes of native tree species (Spies et al. 2010a).

Addressing fish responses to climate change will be especially challenging because of the prominent role of ocean conditions and the importance of nonfederal lands for fish that move through large watersheds (chapter 7). The conservation and restoration strategies of the NWFP can benefit native fish, but there are inherent limits given the complex life histories of anadromous fish and ownership patterns. Populations of introduced or reintroduced fish species may expand under a warming climate and affect native species. Terrestrial and aquatic species responses to climate change will be variable, as mentioned above, or essentially unknown, as with most of the lichens, bryophytes, and invertebrates. We lack scientific assessments of which and how many species may respond negatively to climate change and how management strategies, including protection of climate refugia, silviculture to promote forest resilience, and possibly even managed relocation of organisms might benefit at-risk species (Schwartz et. al. 2012).

Mitigation efforts to limit releases of greenhouse gases and increase carbon storage can be compatible with many NWFP goals. For example, protecting and developing old-growth forests will contribute toward carbon sequestration in forest stands and landscapes (chapter 2). On the other hand, maximizing carbon sequestration will not be compatible with habitat creation for early-successional species (Kline et al. 2016), and may not be consistent with reducing stand density in dry forests to increase resilience to drought, fire, and insects. The tradeoffs between carbon emissions related to thinning and the carbon emissions that are avoided because forests are more resilient to fire- or climate-induced mortality (after thinning) will vary with scale of observation of fire, and forest type (McKinley et al. 2011, Ryan et al. 2010) (chapter 2). Carbon calculators are now available for exploring how different forest management and fire regimes might affect carbon sequestration in the forest ecosystem and in forest products (Zald et al. 2016).

Fire and climate change will also have an impact on some of the NWFP socioeconomic goals. For example, the ability of federal agencies to produce a predictable and sustainable supply of timber, recreation opportunities, nontimber resources such as mushrooms, and fish and game will be challenged as climate change alters weather, ecosystem productivity, and species distributions. Winter recreation associated with snow is already being affected by warmer winters, particularly at lower elevations. And, high-severity fire affects timber stocks and availability of nontimber forest products. As mentioned above, local job creation associated with forest restoration to increase resilience to wildfire, and for fire suppression, can support the Plan goal of contributing to economic development and diversification in communities (chapter 8).

Regional-Scale Issues and Challenges

The regional-scale concerns related to the NWFP goals include (1) the limited ability of federal forest lands to meet some conservation objectives, (2) the need for coordination among management units (e.g., national forests) to provide for population conservation goals and develop standards and guidelines that take regional ecological variability into account, (3) the connectivity and distribution of federal lands as they relate to the capacity of organisms to respond to changing climate and vegetation dynamics, and (4) coordination among ownerships to deal with cross-boundary and regional-scale issues such as wildfire and smoke, watershed processes, populations of sensitive species, and road systems.

The limits of federal lands to meet conservation goals for species and ecosystems were recognized at the time the NWFP was developed. These limits are particularly relevant to the marbled murrelet and the ACS. The marbled murrelet (as well as the northern spotted owl) occur in coastal forests in southwestern Washington, Oregon, and northern California, where the proportion of nonfederal forest land is relatively high (chapter 5). In these areas, continuing loss of marbled murrelet nesting habitat may eventually lead to a large gap in distribution of nesting habitat and thus a potential gap in the marbled murrelet distribution, leading to genetic isolation of northern and southern populations (Raphael et al. 2016). Habitat for six salmonid species is not well provided solely on federal lands because these species find high-quality habitat in lower reaches where most habitat is on private lands (chapter 7). With divergence of forest management intensity between federal and private forest lands, the landscapes may become more "black and white" with old forest on public lands and plantation forests on private lands (Spies et al. 2007). The implications of this landscape change in terms of edge effects and lack of diverse early- and mid-successional stages in the landscape as a whole are not well understood but may result in a reduction in regional biodiversity.

The need for coordination among management units (e.g., national forests, districts) for conservation of populations of listed species and recognition of variability in ecosystems and disturbance regimes was recognized in the development of the NWFP (USDA and USDI 1994b). The need for a regional-scale strategy still exists for the listed species (chapters 5, 4, and 7) (USFWS 2008). Recent science indicates that the regional-scale stratification of disturbance regimes into just two regimes (wet and dry) for purposes of standards and guidelines for management under the NWFP (USDA and USDI 1994b) was too simplistic because it lumped drier, more fire-frequent ecosystems in parts of western Oregon and Washington into one infrequent fire regime, and drier types into a single frequent regime with low- to moderate-severity fire (chapter 3).

Another limitation of the regional perspective that underlies the strategy and implementation of the NWFP is the lack of characterization of regional variability in socioeconomic conditions and aggregation of local-level variability at the human community scale, including community types and their contexts (e.g., proximity to and dependence on federal lands). For example, it might be possible to map regional or local variation in the availability of ecosystem services and well-being of communities (chapter 8) and community dependence on ecosystem services from federal lands. That information could be used to set priorities for meeting socioeconomic objectives and finding areas where restoration needs and socioeconomic needs line up.

The importance of regional connectivity of federal forest lands to provide for movements of plants and animals in response to climate change has been recognized (chapter 3) (Carroll et al. 2010, McRae et al. 2016, Spies et al. 2010a). The distribution of federal lands and reserves appears generally favorable for species that will likely need to move upslope and northward (DellaSala et al. 2016, Spies et al. 2010a). In general, areas occupied by federal lands have a relatively high topo-climatic diversity. Their permeability to movement of vagile vertebrates may be relatively high based on general land cover and use types (fig. 12-10), but it is not known how the distribution and condition of federal lands affects more sessile terrestrial organisms or benefits aquatic organisms.

Quantitative analysis of the effectiveness of the NWFP reserves and federal lands in providing for most species ecological processes, and other aspects of biodiversity under climate change, has been very limited. Carroll et al. (2010) found that "the current reserve system will face challenges conserving its current suite of species under future climates." They suggested that to address climate change for all species revisions to reserve networks designs may be needed. More research is needed to address this issue using updated models of climate, vegetation dynamics, species habitats, population dynamics, and landscape genetics.

The NWFP had a federal lands focus, but it is increasingly acknowledged that an all-lands or a multi-ownership perspective would be beneficial in dealing with issues such as fire, climate change, watersheds, and recovery of listed and at-risk species (chapters 4 and 7) (Bone et al. 2016; Charnley et al. 2017; Spies et al. 2007, 2010b). All-lands approaches can be promoted in several ways including prioritizing actions on federal lands based on conditions (context) in nearby nonfederal lands; providing funding mechanisms to support restoration on public, private, and tribal lands within shared landscapes; and coordinating management actions within watersheds and landscapes, where social and administrative processes enable such actions (Charnley et al. 2017, Knight and Landres 1998).

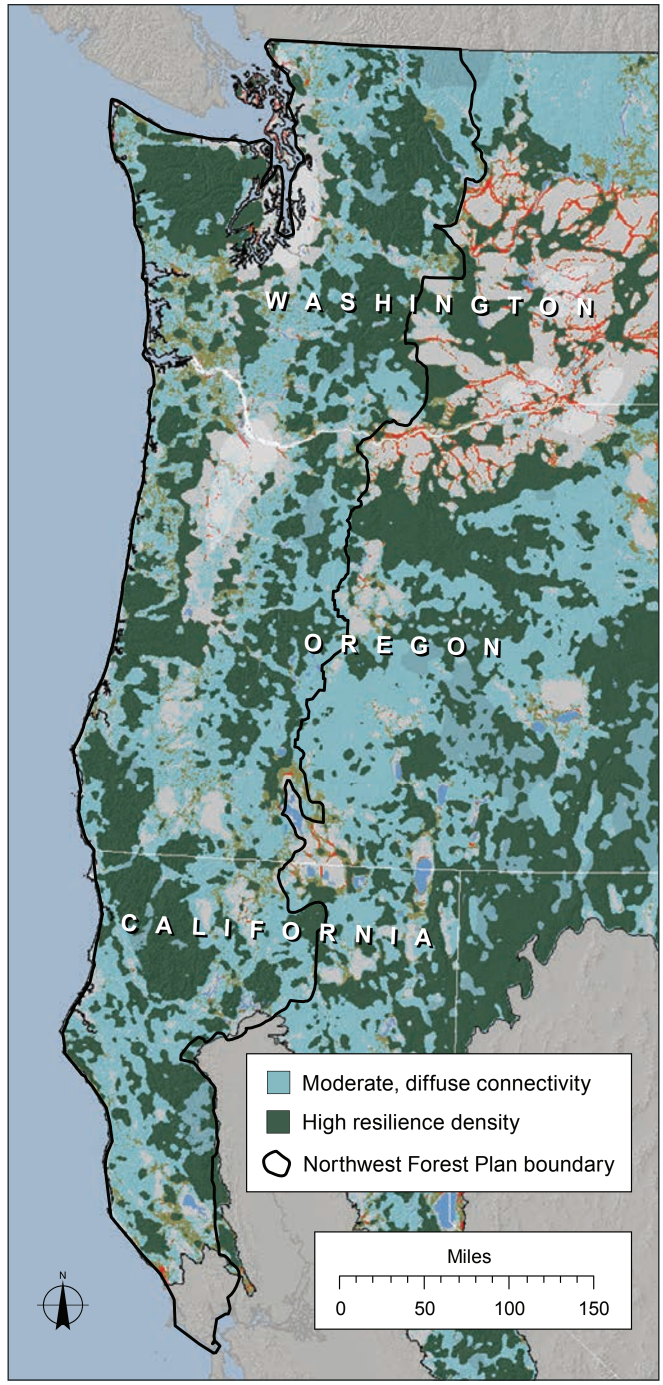

Figure 12-10—Regional connectivity and terrestrial resilience to climate change effects based on land cover types (connectivity) and topoclimatic conditions (resilience). Illustration adapted from McRae et al. 2016. Blue represents moderate levels of diffuse connectivity (movement is largely unrestricted); dark green represents areas of high resilience density (topoclimatic diversity).

Tradeoffs Associated With Restoration

Because the ecological goals of the NWFP are not necessarily consistent with addressing new conservation issues (e.g., the tension between managing for dense old-forest species versus open old-forest or early-seral species), it should not be a surprise that forest management activities for specific restoration goals would have variable effects across a spectrum of ecological and socioeconomic goals. We have touched on some of these in the previous section; here we summarize these in more detail in terms of specific management actions and how they might affect different management goals (table 12-1). Most of these effects are discussed in greater detail in other chapters of this report.

Variable-density thinning in plantations in moist and dry forests—
Variable-density thinning in plantations in uplands and riparian areas to immediately increase vegetation diversity and accelerate future development of large tree boles and crowns has a variety of effects across all fire regimes, as noted elsewhere in this document (chapters 3, 4, 5, and 7). Thinning can have immediate positive effects on several species; e.g., some lichens and bryophytes (chapter 6), and can accelerate growth of larger trees, but it reduces dead wood amounts compared to the unthinned state unless some thinned trees are left on the site. Studies of effects of variable-density thinning on invertebrates in western Washington indicate that the effects can be positive, especially in the short term, or negative depending on time since thinning, forest structure, and environment (Schowalter et al. 2003). Increasing spatial heterogeneity of the tree layer in plantations creates discontinuous fuel beds, increases structural and compositional diversity, and restores some of the heterogeneity that would have occurred in young post-wildfire stands. Similarly, thinning in riparian plantations can accelerate growth of large trees that occurred in variable densities near streams. Dense, uniform plantations are an altered ecosystem that may not serve as a good reference for management in riparian zones, many of which were historically a mosaic of older conifers, hardwoods, and shrub patches, especially near larger streams (chapter 7) (fig. 12-10). Thinning in plantations in riparian areas can also increase spatial heterogeneity of trees and shrubs and increase overall biotic community diversity, but reduce shading, which can increase stream temperatures (chapter 7). The role of thinning in increasing resilience of forests climate change has received only limited empirical study globally (chapter 2) (D'Amato et al. 2013, Elkin et al. 2015, Seidl et al. 2017).

Restoration of fire-excluded forests—
Thinning and prescribed fire to restore structure, composition, and resilience to older forests that historically experienced frequent fire can have numerous site- and landscape-level benefits (chapter 3; table 12-1) (Hessburg et al. 2016) that are both ecological and social. Restoration for ecological integrity and conservation of listed species can improve resilience to climate change and fire, and habitat for open old-growth species. Reducing fuel loads and increasing the heterogeneity of amounts and types of fuel can also reduce the potential extent of large patches of high-severity fire that result in losses of denser forest habitat. This practice can have adverse effects on northern spotted owls (but see North et al. [2017] for a different perspective) and some species such as fisher and marten that use dead wood as sites for foraging, resting, and denning. Little published science exists about blending the goals of conservation of northern spotted owl habitat and restoration of fire-dependent forest ecosystems at landscape scales. As experience with the Blue River plan (Cissel et al. 1999) indicates, this is both an ecological and socioeconomic problem that requires more research and evaluation through adaptive management and collaborative landscape efforts that try new approaches to the problem.

Restoration of fire-excluded forests also has social and economic benefits, particularly by reducing the risk of loss of property, structures, and lives to high-severity wildfire in the wildland-urban interface; by producing wood products and biomass that can be utilized; and by creating jobs. Tradeoffs include the impacts of smoke from prescribed fire treatments, the risk of escaped prescribed fire, and the cost of restoration treatments in areas where there are insufficient larger trees to provide revenue to offset restoration costs

Early-seral vegetation in moist forests—

Given that fire suppression has reduced the occurrence of early-seral vegetation, innovative silviculture including prescribed fire (such as ecological forestry) (Franklin et al. 2007), could be used to create large enough patches of early-seral conditions that are minimally influenced (e.g., by shade and belowground effects) from adjacent forest areas. To reduce impacts on existing older forests, such actions would be best focused on existing plantations, especially in matrix areas. Such activities would allow for establishment and persistence of early-successional species, including shrubs, and would contain large-diameter dead and some live trees that would be characteristic of higher severity post-wildfire environments (Franklin and Johnson 2012, Franklin et al. 2007) and that would serve as "legacy" elements of the previous stand conditions. The amount of retention of live trees would be variable to match variation in fire effects and site capacity at patch and landscape scales. Prescribed fire could be used in conjunction with this action to approximate some of effects of wildfire, especially on soil surface layers and understory plant and animal communities. This type of silviculture could meet diverse ecological and socioeconomic goals in both regimes of the moist forests and could target stands of any age because wildfire would occur across the full range of successional stages. However, when applied in older forests in the matrix, there are some tradeoffs (table 12-1). Large early-seral and nonforest patches do not provide habitat for late-successional species unless those species use early-successional and edge environments for some facet of their life history requirements. Cutting larger or older trees to create early-seral patches can provide larger volumes of wood for local mills, but it may not be socially acceptable because the focus and expectations of the Plan are currently to protect all remaining older forests from logging, and such harvest may conflict with the need to protect owl habitat given the threat of the barred owl. Recognizing these concerns, Franklin and Johnson (2012) have proposed that this type of habitat creation focus on stands less than 80 years old in the matrix. When applied in older plantations, this activity could produce significant amounts of wood and be a potential win-win for biodiversity and socioeconomic values. It should be noted, however, that there is little research and management experience in this type of restoration. In addition, using mechanical treatments to create early-successional habitat in younger forests and plantations will not provide large dead trees and other vegetation structures of late-successional and old-growth forests, nor some of the fire effects of naturally created early-successional vegetation (e.g., very large patches of early-seral ecosystems).

Post-wildfire management—

Post-wildfire management typically includes both salvage logging and planting of trees, which may or may not occur together in management. The ecological effects of postfire salvage logging can differ depending on treatment, fire severity, and biophysical setting (Peterson et al. 2009), but, in general, much existing research indicates that salvage logging does not have beneficial ecological effects on terrestrial or aquatic ecosystems (chapter 3) (table 12-3). However, there may be some exceptions to this rule. Peterson et al. (2015) and Hessburg et al. (2016) identified situations, e.g., concerns about lack of seed sources or reburns that maintain undesirable shrub fields, in which postfire wood removal might meet ecological goals. These include (1) fuel reduction treatments that reducs levels of large woody fuels derived from shade-tolerant species that may have accumulated under fire suppression and may pose a risk to soil fertility were the area to reburn; and (2) fuel treatments to reduce potential for high-severity reburns, and planting of trees to speed rate of forest succession where the potential for large semistable patches of shrubs is high and regeneration is lacking (Coppoletta et al. 2016, Dodson and Root 2013, Lauvaux et al. 2016, Meng et al. 2015); and (3) to reduce surface fuels that may impede establishment of trees. Sudden oak death also is likely contributing to ecologically novel configurations of dead trees and high fuels that may warrant interventions to reduce the potential for undesirable effects of reburn on soils.

Where timber salvage is conducted, reserving dense patches of snags adjacent to salvaged stands, rather than uniformly retaining small numbers of snags across a landscape, may be essential for sustaining populations of

Table 12-3—Summary of socioecological impacts of postfire management (salvage or planting)

Issue	Cons	Pros
Carbon	Carbon in dead trees may be slowly released as wood decays, and some may enter long-term pools in soils or in streams	Burned trees can be used as harvested wood products or can offset energy from more carbon-intensive energy sources when burned in biomass facilities; replanting of trees has potential to accelerate long-term carbon storage in areas where natural regeneration is poor
Wildlife habitat	Negative impacts on wildlife communities of removing biological "legacies" such as standing and down wood, particularly "early-successional" species that depend on standing snags	Planting of trees can accelerate forest development and reestablishment of late-successional habitat
Erosion	Mechanical activity can pose risks of increased erosion and runoff	Residual materials can be used as source of ground cover
Wood loading to streams	Removal can interrupt important process for storing sediments and reforming aquatic habitats	Reducing excessive wood loading could lessen risk of debris jams and downstream culvert/bridge failures
Fuel loading/fire hazard	Salvage can increase loading of fine fuels, leading to increased fire severity upon reburn; planted stands are highly vulnerable to fire for decades	Removal of excessive fuel load can moderate future fire severity and fire behavior in some contexts; can reduce risk to firefighters
Forest development	Salvage has potential to affect natural revegetation by trees and shrubs	Salvage plus replanting can accelerate return to forest conditions in areas
Economic returns	Investments in planted stands may be lost, especially as climatic conditions become less favorable to tree establishment and more favorable to frequent reburns, and they may also complicate use of fire at landscape scales	Timber from burned areas has high economic value, and returns can be used to offset costs of hazard reduction and long-term restoration; replanting can accelerate regrowth of timber-producing forests

early-successional species such as black-backed woodpecker (*Picoides arcticus*) (White et al. 2016b). Within riparian areas, more research is needed to understand variation in wood loading and whether there are loads that are detrimental to stream function, as well as the effects of riparian snag patches of different densities and sizes. As with terrestrial systems, retaining large snags that are likely to remain standing longer, and which are more likely to form persistent elements of aquatic ecosystems, could help to extend and moderate the input of large wood. Fuel hazard reduction might be achieved in part by removing smaller dead trees for biomass utilization or masticating them into ground cover where soils are severely burned and lack protective cover.

Roads—

The ecological effects of roads have been extensively reviewed in the literature (chapter 7) (Fahrig and Rytwinski 2009, Jones et al. 2000, Trombulak and Frissell 2000). The ecological effects of roads affect both terrestrial and aquatic ecosystems but are especially pronounced for aquatic ecosystems and species as the following list of impacts (chapter 7) indicates:

1. Accelerating erosion and increasing sediment loading.
2. Imposing barriers to the migration of aquatic organisms, including access to floodplains and off-channel habitats.
3. Increasing stream temperatures.
4. Causing changes in channel morphology.

5. Introducing exotic species.
6. Increasing harvest and poaching pressure.
7. Changing hillslope hydrology and resulting peak flows.

In the case of hydrological processes, the majority of roads have negligible effects, suggesting the need for a landscape approach to identity problem roads and prioritize road decommissioning. Hydrologically problematic roads constrain floodplains or have direct hydrologic connectivity with fish-bearing streams, but most streams in a network are not fish bearing.

On the other hand, roads are needed for forest restoration management, recreation, access to tribal resources and nontimber forest products, timber harvesting, and fire suppression. Roads are the primary way for people to access public lands, including private inholdings and historical tribal use areas. Decommissioning roads can help both reduce ecological impacts and reduce maintenance costs, which can be significant, but some road systems area still needed to meet other objectives. For example, roads provide access to forests and wilderness areas and are the pathways to special places to which people form strong attachments through repeated use. Roads also provide access to areas of the forest that generate incomes and provide jobs, as well as access to food and forage used by the public for everyday sustenance and survival. The costs associated with road decommissioning, which involves regrading, removing culverts, and revegetation, often make this option impractical. Roads that may be decommissioned by default through neglect may become safety hazards and sources of public conflict. Roads and road decommissioning are a prime example of tradeoffs associated with meeting competing goals for federal forests, including ecological restoration.

Uncertainty and Risk in Forest Planning and Management

Uncertainty and risk have long been a part of forest management and planning. However, as management objectives have shifted from commodity production to a broader range of ecological and social values from complex ecological and social systems (Moore and Conroy 2006, Rose and Chapman 2003), it has become even more crucial to consider ways of dealing with uncertainty, risk, and tradeoffs (Spies et al. 2010a). In addition, the threats from climate change, undesirable fire effects, invasive species, and social change introduce new drivers of forest ecosystems and management goals that are difficult to predict, control, and have variable effects on ecosystems and forest values. Uncertainty is defined as lack of information that falls on a continuum between absolute determinism and total ignorance (Walker et al. 2003). Risk can be defined as the probability (often not well known) of some, often undesirable, occurrence.

Uncertainty and risk pervade our understanding of the species, ecosystems, and social systems of the NWFP area. We know a great deal, of course, as the chapters of this synthesis demonstrate, but we also know that our knowledge in some key areas (e.g., persistence of the northern spotted owl and climate change effects, suitability of conditions other than old growth being favorable for fish and other aquatic organisms) is uncertain, and that the ability of management to achieve particular outcomes can be quite unsure. We also know that many forest values are at risk from influences that are both internal and external to the NWFP area and outside the control of forest managers (e.g., climate change and markets for wood products). Although concepts of uncertainty and risk are well known from the forest planning literature, the practical applications of this theory in decision support models and management are rare (Pasalodos-Tato et al. 2013). Managers and scientists may not be comfortable in admitting to the public that they are unsure of outcomes of proposed actions, but ignoring or not acknowledging uncertainties, risks, and tradeoffs can lead to poor decisions and bad planning alternatives (Pasalodos-Tato (2013). Although uncertainty is pervasive, it should not necessarily be seen as a reason for inaction (Dessai and Hulme 2004).

Several strategies exist for incorporating uncertainty and risk in forest management or biodiversity conservation. For example, Lindenmayer et al. (2000) suggested four approaches: (1) establish biodiversity priority areas (e.g., reserves) managed primarily for the conservation of biological diversity; (2) within production forests, apply structure-based indicators including structural complexity, connectivity, and heterogeneity; (3) use multiple conservation strategies at multiple spatial scales, spreading out risk in wood-production forests; and (4) adopt an adaptive management approach to test the validity of structure-based indices of biological diversity by treating management practices as experiments. Lindenmayer et al. (2000) also noted that "a biodiversity priority area should not imply a lack of need for active management regimes inside that area…such as the restoration of burning regimes that may be required by taxa dependent on particular seral stages or vegetation mosaics." Others have also called for risk spreading by creating heterogeneous systems at stand and landscape scales (Hessburg et al. 2016, O'Hara and Ramage 2013). In general, adaptive management (including monitoring) is considered one of the most important strategies for dealing with uncertainty (e.g., acknowledging it and reducing it) in forest planning and management (Keenan 2015, Moore and Conroy 2006, USDA FS 2012). Although more passive learning approaches can be successful, active and intentional adaptive management is much more likely to reduce uncertainty (McCarthy and Possingham 2007). It should be reiterated that active adaptive management is expensive and time consuming, however, how often have scientists and managers looked back 10 years and lamented lack of action to pursue such work?

Other approaches for dealing with uncertainty, risk and tradeoffs involve governance systems and interactions with stakeholders in plan development and implementation. The goals here are not so much to reduce uncertainty but to incorporate it into decisionmaking and communications with the public to provide more flexibility to change plans and management approaches to meet new challenges. Strategies include communication by managers with communities (in the case of natural hazards like fire), collaboratives, partnerships with nongovernmental organizations and planning boards (Calkin et al. 2011), and engaging stakeholders to improve plans and decisionmaking (Bizikova and Krcmar 2015, Keenan 2015).

Scenario analysis can help deal with and communicate to stakeholders the reality that social-ecological system complexity and stochasticity preclude prediction and certainty about management effects. Scenario analysis was used to inform forest management and policy across 13 states in the Southeastern United States (Wear and Greis 2012). In scenario analysis, a range of plausible futures is identified, and the consequences of different management strategies are evaluated with models (e.g., discussion/decision support tools) or expert opinion. This approach can help identify management alternatives that are likely to fail under certain futures and other alternatives that may provide some level of desired outcomes across a range of possible futures. Such efforts may help communicate sources of uncertainty and the idea that plans need to be flexible and adaptive to respond to unexpected and undesirable future outcomes and tradeoffs. However, this approach is also very labor intensive, involving much up-front work before engaging with stakeholders to develop and evaluate scenarios (Bizikova and Krcmar 2015). The challenges are many, including designing the social process of stakeholder engagement and interactions of stakeholders with data and models.

Policy research indicates that in our current biophysical and socioeconomic environment, forest plans must not only meet ecological and socioeconomic goals but also be robust and adaptable over time (Walker et al. 2013). Walker et al. (2013) listed three key principles to guide development of robust forest plans:

- Explore a wide variety of relevant uncertainties including natural variability, external changes, and policy responses.
- Connect short-term targets with long-term goals.
- Commit to short-term actions that keep options open for the future.

The NWFP was designed to be adaptable (e.g., through research, monitoring, and adaptive management), but as we described above, the adaptive management component of the Plan and some of the monitoring components did not survive for various social and economic reasons. Nevertheless, the idea that forest plans should be adaptable and underpinned by adaptive management is still considered the best way forward in a dynamic and uncertain world.

Information Gaps, Research Needs, and Limitations

Monitoring—

We lack information about the amount, pattern, and type of restoration activities that have occurred in upland and riparian forests. Implementation monitoring has not occurred to a degree that we can know the rate, pattern, and type of restoration actions across the NWFP area. Effectiveness monitoring has provided useful information (e.g., about the northern spotted owl and marbled murrelet), but disinvestment in some aspects of NWFP monitoring over time (e.g., socioeconomic, implementation, Survey and Manage species) has limited the amount and usefulness of the monitoring information produced. Research is needed to determine how well the current set of monitoring metrics (e.g., old-growth index) address issues related to fire exclusion (e.g., metrics for open canopy, old-growth forests) and climate change, and how effectiveness monitoring can be better linked with validation monitoring and research. Research is also needed to better understand what is causing the monitoring trends observed and how to address undesirable trends.

Climate change—

Uncertainties about the effects of climate change on ecosystems, including fire activity, remain large owing to regional variability, complex interactions, and the coarse spatial scale of projections. Having large areas dedicated to promoting biodiversity and resilience to climate change is a foundational strategy, but we lack quantitative analyses of how different management approaches to biodiversity conservation affect vulnerability to climate change. Silviculture, including innovative tree planting strategies, may help improve resilience of forests to climate change impacts (e.g., large patches of high-severity fire). However, we lack information on how future vegetation communities might form and adapt to different climate scenarios to fully understand the interactions and tradeoffs. We also are challenged to estimate how vegetation might change across time and landscapes under different climate scenarios and the degree to which various measures of and objectives for "forest resilience" may be met. This lack of information also tempers our confidence in climate change adaptation strategies for human communities. Landscape-scale models and tools are needed to analyze scenarios and the effects of alternative landscape designs on species, ecosystems, and human communities. New monitoring field studies and assessment tools are needed to evaluate stress and mortality in forests at landscape scales and to test hypotheses from landscape simulation models that are a major source of information about possible future climate change effects.

Species and ecosystems—

We have virtually no published information about how northern spotted owls respond to wildfires, including increased frequency and severity of fire. We also need to improve our understanding about interactions between northern spotted owls and barred owls and their niche separations to help identify key areas for northern spotted owl conservation.

Effects of fire suppression (e.g., increased forest density and increased proportion of shade-tolerant trees) on ecosystem processes and population responses of plants and animals are not well understood in the area of the NWFP. More research has been conducted on how changes in stand structure and composition affect fire behavior than on how those altered forest conditions affect resilience to drought, biodiversity and ecosystem function, and successional trajectories.

Conservation and restoration strategies—

The limits (ecological and social) to restoring forest ecological integrity (per the 2012 planning rule) and resilience with fire (both prescribed and wildfire managed to achieve resource objectives) across diverse landscapes are not well understood. More fundamentally, we need research to help develop definitions and metrics of integrity and resilience so that managers can operationalize them at different scales. It is unclear if we have passed tipping points (e.g., crossed ecological and socioecological thresholds that make it difficult to restore desired conditions) in some landscapes that have been transformed by the cumulative effects of altered disturbance regimes and climate change. In addition, the ecological and social impacts of using surrogates (e.g., mechanical fuels treatments) for fire are also not well understood across the fire regimes of the NWFP area, especially for biodiversity (most work has focused on forest structure and composition change, and fire behavior); previous work suggested that such surrogates may not serve well if they do not pay attention to biological legacies (Franklin et al. 2000). For example, research is needed to help us understand how well mechanical methods and prescribed fire create diverse early-successional habitat and functions, especially when applied to forest plantations. Although theory supports the hypothesis that biodiversity and ecosystem function associated with post-clearcutting environments and young plantations (e.g., on private lands) are different from post-wildfire or post-windthrow environments, no empirical research has been conducted.

Relatively little published research has focused on how well the regional NWFP strategy of reserves and associated management guidelines will meet biodiversity goals under changing climate and fire regimes. Research is needed to understand the ecological tradeoffs associated with alternative conservation land allocations and designs based on different ecological priorities (e.g., single species versus multiple species and processes).

Tradeoffs associated with alternative management strategies—

Although we have some knowledge of the tradeoffs associated with restoration and conservation strategies to meet ecological and socioeconomic goals, we generally lack knowledge of how those tradeoffs and interactions differ across the region, with scale, and over time. Reliance on precautionary approaches that avoid interventions may produce unintended outcomes because no action (e.g., not thinning a plantation or not using fire) may have undesirable effects (e.g., less biotic community diversity). In such cases, rigorous adaptive management approaches (e.g., learning by doing) are considered the best way to address uncertainty and complexity (Walters 1986). Research is needed for understanding the long-term and landscape-scale effects of restoration on terrestrial and aquatic species, biodiversity elements, and ecosystems and how these actions interact with social systems.

Scientific literature has been fairly clear in indicating that the benefits from salvage logging are generally economic, in the form of wood products, rather than ecological. However, we lack information on the long-term effects of salvage logging in burned forests whose density and composition have been heavily altered by fire exclusion before the fire. As the likelihood of reburn in immature forests increases with climate change, the rationale for such interventions may grow. In addition, we lack information on when and where planting might be needed and what kind of salvage might be appropriate, if at all, to facilitate recovery of desired forest conditions following large high-severity wildfire events. Finally, where salvage logging is conducted for economic objectives, we lack studies that quantify the ecological effects of salvage logging when managers seek to meet both ecological and economic goals through carefully planned approaches to post-wildfire management.

Social-ecological interactions and collaboration—

Although ecosystem services are now widely recognized as a framework for characterizing the range of values on federal forests, relatively little quantification and application have occurred on federal lands. Some ecosystem services, particularly cultural services such as support for spirituality or solitude, are important to many, but difficult to quantify or monetize. In addition, the potential for tradeoffs among ecosystem services (e.g., carbon sequestration, habitat for some species of wildlife, water supply, and regulation of fire), particularly across long periods and large areas, is not well understood. Research is needed to determine the best methods for quantifying ecosystem services, understanding tradeoffs, and using qualitative approaches in planning and management when quantification of ecosystem services does not exist. In addition, research is needed to determine the costs and benefits (e.g., providing more public support for investment in public lands) of using an ecosystem management framework compared to alternative ways of valuing and communicating the benefits that public lands provide.

Low income and minority populations protected by the 1994 Executive Order on Environmental Justice have increased throughout the NWFP area over the past two decades. This trend increases the need for ongoing research into how these populations relate to federal forests and are affected by their management. There is a fairly substantive literature about how minority populations relate to national forests in terms of work (e.g., forestry services work, commercial NTFP harvesting). However, apart from recreation, little information is available about noneconomic relations between federal forests and low-income or minority populations (other than American Indians). Furthermore, research is only beginning to fill the gap in knowledge about the environmental justice implications of Forest Service management actions. For example, there remains a lack of information about how fire—managed, prescribed, or wild—and associated smoke affect low income and minority populations in the Plan area. There is also little information about how management activities that influence forest structure and composition affect uses and values of associated species that are valued by these populations.

The ability to undertake active management to achieve diverse ecological and socioeconomic goals is constrained by many factors, but limited public trust in federal managers is among the most critical, especially when it comes to working in forests with larger or older trees in frequent and moderately frequent fire regimes. Forest landscape collaboratives provide socioecological laboratories for studying how interactions among stakeholders and federal managers affect the ability to achieve restoration and resilience to fire and climate change. These collaboratives are relatively new, and study results are still unfolding. However, findings thus far suggest that collaboratives have not been a cure-all for resolving conflicts about public values and minimizing litigation, but in some cases participants have suggested that progress has been made on those measures (Schultz et al. 2012, Urgenson et al. 2017). A contributing factor to those trends has been social learning by agency staff in managing their roles (Butler 2013), adopting new approaches such as multiparty monitoring and use of stewardship contracts, as well as picking collaborative projects that have a high likelihood of success. More information is needed about public responses to restoration management efforts, especially in complex contexts such as mixed-severity fire regimes (Urgenson et al. 2017), and addressing socioecological objectives including timber production while applying nonindustrial, ecological forestry methods.

We lack understanding of how trust at different organizational scales (individual, district, forest, national) affects public understanding of and support for various types of active forest management strategies. Finally, although research suggests that the efforts required for collaboration can be taxing on both agency staff and community stakeholders (Urgenson et al. 2017), we lack information on appropriate forms and levels of support to bolster the capacity of both for long-term engagement in collaborative processes.

Conclusions and Management Considerations

The goals of the NWFP for federal forests occur within a diverse, dynamic, and complex social-ecological system that has changed in significant ways since the Plan was implemented. For example, the capacity of the agency and of the forest industry to conduct restoration efforts across landscapes has declined significantly; budgets for managing resources are greatly diminished, and wildfire suppression programs and budgets overshadow most other work. The contributions of public forest lands to ecosystem services (e.g., carbon sequestration and water supply) are now more widely recognized than ever, but the ecosystem services framework has only just begun to be implemented at forest and project scales and not been applied yet in assessments and forest plan revision (Deal et al. 2017b). A major change in biodiversity conservation policy has also occurred for the Forest Service in the form of the 2012 planning rule, which emphasizes whole ecosystem approaches to conservation in contrast to previous planning rules, which emphasized population viability of individual species, and which the agency considered "procedurally burdensome to implement" (Schultz et al. 2013). NWFP monitoring indicates that progress is being made toward meeting several of the original long-term goals, namely maintenance of vegetation conditions that support northern spotted owls and marbled murrelets, protecting dense old-growth forests, providing habitat for aquatic and riparian-associated organisms, and reducing the loss of mature and old forests to logging, (Bormann et al. 2006, DellaSala et al. 2015). Other goals, such as providing for a predictable timber harvest to support rural communities, road decommissioning, adaptation, learning through adaptive management (Bormann et al. 2006, Burns et al. 2011) (chapter 8), and effectiveness and validation monitoring of old-forest species and biodiversity (chapter 6) have not been realized. Finally, Congressional legislation that provided alternative formulas for payments to counties most affected by the Plan to mitigate the financial impacts of reduced timber harvesting were realized in the short to mid term, but their long-term viability remains uncertain (Phillips 2006). In addition, new concerns have emerged that were not part of the original Plan, including a major threat to populations of the northern spotted owl from the native invasive barred owl, widespread loss of fire-dependent ecosystems including open old-growth, early-seral forests, nonforest communities, increased influence of exotic invasive species, and climate change.

Over the past 150 years, timber harvest, fire exclusion, and the loss of American Indian burning have profoundly changed both moist and dry forests of the NWFP area. Although the motivation for the Plan arose from halting 20th century clearcutting of old growth, moist forests and the associated loss of habitat for the spotted owl habitat and other old-growth forest species, the dry forests, which occupy about 43 percent of the Plan area, probably have experienced much more pervasive ecological changes as a result of human activity (chapter 3). Key changes in dry forests are loss of large, typically open grown, fire-resistant trees to logging; large increases in surface and canopy fuels and their connectivity; widespread shifts in seral-stage dominance; and changes in the patch size distributions of those seral stages. These changes have affected all species and processes; some in favorable ways (e.g., more habitat for dense, young multistory forest associates) and others in unfavorable ways (e.g., loss of open old-growth and early-seral forests, and associated resilience to fire and drought). Changes in moist forests are also significant, but they have been affected differently by logging and fire exclusion. Here, intensive timber harvest has been the primary impact on biodiversity by dramatically fragmenting and reducing the amount of closed-canopy old-growth forests, and habitats for the associated species. Fire exclusion in moist forests has also had important effects as well; historical fires created a highly diverse seral-stage patchwork with many patches of early- and mid-seral-aged forest. This patchwork is now highly altered.

Strategies are available to move these ecosystems, forests, landscapes, and species toward conditions that appear better aligned with policy direction (e.g., ecological integrity under the 2012 planning rule) and with current social values, both utilitarian (e.g., clean water, sustainable production of wood and special forest products, recreation) and intrinsic (nature for its own sake). The challenge will be to determine how to prioritize restoration goals and distribution actions across landscapes. Ecological history can be a valuable guide for restoration, but land managers, in reality, cannot restore ecosystems to any particular historical period or condition, or meet all management objectives in one area of land. However, they can learn from the historical conditions about the kinds of patterns and patch size distributions that offered the best hedging strategies against large wildfires and climate warming. Managers can take actions that increase the likelihood of retaining desired ecosystem services, species, intrinsic values of forests, and resilience to climate change and disturbances, even if their actions produce forest conditions that are altered relative to the pre-Euro-American period. Ecological and social history demonstrates that change is inherent in these forests, and we appear to be entering a new period of rapid change with uncertain outcomes.

Species and ecosystems—

The current outlook for widespread persistence of the northern spotted owls is not good. It appears unlikely that the northern spotted owl can persist without significant reduction in barred owl populations. However, 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), northern spotted owl populations would likely have already become moribund. Forests capable of supporting interconnected populations of northern spotted owls have increased or stayed relatively stable at the Plan scale. However, the rapid pace of climate and fire regime change suggests that recent trends may not continue. 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 increase rather than reduce future resilience to wildfire and climate change effects.

Under the original NWFP goals, an emphasis on multilayered old-growth forest conservation was critical given its relationship to owl habitat occurrence and its reduced abundance through harvesting. However, the 2012 planning rule emphasizes ecological integrity and resilience (ecosystem goals that were not part of the NWFP goals), and deemphasizes species viability approaches, a policy change that could significantly affect the conservation goals for biodiversity in the NWFP area. Managing to maintain current levels and patterns of multilayered old forests in dry forest zones (the NWFP goal) will not promote resilience of those dry forests to climate change, fire, and other stressors, and it will not restore more natural ecosystem dynamics. The new rule also has implications for supporting human communities, including tribes with protected treaty rights. Finally, the using ecological integrity as a guide means that conserving biodiversity in this region is more than just conserving dense old-growth forests—other stages are valuable, including open old growth, diverse early- and mid-successional post-wildfire vegetation, wetlands, oak-dominated forest patches and woodlands, and shrub-lands and grasslands.

Conservation and restoration—
The contribution of federal lands to the conservation and recovery of ESA-listed fish, northern spotted owl, and marbled murrelet populations 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. Contributions from streams and forests on nonfederal lands are important to achieving NWFP conservation goals, especially under climate change, which may shift species distributions. Transboundary collaborative efforts can help to address challenges such as restoration of fire regimes, and can enhance conservation efforts, especially when supported with innovative arrangements to share funding, resources, information, or liability, such as the Fire Learning Network and Training Exchange (TREX) program to support prescribed burning (fig. 12-11) (Goldstein and Butler 2010). These efforts have supported collaborations that have engaged tribes, including the Western Klamath Restoration Partnership (see chapter 11). Such approaches combined with other incentives can help to increase conservation on nonfederal lands, but further research to evaluate the impact of particular approaches within the NWFP context is needed.

Under current goals, a restoration strategy would likely combine efforts to ameliorate anthropogenic impacts, such as culverts that are likely to fail in priority watershed areas, as well as some dams and diversions used for irrigation water withdrawal, while also directing active management interventions, such as intensive thinning and use of fire, to restore degraded systems or at least increase their resilience to climate change and fire. Such active management may be particularly valuable in areas where both fire regimes and forest structure have been dramatically altered, because it can increase the likelihood that wildfires will help promote rather than erode resilience.

With congressional reserves, LSRs and riparian reserves, and administratively withdrawn areas occupying more than 80 percent of the Forest Service and BLM land base in the NWFP area, rates of additional fragmentation of older forests outside of reserves from management activities on federal lands will be very low. Landscape-level change will be dominated by succession of young and mid-seral forests, with increasing area of disturbance from wildfire. Concerns over connectivity among old-growth forests and LSRs have shifted to climate change effects and access to climate refugia, although the effects of past logging on connectivity remain. The widespread effects of roads on species and ecosystem processes also remain a conservation concern, especially those that constrain full floodplain functioning or contribute high sediment loads.

The small amount of logging within nonreserved northern spotted owl habitat or 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 largely a result of the Survey and Manage program and changes in the social acceptability of cutting old growth in the matrix. The lack of harvesting of older forests outside the reserves means that a major motivation for adding hundreds of species to the Survey and Manage lists no longer

Figure 12-11—2015 Klamath River Training Exchange prescribed fire at night.

exists (i.e., the older forest habitat needs of the northern spotted owl do not necessarily cover the needs of other late-successional species). The Survey and Manage program was abolished under its economic weight and because fewer older forests were being logged than originally projected.

Fire suppression in some parts of the moist forest region has reduced the amount of structurally diverse early-seral vegetation over the past several decades. It also has likely reduced the diversity of older forest structural and composition conditions and landscape diversity in the drier parts of the moist forest zone. Managers could explore opportunities to restore fire effects in these systems through combinations of thinning, prescribed burning, and managing wildfires. In theory, such restoration actions could occur in the matrix in forests with old trees (e.g., greater than 80 years old), but the ecological and social acceptability of this activity are unknown. The issue is well suited for adaptive management studies. Possible win-win (wood production and biodiversity) alternatives are to create early-seral vegetation in plantations in the matrix or to do more active management in plantations in riparian reserves using principles of ecological forestry or restoration silviculture.

A major challenge to management for resilience to fire and climate change exists in landscapes that historically experienced frequent fire in northern California, southern Oregon, and the eastern Cascade Range of Oregon and Washington. Fires in these areas have been much less frequent in recent decades than historically. However, some recent fires have created larger patches of high-severity fire compared to the historical regime, likely as a result of fuel continuity. The denser forests and more shade-tolerant tree species have increased the area of northern spotted owl habitat despite losses to fire in recent years (chapter 3). Landscapes that include northern spotted owl habitat reserves, 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. Prioritizing conservation of dense forest habitats that have increased in area with fire exclusion is not congruent with managing forests for ecological integrity or resilience to fire and climate change. Management strategies that promote resilience in fire-prone forest landscapes include restoring fire and the patchwork of open and closed-canopy forests, and tailoring these conditions to topography. Landscape-level strategies are needed to provide for dense forest conditions, where they would typically occur, and would be more likely to persist in the face of coming wildfires and a steadily warming climate. Finding and implementing these strategies is both a technical and social problem that is perhaps the most difficult challenge that land managers will face in the near term.

Scientists are becoming more aware that active management within reserves or redesign of reserves may be needed to conserve biodiversity in fire-frequent landscapes, where human activities have excluded fire and 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. Many studies suggest that conservation strategies (and reserve design) should periodically be reevaluated to determine how well they are meeting original and any new goals, and to make possible changes to standards and guidelines and reserve or habitat conservation area boundaries. This may include expanding reserves, increasing connectivity of reserves, shifting locations of reserves (e.g., for small reserves), or using dynamic landscape approaches based on historical disturbance regimes to guide management. Ideally, meeting ecosystem goals for reserves would require areas that are large enough to support fire and other key natural disturbance processes. Meeting both fine- and coarse-filter objectives in these dry forests requires landscape-scale approaches that can integrate potentially competing ecological goals over large areas and long time frames. Using disturbance-based management approaches to conservation is likely to require robust social engagement to increase transparency, public understanding, and trust in managers.

Social-ecological interactions—

For much of the 20th century, timber production was the central way in which federal forests in the NWFP area contributed to community socioeconomic well-being. Although timber production remains important today in some Plan-area communities, the economies of many communities have shifted or diversified their focus over the past two decades. 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 have changed. Better understanding and consideration of the economic development trajectories of different communities will help to identify forest management activities that best contribute to their well-being. 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 forests of the NWFP area provide many ecosystems services to people of the region, in addition to wood. Carbon sequestration, water supply, and recreation are among some of the most valuable of these services. Several policies (table 12-2) direct the agency to use ecosystem management frameworks in planning. However, efforts to quantify and communicate ecosystem services and characterize the associated tradeoffs have yet to be applied in forest plan revision, and there is much to be learned about the most effective ways to use ecosystem services at project and forest scales, though some examples are beginning to appear.

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 and thus created a financial barrier to fully accomplishing forest restoration. With declining agency capacity, it will be difficult to impossible to maximize all of these objectives, and prioritization likely would be necessary for making progress or goals. Nongovernmental organizations (NGOs) and other government agencies may help managers meet their social and ecological goals. As outlined in chapter 11, an emphasis on engaging 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. Approaches such as disturbance-based management or "ecological forestry" may provide a way for federal forests to contribute to local timber-based economies, while providing early-successional habitat and vegetation dependent on fire that has been excluded by fire suppression to meet other management objectives.

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 into an uncertain future. In addition, efforts to collaborate with neighboring landowners in planning and implementing management activities for landscape-level treatments can contribute to increasing forest resilience to climate change, invasive species, and wildfire, and to provide desired ecosystem services (e.g., owl and fish habitat) in mixed-ownership landscapes. Any strategies to promote resilience will need to recognize complex ecological and social system dynamics operating across land ownerships, as well as tensions that arise among competing goals, by adopting long-term and landscape-scale perspectives that include transparent accountability for all involved.

Major disturbances such as large wildfires can promote desired conditions and reestablish key ecosystem processes and species over larger areas of 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 agency-wide decline in staffing, a decades-long history of budget cuts in non-wildfire areas, limited or absent infrastructure for wood processing of forest products, and monetary resource shifts toward fighting wildfires rather than restoring forests. Currently, nearly 55 to 60 percent of the total Forest Service budget each year goes to fighting fires, up from 17 percent 25 years ago.

The challenges ahead for public lands may well require new staffing and partnerships to get work done and new approaches to the problem of restoration. For example, managing natural ignitions for resource benefit may be a particularly cost-effective means of treating landscapes, but prior, large-scale, and widespread fire use planning is likely needed to make these methods effective.

Nevertheless, these opportunities for managing wildfire for resource benefit will pose difficult challenges for managers. Careful assessment of risk to life and property is paramount.

Tradeoffs associated with management—
All management choices involve some social and ecological tradeoffs among the goals of the NWFP. For example,

1. 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 predators, and can reduce amounts of dead wood that are habitat of other species.
2. 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.
3. 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 less than 80 years old in LSRs to promote old-growth forest development will not sustain wood production for local communities (chapter 8). Future wood production depends on management in the matrix, where the NWFP allows timber harvest even from older forests. There is no new science that specifically indicates that timber management using retention silviculture in forests over 80 years old in the matrix is inconsistent with the original goals of the NWFP. In addition, partial stand-replacement fires were part of the historical dynamics of some older forests of the moist zone, and the ecological effects of excluding this type of disturbance are not well understood but might convey some resilience to climate and future fire. Given the social pressure to avoid logging of older trees, management in existing plantations for wood in the matrix would appear to be the most socially acceptable way to provide economic returns to support local communities while promoting biodiversity associated with early-seral ecosystems. In addition, it will be valuable to demonstrate how other ecosystems services (e.g., water, recreation) contribute to the mix of values of federal forests, and how effectively active management can meet ecological and social goals.

Monitoring and adaptive management—
The long-term NWFP monitoring program and complementary research efforts of countless agency, university, tribal, and NGO scientists have provided managers, researchers, and stakeholders with an enormous amount of information on how species, ecosystems, and social systems in the NWFP area interact, and have changed over the past 23 years. There will be a need for sustained technical and scientific capacity in the management agencies to keep up with and help translate the large volumes of rapidly expanding scientific knowledge and tools into guidance for planning and management. However, the capacity of agencies to generate new knowledge has precipitously declined, threatening their ability to sustain the flow of information that can lead to more effective management and policies. Scientific uncertainties and debates will continue. Although they may be frustrating to managers, scientists, and the public, the debates also spur research that can lead to new understanding and discovery of knowledge that challenges assumptions, and improve our ability to set and meet attainable goals for forests and aquatic and riparian ecosystems. Further, areas of scientific uncertainty, highlighted by risk analysis, can be clearly articulated to managers and decisionmakers who engage in risk management. Development, evaluation, and testing of new, highly integrated conservation strategies are encouraged to deal with changing knowledge, new perspectives on fire regimes, climate change, invasive species, and recognition of tradeoffs in pursuing biodiversity goals (e.g., coarse filter and fine filter), and other ecological and social dimensions of forest ecosystem management. These forest and social systems will undoubtedly change in the next 23 years. Continuation of monitoring, research, public engagement, and adaptive management will help managers and society adapt to these changes and to meet old and new goals.

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Scientific and common names of plant species identified in this report

Scientific name	Common name
Abies amabilis (Douglas ex Loudon) Douglas ex Forbes	Pacific silver fir
Abies concolor (Gord. & Glend.) Lindl. ex Hildebr.	White fir
Abies grandis (Douglas ex D. Don) Lindl.	Grand fir
Abies lasiocarpa (Hook.) Nutt.	Subalpine pine
Abies magnifica A. Murray bis	California red fir
Abies procera Rehder	Noble fir
Acer circinatum Pursh	Vine maple
Acer macrophyllum Pursh	Bigleaf maple
Achlys triphylla (Sm.) DC.	Sweet after death
Adenocaulon bicolor Hook.	American trailplant
Alliaria petiolata (M. Bieb.) Cavara & Grande	Garlic mustard
Alnus rubra Bong.	Red alder
Amelanchier alnifolia (Nutt.) Nutt. ex M. Roem.	Saskatoon serviceberry
Anemone oregana A. Gray	Blue windflower
Apocynum cannabinum L.	Dogbane
Arbutus menziesii Pursh)	Madrone
Arceuthobium M. Bieb.	Dwarf mistletoe
Arceuthobium occidentale Engelm.	Gray pine dwarf mistletoe
Arceuthobium tsugense Rosendahl	Hemlock dwarf mistletoe
Arctostaphylos nevadensis A. Gray	Pinemat manzanita
Brachypodium sylvaticum (Huds.) P. Beauv.	False brome
Brodiaea coronaria (Salisb.) Engl.	Cluster-lilies
Callitropsis nootkatensis (D. Don) Oerst. ex D.P. Little	Alaska yellow-cedar
Calocedrus decurrens (Torr.) Florin	Incense cedar
Cannabis L.	Marijuana
Carex barbarae Dewey and *C. obnupta* L.H. Bailey	Sedges
Centaurea solstitialis L.	Yellow starthistle
Chamaecyparis lawsoniana (A. Murray bis) Parl.	Port Orford cedar
Chimaphila menziesii (R. Br. ex D. Don) Spreng.	Little prince's pine
Chimaphila umbellata (L.) W.P.C. Barton	Pipsissewa
Clematis vitalba L.	Old man's beard
Clintonia uniflora Menzies ex Schult. & Schult. f.) Kunth	Bride's bonnet
Coptis laciniata A. Gray	Oregon goldthread
Corylus cornuta Marshall var. *californica* (A. DC.) Sharp	California hazel
Cornus canadensis L.	Bunchberry dogwood
Cytisus scoparius (L.) Link	Scotch broom
Disporum hookeri (Torr.) G. Nicholson var. *hookeri*	Drops-of-gold
Fallopia japonica (Houtt.) Ronse Decr. var. *japonica*	Japanese knotweed
Gaultheria ovatifolia A. Gray	Western teaberry
Gaultheria shallon Pursh	Salal

Scientific name	Common name
Gentiana douglasiana Bong.	Swamp gentian
Geranium lucidum L.	Shining geranium
Geranium robertianum L.	Robert geranium
Goodyera oblongifolia Raf.	Western rattlesnake plantain
Hedera helix L.	English ivy
Heracleum mantegazzianum Sommier & Levier	Giant hogweed
Hesperocyparis sargentii (Jeps.) Bartel	Sargent's cypress
Hieracium aurantiacum L.	Orange hawkweed
Ilex aquifolium L.	English holly
Iris pseudacorus L.	Paleyellow iris
Juniperus occidentalis Hook.	Western juniper
Lamiastrum galeobdolon (L.) Ehrend. & Polatschek	Yellow archangel
Lilium occidentale Purdy	Western lily
Linnaea borealis L.	Twinflower
Lithocarpus densiflorus (Hook. & Arn.) Rehder	Tanoak
Lonicera hispidula Pursh	Honeysuckle
Lupinus albicaulis Douglas	Sickle-keeled lupine
Lycopodium clavatum L.	Running clubmoss
Lythrum salicaria L.	Purple loosestrife
Mahonia nervosa (Pursh) Nutt.	Cascade barberry
Malus fusca (Raf.) C.K. Schneid.	Pacific crabapple
Notholithocarpus densiflorus (Hook. & Arn.) P.S. Manos, C.H. Cannon, & S.H. Oh	Tanoak
Notholithocarpus densiflorus (Hook. & Arn.) P.S. Manos, C.H. Cannon, & S.H. Oh var. *echinoides* (R.Br. ter) P.S. Manos, C.H. Cannon & S.H. Oh	Shrub form of tanoak
Nuphar polysepala (Engelm.)	Yellow pond lily
Nymphoides peltata (S.G. Gmel.) Kuntze	Yellow floating heart
Osmorhiza chilensis Hook. & Arn.	Sweetcicely
Phalaris arundinacea L.	Reed canarygrass
Picea engelmannii Parry ex Engelm.	Engelmann spruce
Picea sitchensis (Bong.) Carrière	Sitka spruce
Pinus albicaulis Engelm.	Whitebark pine
Pinus attenuata Lemmon	Knobcone pine
Pinus contorta Douglas ex Loudon	Lodgepole pine
Pinus contorta Douglas ex Loudon var. *contorta*	Beach pine, shore pine
Pinus jeffreyi Balf.	Jeffrey pine
Pinus lambertiana Douglas	Sugar pine
Pinus monticola Douglas ex D. Don)	Western white pine
Pinus ponderosa Lawson & C. Lawson	Ponderosa pine
Populus trichocarpa L. ssp. *trichocarpa* (Torr. & A. Gray ex Hook) Brayshaw	Black cottonwood
Potamogeton crispus L.	Curly pondweed
Potentilla recta L.	Sulphur cinquefoil

Scientific name	Common name
Prunus emarginata (Douglas ex Hook. D. Dietr.)	Bitter cherry
Pseudotsuga menziesii (Mirb.) Franco	Douglas-fir
Pteridium aquilinum (L. Kuhn)	Brackenfern
Pueraria montana (Lour.) Merr. var. *lobata* (Willd.) Maesen & S.M. Almeida ex Sanjappa & Predeep	Kudzu
Pyrola asarifolia Sweet	American wintergreen
Quercus agrifolia Née var. *oxyadenia* (Torr.) J.T. Howell	Coastal live oak
Quercus berberidifolia Liebm.	Scrub oak
Quercus chrysolepis Liebm.	Canyon live oak
Quercus douglasii Hook. & Arn.	Blue oak
Quercus garryana Douglas ex hook.	Oregon white oak
Quercus kelloggi Newberry	California black oak
Quercus lobata Née	Valley oak
Rhamnus purshiana (DC.) A. Gray	Cascara
Rhododendron groenlandicum Oeder	Bog Labrador tea
Rhododendron macrophyllum D. Don ex G. Don	Pacific rhododendron
Ribes lacustre (Pers.) Poir.	Prickly currant
Rubus armeniacus Focke	Himalayan blackberry
Salix exigua Nutt.	Sandbar willow
Senecio bolanderi A. Gray	Bolander's ragwort
Sequoia sempervirens (Lamb. ex D. Don) Endl.	Redwood
Smilacina stellata (L.) Desf.	Starry false Solomon's seal
Synthyris reniformis (Douglas ex Benth.) Benth.	Snowqueen
Taxus brevifolia Nutt.	Pacific yew
Thuja plicata Donn ex D. Don	Western redcedar
Tiarella trifoliate L.	Threeleaf foamflower
Trapa natans L.	Water chestnut
Trillium ovatum Pursh	Pacific trillium
Tsuga heterophylla (Raf.) Sarg.	Western hemlock
Tsuga mertensiana (Bong.) Carrière	Mountain hemlock
Typha latifolia L.	Cattails
Umbellularia californica (Hook. & Arn.) Nutt.	California bay laurel
Vaccinium alaskaense Howell	Alaska blueberry
Vaccinium membranaceum Douglas ex Torr.	Thinleaf huckleberry, big huckleberry
Vaccinium ovatum Pursh	Evergreen huckleberry
Vaccinium oxycoccos L.	Small cranberry
Vaccinium parvifolium Sm.	Red huckleberry
Vancouveria hexandra (Hook.) C. Morren & Decne.	White insideout flower
Xerophyllum tenax (Pursh) Nutt.	Beargrass

Glossary

This glossary is provided to help readers understand various terms used in the Northwest Forest Plan (NWFP) science synthesis. Sources include the Forest Service Handbook (FSH), the Code of Federal Regulations (CFR), executive orders, the Federal Register (FR), and various scientific publications (see "Glossary Literature Cited"). The authors have added working definitions of terms used in the synthesis and its source materials, especially when formal definitions may be lacking or when they differ across sources.

active management—Direct interventions to achieve desired outcomes, which may include harvesting and planting of vegetation and the intentional use of fire, among other activities (Carey 2003).

adaptive capacity—The ability of ecosystems and social systems to respond to, cope with, or adapt to disturbances and stressors, including environmental change, to maintain options for future generations (FSH 1909.12.5).

adaptive management—A structured, cyclical process for planning and decisionmaking in the face of uncertainty and changing conditions with feedback from monitoring, which includes using the planning process to actively test assumptions, track relevant conditions over time, and measure management effectiveness (FSH 1909.12.5). Additionally, adaptive management includes iterative decisionmaking, through which results are evaluated and actions are adjusted based on what has been learned.

adaptive management area (AMA)—A portion of the federal land area within the NWFP area that was specifically allocated for scientific monitoring and research to explore new forestry methods and other activities related to meeting the goals and objectives of the Plan. Ten AMAs were established in the NWFP area, covering about 1.5 million ac (600 000 ha), or 6 percent of the planning area (Stankey et al. 2003).

alien species—Any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to a particular ecosystem (Executive Order 13112). The term is synonymous with exotic species, nonindigenous, and nonnative species (see also "invasive species").

allochthonous inputs—Material, specifically food resources, that originates from outside a stream, typically in the form of leaf litter.

amenity communities—Communities located near lands with high amenity values.

amenity migration—Movement of people based on the draw of natural or cultural amenities (Gosnell and Abrams 2011).

amenity value—A noncommodity or "unpriced" value of a place or environment, typically encompassing aesthetic, social, cultural, and recreational values.

ancestral lands (of American Indian tribes)—Lands that historically were inhabited by the ancestors of American Indian tribes.

annual species review—A procedure established under the NWFP in which panels of managers and biologists evaluate new scientific and monitoring information on species to potentially support the recommendation of changes in their conservation status.

Anthropocene—The current period (or geological epoch) in which humans have become a dominant influence on the Earth's climate and environment, generally dating from the period of rapid growth in industrialization, population, and global trade and transportation in the early 1800s (Steffen et al. 2007).

Aquatic Conservation Strategy (ACS) —A regional strategy applied to aquatic and riparian ecosystems across the area covered by the NWFP) (Espy and Babbit 1994) (see chapter 7 for more details).

at-risk species—Federally recognized threatened, endangered, proposed, and candidate species and species of conservation concern. These species are considered at risk of low viability as a result of changing environmental conditions or human-caused stressors.

best management practices (BMPs) (for water quality)—Methods, measures, or practices used to reduce or eliminate the introduction of pollutants and other detrimental impacts to water quality, including but not limited to structural and nonstructural controls and to operation and maintenance procedures.

biodiversity—In general, the variety of life forms and their processes and ecological functions, at all levels of biological organization from genes to populations, species, assemblages, communities, and ecosystems.

breeding inhibition—Prevention of reproduction in healthy adult individuals.

bryophytes—Mosses and liverworts.

canopy cover—The downward vertical projection from the outside profile of the canopy (crown) of a plant measured in percentage of land area covered.

carrying capacity—The maximum population size a specific environment can sustain.

ceded areas—Lands that particular tribes ceded to the United States government by treaties, which have been catalogued in the Library of Congress.

climate adaptation—Management actions to reduce vulnerabilities to climate change and related disturbances.

climate change—Changes in average weather conditions (including temperature, precipitation, and risk of certain types of severe weather events) that persist over multiple decades or longer, and that result from both natural factors and human activities such as increased emissions of greenhouse gases (U.S. Global Change Research Program 2017).

coarse filter—A conservation approach that focuses on conserving ecosystems, in contrast to a "fine filter" approach that focuses on conserving specific species. These two approaches are generally viewed as complementary, with fine-filtered strategies tailored to fit particular species that "fall through the pores" of the coarse filter (Hunter 2005). See also "mesofilter."

co-management—Two or more entities, each having legally established management responsibilities, working collaboratively to achieve mutually agreed upon, compatible objectives to protect, conserve, use, enhance, or restore natural and cultural resources (81 FR 4638).

collaborative management—Two or more entities working together to actively protect, conserve, use, enhance, or restore natural and cultural resources (81 FR 4638).

collaboration or collaborative process—A structured manner in which a collection of people with diverse interests share knowledge, ideas, and resources, while working together in an inclusive and cooperative manner toward a common purpose (FSH 1909.12.05).

community (plant and animal)—A naturally occurring assemblage of plant and animal species living within a defined area or habitat (36 CFR 219.19).

community forest—A general definition is forest land that is managed by local communities to provide local benefits (Teitelbaum et al. 2006). The federal government has specifically defined community forest as "forest land owned in fee simple by an eligible entity [local government, nonprofit organization, or federally recognized tribe] that provides public access and is managed to provide community benefits pursuant to a community forest plan" (36 CFR 230.2).

community of place or place-based community—A group of people who are bound together because of where they reside, work, visit, or otherwise spend a continuous portion of their time.

community resilience—The capacity of a community to return to its initial function and structure when initially altered under disturbance.

community resistance—The capacity of a community to withstand a disturbance without changing its function and structure.

composition—The biological elements within the various levels of biological organization, from genes and species to communities and ecosystems (FSM 2020).

congeneric—Organisms that belong to the same taxonomic genus, usually belonging to different species.

connectivity (of habitats)—Environmental conditions that exist at several spatial and temporal scales that provide landscape linkages that permit (a) the exchange of flow, sediments, and nutrients; (b) genetic interchange of genes among individuals between populations; and (c) the long-distance range shifts of species, such as in response to climate change (36 CFR 219.19).

consultation (tribal)—A formal government-to-government process that enables American Indian tribes and Alaska Native Corporations to provide meaningful, timely input, and, as appropriate, exchange views, information, and recommendations on proposed policies or actions that may affect their rights or interests prior to a decision. Consultation is a unique form of communication characterized by trust and respect (FSM 1509.05).

corticosterone—A steroid hormone produced by many species of animals, often as the result of stress.

cryptogam—An organism that reproduces by spores and that does not produce true flowers and seeds; includes fungi, algae, lichens, mosses, liverworts, and ferns.

cultural keystone species—A species that significantly shapes the cultural identity of a people, as reflected in diet, materials, medicine, or spiritual practice (Garibaldi and Turner 2004).

cultural services—A type of ecosystem service that includes the nonmaterial benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences (Sarukhán and Whyte 2005).

desired conditions—A description of specific social, economic, or ecological characteristics toward which management of the land and resources should be directed.

disturbance regime—A description of the characteristic types of disturbance on a given landscape; the frequency, severity, and size distribution of these characteristic disturbance types and their interactions (36 CFR 219.19).

disturbance—Any relatively discrete event in time that disrupts ecosystem, watershed, community, or species population structure or function, and that changes resources, substrate availability, or the physical environment (36 CFR 219.19).

dynamic reserves—A conservation approach in which protected areas are relocated following changes in environmental conditions, especially owing to disturbance.

early-seral vegetation—Vegetation conditions in the early stages of succession following an event that removes the forest canopy (e.g., timber harvest, wildfire, windstorm), on sites that are capable of developing a closed canopy (Swanson et al. 2014). A nonforest or "pre-forest" condition occurs first, followed by an "early-seral forest" as young shade-intolerant trees form a closed canopy.

ecocultural resources—Valued elements of the biophysical environment, including plants, fungi, wildlife, water, and places, and the social and cultural relationships of people with those elements.

ecological conditions—The biological and physical environment that can affect the diversity of plant and animal communities, the persistence of native species, invasibility, and productive capacity of ecological systems. Ecological conditions include habitat and other influences on species and the environment. Examples of ecological conditions include the abundance and distribution of aquatic and terrestrial habitats, connectivity, roads and other structural developments, human uses, and occurrence of other species (36 CFR 219.19).

ecological forestry—A ecosystem management approach designed to achieve multiple objectives that may include conservation goals and sustainable forest management and which emphasizes disturbance-based management and retention of "legacy" elements such as old trees and dead wood (Franklin et al. 2007).

ecological integrity—The quality or condition of an ecosystem when its dominant ecological characteristics (e.g., composition, structure, function, connectivity, and species composition and diversity) occur within the natural range of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human influence (36 CFR 219.19).

ecological keystone species—A species whose ecological functions have extensive and disproportionately large effects on ecosystems relative to its abundance (Power et al. 1996).

ecological sustainability—The capability of ecosystems to maintain ecological integrity (36 CFR 219.19).

economic sustainability—The capability of society to produce and consume or otherwise benefit from goods and services, including contributions to jobs and market and nonmarket benefits (36 CFR 219.19).

ecoregion—A geographic area containing distinctive ecological assemblages, topographic and climatic gradients, and historical land uses.

ecosystem—A spatially explicit, relatively homogeneous unit of the Earth that includes all interacting organisms and elements of the abiotic environment within its boundaries (36 CFR 219.19).

ecosystem diversity—The variety and relative extent of ecosystems (36 CFR 219.19).

ecosystem integrity—See "ecological integrity."

ecosystem management—Management across broad spatial and long temporal scales for a suite of goals, including maintaining populations of multiple species and ecosystem services.

ecosystem services—Benefits that people obtain from ecosystems (see also "provisioning services," "regulating services," "supporting services," and "cultural services").

ectomycorrhizal fungi—Fungal species that form symbiotic relationships with vascular plants through roots, typically aiding their uptake of nutrients. Although other mycorrhizal fungi penetrate their host's cell walls, ectomycorrhizal fungi do not.

endangered species—Any species or subspecies that the Secretary of the Interior or the Secretary of Commerce has deemed in danger of extinction throughout all or a significant portion of its range (16 U.S.C. Section 1532).

endemic—Native and restricted to a specific geographical area.

El Niño Southern Oscillation (ENSO)—A band of anomalously warm ocean water temperatures that occasionally develops off the western coast of South America and can cause climatic changes across the Pacific Ocean. The extremes of this climate pattern's oscillations cause extreme weather (such as floods and droughts) in many regions of the world.

environmental DNA (eDNA)—Genetic material (DNA) contained within small biological and tissue fragments that can be collected from aquatic, terrestrial, and even atmospheric environments, linked to an individual species, and used to indicate the presence of that species.

environmental justice populations—Groups of people who have low incomes or who identify themselves as African American, Asian or Pacific Islander, American Indian or Alaskan Native, or of Hispanic origin.

ephemeral stream—A stream that flows only in direct response to precipitation in the immediate locality (watershed or catchment basin), and whose channel is at all other times above the zone of saturation.

epicormic—Literally, "of a shoot or branch," this term implies growth from a previously dormant bud on the trunk or a limb of a tree.

epiphyte—A plant or plant ally (including mosses and lichens) that grows on the surface of another plant such as a tree, but is not a parasite.

even-aged stand—A stand of trees composed of a single age class (36 CFR 219.19).

fecundity—The reproductive rate of an organism or population.

federally recognized Indian tribe—An Indian tribe or Alaska Native Corporation, band, nation, pueblo, village, or community that the Secretary of the Interior acknowledges to exist as an Indian tribe under the Federally Recognized Indian Tribe List Act of 1994, 25 U.S.C. 479a (36 CFR 219.19).

fine filter—A conservation approach that focuses on conserving individual species in contrast to a “coarse filter” approach that focuses on conserving ecosystems; these approaches are generally viewed as complementary with fine-filtered strategies tailored to fit particular species that “fall through the pores” of the coarse filter (Hunter 2005). See also “mesofilter.”

fire-dependent vegetation types—A vegetative community that evolved with fire as a necessary contributor to its vitality and to the renewal of habitat for its member species.

fire exclusion—Curtailment of wildland fire because of deliberate suppression of ignitions, as well as unintentional effects of human activities such as intensive grazing that removes grasses and other fuels that carry fire (Keane et al. 2002).

fire intensity—The amount of energy or heat release during fire.

fire regime—A characterization of long-term patterns of fire in a given ecosystem over a specified and relatively long period of time, based on multiple attributes, including frequency, severity, extent, spatial complexity, and seasonality of fire occurrence.

fire regime, low frequency, high severity—A fire regime with long return intervals (>200 years) and high levels of vegetation mortality (e.g., ~70 percent basal area mortality in forested ecosystems), often occurring in large patches (>10,000 ac [4047 ha]) (see chapter 3 for more details).

fire regime, moderate frequency, mixed severity—A fire regime with moderate return intervals between 50 and 200 years and mixtures of low, moderate, and high severity; high-severity patches would have been common and frequently large (>1,000 ac [>405 ha]) (see chapter 3 for more details).

fire regime, very frequent, low severity—A fire regime with short return intervals (5 to 25 years) dominated by surface fires that result in low levels of vegetation mortality (e.g., <20 percent basal area mortality in forested ecosystems), with high-severity fire generally limited to small patches (<2.5 ac [1 ha]) (see chapter 3 for more details).

fire regime, frequent, mixed severity—A fire regime with return intervals between 15 and 50 years that burns with a mosaic of low-, moderate-, and high-severity patches (Perry et al. 2011) (see chapter 3 for more details).

fire rotation—Length of time expected for a specific amount of land to burn (some parts might burn more than once or some not at all) based upon the study of past fire records in a large landscape (Turner and Romme 1994).

fire severity—The magnitude of the effects of fire on ecosystem components, including vegetation or soils.

fire suppression—The human act of extinguishing wildfires (Keane et al. 2002).

floodplain restoration—Ecological restoration of a stream or river’s floodplain, which may involve setback or removal of levees or other structural constraints.

focal species—A small set of species whose status is assumed to infer the integrity of the larger ecological system to which it belongs, and thus to provide meaningful information regarding the effectiveness of a resource management plan in maintaining or restoring the ecological conditions to maintain the broader diversity of plant and animal communities in the NWPF area. Focal species would be commonly selected on the basis of their functional role in ecosystems (36 CFR 219.19).

food web—Interconnecting chains between organisms in an ecological community based upon what they consume.

Forest Ecosystem Management Assessment Team (FEMAT)—An interdisciplinary team that included expert ecological and social scientists, analysts, and managers assembled in 1993 by President Bill Clinton to develop options for ecosystem management of federal forests within the range of the northern spotted owl (FEMAT 1993).

forest fragmentation—The patterns of dispersion and connectivity of nonhomogeneous forest cover (Riitters et al. 2002). See also "landscape fragmentation" and "habitat fragmentation" for specific meanings related to habitat loss and isolation.

frequency distribution—A depiction, often appearing in the form of a curve or graph, of the abundance of possible values of a variable. In this synthesis report, we speak of the frequency of wildfire patches of various sizes.

fuels (wildland)—Combustible material in wildland areas, including live and dead plant biomass such as trees, shrub, grass, leaves, litter, snags, and logs.

fuels management—Manipulation of wildland fuels through mechanical, chemical, biological, or manual means, or by fire, in support of land management objectives to control or mitigate the effects of future wildland fire.

function (ecological)—Ecological processes, such as energy flow; nutrient cycling and retention; soil development and retention; predation and herbivory; and natural disturbances such as wind, fire, and floods that sustain composition and structure (FSM 2020). See also "key ecological function."

future range of variation (FRV)—The natural fluctuation of pattern components of healthy ecosystems that might occur in the future, primarily affected by climate change, human infrastructure, invasive species, and other anticipated disturbances.

gaps (forest)—Small openings in a forest canopy that are naturally formed when one or a few canopy trees die (Yamamoto 2000).

genotype—The genetic makeup of an individual organism.

glucocorticoid—A class of steroid hormones produced by many species of animals, often as the result of stress.

goals (in land management plans)—Broad statements of intent, other than desired conditions, that do not include expected completion dates (36 CFR part 219.7(e)(2)).

guideline—A constraint on project and activity decision-making that allows for departure from its terms, so long as the purpose of the guideline is met (36 CFR section 219.15(d)(3)). Guidelines are established to help achieve or maintain a desired condition or conditions, to avoid or mitigate undesirable effects, or to meet applicable legal requirements.

habitat—An area with the environmental conditions and resources that are necessary for occupancy by a species and for individuals of that species to survive and reproduce.

habitat fragmentation—Discontinuity in the spatial distribution of resources and conditions present in an area at a given scale that affects occupancy, reproduction, and survival in a particular species (see "landscape fragmentation").

heterogeneity (forest)—Diversity, often applied to variation in forest structure within stands in two dimensions: horizontal (e.g., single trees, clumps of trees, and gaps of no trees), and vertical (e.g., vegetation at different heights from the forest floor to the top of the forest canopy), or across large landscapes (North et al. 2009).

hierarchy theory—A theory that describes ecosystems at multiple levels of organization (e.g., organisms, populations, and communities) in a nested hierarchy.

high-severity burn patch—A contiguous area of high-severity or stand-replacing fire.

historical range of variation (HRV)—Past fluctuation or range of conditions in the pattern of components of ecosystems over a specified period of time.

hybrid ecosystem—An ecosystem that has been modified from a historical state such that it has novel attributes while retaining some original characteristics (see "novel ecosystem").

hybrid—Offspring resulting from the breeding of two different species.

inbreeding depression—Reduced fitness in a population that occurs as the result of breeding between related individuals, leading to increased homogeneity and simplification of the gene pool.

in-channel restoration—Ecological restoration of the channel of a stream or river, often through placement of materials (rocks and wood) or other structural modifications.

individuals, clumps, and openings (ICO) method—A method that incorporates reference spatial pattern targets based upon individual trees, clumps of trees, and canopy openings into silvicultural prescriptions and tree-marking guidelines (Churchill et al. 2013).

Interagency Special Status and Sensitive Species Program (ISSSSP)—A federal agency program, established under the U.S. Forest Service Pacific Northwest Region and Bureau of Land Management Oregon/Washington state office. The ISSSSP superseded the Survey and Manage standards and guidelines under the NWFP and also addresses other species of conservation focus, coordinates development and revision of management recommendations and survey protocols, coordinates data management between the agencies, develops summaries of species biology, and conducts other tasks.

intermittent stream—A stream or reach of stream channel that flows, in its natural condition, only during certain times of the year or in several years, and is characterized by interspersed, permanent surface water areas containing aquatic flora and fauna adapted to the relatively harsh environmental conditions found in these types of environments.

invasive species—An alien species (or subspecies) whose deliberate, accidental, or self-introduction is likely to cause economic or environmental harm or harm to human health (Executive Order 13112).

key ecological function—The main behaviors performed by an organism that can influence environmental conditions or habitats of other species.

key watersheds—Watersheds that are expected to serve as refugia for aquatic organisms, particularly in the short term, for at-risk fish populations that have the greatest potential for restoration, or to provide sources of high-quality water.

land and resource management plan (Forest Service)—A document or set of documents that provides management direction for an administrative unit of the National Forest System (FSH 1909.12.5).

landform—A specific geomorphic feature on the surface of the Earth, such as a mountain, plateau, canyon, or valley.

landscape—A defined area irrespective of ownership or other artificial boundaries, such as a spatial mosaic of terrestrial and aquatic ecosystems, landforms, and plant communities, repeated in similar form throughout such a defined area (36 CFR 219.19).

landscape fragmentation—Breaking up of continuous habitats into patches as a result of human land use and thereby generating habitat loss, isolation, and edge effects (see "habitat fragmentation").

landscape genetics—An interdisciplinary field of study that combines population genetics and landscape ecology to explore how genetic relatedness among individuals and subpopulations of a species is influenced by landscape-level conditions.

landscape hierarchy—Organization of land areas based upon a hierarchy of nested geographic (i.e., different-sized) units, which provides a guide for defining the functional components of a system and how components at different scales are related to one another.

late-successional forest—Forests that have developed after long periods of time (typically at least 100 to 200 years) following major disturbances, and that contain a major component of shade-tolerant tree species that can regenerate beneath a canopy and eventually grow into the canopy in which small canopy gaps occur (see chapter 3 for more details). Note that FEMAT (1993) and the NWFP also applied this term to older (at least 80 years) forest types, including both old-growth and mature forests, regardless of the shade tolerance of the dominant tree species (e.g., 90-year-old forests dominated by Douglas-fir were termed late successional).

leading edge—The boundary of a species' range at which the population is geographically expanding through colonization of new sites.

legacy trees—Individual trees that survive a major disturbance and persist as components of early-seral stands (Franklin 1990).

legacies (biological)—Live trees, seed and seedling banks, remnant populations and individuals, snags, large soil aggregates, hyphal mats, logs, uprooted trees, and other biotic features that survive a major disturbance and persist as components of early-seral stands (Franklin 1990, Franklin et al. 2002).

lentic—Still-water environments, including lakes, ponds, and wet meadows.

longitudinal studies—Studies that include repeated observations on the same response variable over time.

lotic—Freshwater environments with running water, including rivers, streams, and springs.

low-income population—A community or a group of individuals living in geographic proximity to one another, or a set of individuals, such as migrant workers or American Indians, who meet the standards for low income and experience common conditions of environmental exposure or effect (CEQ 1997).

managing wildfire for resource objectives—Managing wildfires to promote multiple objectives such as reducing fire danger or restoring forest health and ecological processes rather than attempting full suppression. The terms "managed wildfire" or "resource objective wildfire" have also been used to describe such events (Long et al. 2017). However, fire managers note that many unplanned ignitions are managed using a combination of tactics, including direct suppression, indirect containment, monitoring of fire spread, and even accelerating fire spread, across their perimeters and over their full duration. Therefore, terms that separate "managed" wildfires from fully "suppressed" wildfires do not convey that complexity. (See "Use of wildland fire," which also includes prescribed burning).

matrix—Federal and other lands outside of specifically designated reserve areas, particularly the late-successional reserves under the NWFP, that are managed for timber production and other objectives.

mature forest—An older forest stage (>80 years) prior to old-growth in which trees begin attaining maximum heights and developing some characteristic, for example, 80 to 200 years in the case of old-growth Douglas-fir/western hemlock forests, often (but not always) including big trees (>50 cm diameter at breast height), establishment of late-seral species (i.e., shade-tolerant trees), and initiation of decadence in early species (i.e., shade-intolerant trees).

mesofilter—A conservation approach that "focuses on conserving critical elements of ecosystems that are important to many species, especially those likely to be overlooked by fine-filter approaches, such as invertebrates, fungi, and nonvascular plants" (Hunter 2005).

meta-analysis—A study that combines the results of multiple studies**.**

minority population—A readily identifiable group of people living in geographic proximity with a population that is at least 50 percent minority; or, an identifiable group that has a meaningfully greater minority population than the adjacent geographic areas, or may also be a geographically dispersed/transient set of individuals such as migrant workers or Americans Indians (CEQ 1997).

mitigation (climate change)—Efforts to reduce anthropogenic alteration of climate, in particular by increasing carbon sequestration.

monitoring—A systematic process of collecting information to track implementation (implementation monitoring), to evaluate effects of actions or changes in conditions or relationships (effectiveness monitoring), or to test underlying assumptions (validation monitoring) (see 36 CFR 219.19).

mosaic—The contiguous spatial arrangement of elements within an area. In regions, this is typically the upland vegetation patches, large urban areas, large bodies of water, and large areas of barren ground or rock. However, regional mosaics can also be described in terms of land ownership, habitat patches, land use patches, or other elements. For landscapes, this is typically the spatial arrangement of landscape elements.

multiaged stands—Forest stands having two or more age classes of trees; this includes stands resulting from variable-retention silvicultural systems or other traditionally even-aged systems that leave residual or reserve (legacy) trees.

multiple use—The management of all the various renewable surface resources of the National Forest System so that they are used in the combination that will best meet the needs of the American people; making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions; that some land will be used for less than all of the resources; and harmonious and coordinated management of the various resources, each with the other, without impairment of the productivity of the land, with consideration being given to the relative values of the various resources, and not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output, consistent with the Multiple-Use Sustained-Yield Act of 1960 (16 U.S.C. 528–531) (36 CFR 219.19).

natal site—Location of birth.

native knowledge—A way of knowing or understanding the world, including traditional ecological, and social knowledge of the environment derived from multiple generations of indigenous peoples' interactions, observations, and experiences with their ecological systems. This knowledge is accumulated over successive generations and is expressed through oral traditions, ceremonies, stories, dances, songs, art, and other means within a cultural context (36 CFR 219.19).

native species—A species historically or currently present in a particular ecosystem as a result of natural migratory or evolutionary processes and not as a result of an accidental or deliberate introduction or invasion into that ecosystem (see 36 CFR 219.19).

natural range of variation (NRV)—The variation of ecological characteristics and processes over specified scales of time and space that are appropriate for a given management application (FSH 1909.12.5).

nested hierarchy—The name given to the hierarchical structure of groups within groups used to classify organisms.

nontimber forest products (also known as "special forest products")—Various products from forests that do not include logs from trees but do include bark, berries, boughs, bryophytes, bulbs, burls, Christmas trees, cones, ferns, firewood, forbs, fungi (including mushrooms), grasses, mosses, nuts, pine straw, roots, sedges, seeds, transplants, tree sap, wildflowers, fence material, mine props, posts and poles, shingle and shake bolts, and rails (36 CFR part 223 Subpart G).

novel ecosystem—An ecosystem that has experienced large and potentially irreversibly modifications to abiotic conditions or biotic composition in ways that result in a composition of species, ecological communities, and functions that have never before existed, and that depart from historical analogs (Hobbs et al. 2009). See "hybrid ecosystem" for comparison.

old-growth forest—A forest distinguished by old trees (>200 years) and related structural attributes that often (but not always) include large trees, high biomass of dead wood (i.e., snags, down coarse wood), multiple canopy layers, distinctive species composition and functions, and vertical and horizontal diversity in the tree canopy (see chapter 3). In dry, fire-frequent forests, old growth is characterized by large, old fire-resistant trees and relatively open stands without canopy layering.

palustrine—Inland, nontidal wetlands that may be permanently or temporarily flooded and are characterized by the presence of emergent vegetation such as swamps, marshes, vernal pools, and lakeshores.

passive management—A management approach in which natural processes are allowed to occur without human intervention to reach desired outcomes.

patch—A relatively small area with similar environmental conditions, such as vegetative structure and composition. Sometimes used interchangeably with vegetation or forest stand.

Pacific Decadal Oscillation (**PDO)**—A recurring (approximately decadal-scale) pattern of ocean-atmosphere —a stream or reach of a channel that flows continuously or nearly so throughout the year and whose upper surface is generally lower than the top of the zone of saturation in areas adjacent to the stream.

perennial stream—A stream or reach of a channel that flows continuously or nearly so throughout the year and whose upper surface is generally lower than the top of the zone of saturation in areas adjacent to the stream.

phenotype—Physical manifestation of the genetic makeup of an individual and its interaction with the environment.

place attachment—The "positive bond that develops between groups or individuals and their environment" (Jorgensen and Stedman 2001: 234).

place dependence— "The strength of an individual's subjective attachment to specific places" (Stokols and Shumaker 1982: 157).

place identity—Dimensions of self that define an individual's [or group's] identity in relation to the physical environment through ideas, beliefs, preferences, feelings, values, goals, and behavioral tendencies and skills (Proshansky 1978).

place-based planning—"A process used to involve stakeholders by encouraging them to come together to collectively define place meanings and attachments" (Lowery and Morse 2013: 1423).

plant association—A fine level of classification in a hierarchy of potential vegetation that is defined in terms of a climax-dominant overstory tree species and typical understory herb or shrub species.

population bottleneck—An abrupt decline in the size of a population from an event, which often results in deleterious effects such as reduced genetic diversity and increased probability of local or global extirpation.

potential vegetation type (PVT)—Native, late-successional (or "climax") plant community that reflects the regional climate, and dominant plant species that would occur on a site in absence of disturbances (Pfister and Arno 1980).

poverty rate—A measure of financial income below a threshold that differs by family size and composition.

precautionary principle—A principle that if an action, policy, or decision has a suspected risk of causing harm to the public or to the environment, and there is no scientific consensus that it is not harmful, then the burden of proof that it is not harmful falls on those making that decision. Particular definitions of the principle differ, and some applications use the less formal term, "precautionary approach." Important qualifications associated with many definitions include (1) the perceived harm is likely to be serious, (2) some scientific analysis suggests a significant but uncertain potential for harm, and (3) applications of the principle emphasize generally constraining an activity to mitigate it rather than "resisting" it entirely (Doremus 2007).

prescribed fire—A wildland fire originating from a planned ignition to meet specific objectives identified in a written and approved prescribed fire plan for which National Environmental Policy Act requirements (where applicable) have been met prior to ignition (synonymous with controlled burn).

primary recreation activity—A single activity that caused a recreation visit to a national forest.

probable sale quantity—An estimate of the average amount of timber likely to be awarded for sale for a given area (such as the NWFP area) during a specified period.

provisioning services—A type of ecosystem service that includes clean air and fresh water, energy, food, fuel, forage, wood products or fiber, and minerals.

public participation geographic information system (PPGIS)—Using spatial decisionmaking and mapping tools to produce local knowledge with the goal of including and empowering marginalized populations (Brown and Reed 2009).

public values—Amenity values (scenery, quality of life); environmental quality (clean air, soil, and water); ecological values (biodiversity); public use values (outdoor recreation, education, subsistence use); and spiritual or religious values (cultural ties, tribal history).

record of decision (ROD)—The final decision document that amended the planning documents of 19 national forests and seven Bureau of Land Management districts within the range of the northern spotted owl (the NWFP area) in April 1994 (Espy and Babbit 1994).

recreation opportunity—An opportunity to participate in a specific recreation activity in a particular recreation setting to enjoy desired recreation experiences and other benefits that accrue. Recreation opportunities include non-motorized, motorized, developed, and dispersed recreation on land, water, and in the air (36 CFR 219.19).

redundancy—The presence of multiple occurrences of ecological conditions, including key ecological functions (functional redundancy), such that not all occurrences may be eliminated by a catastrophic event.

refugia—An area that remains less altered by climatic and environmental change (including disturbances such as wind and fire) affecting surrounding regions and that therefore forms a haven for relict fauna and flora.

regalia—Dress and special elements made from a variety of items, including various plant and animal materials, and worn for tribal dances and ceremonies.

regulating services—A type of ecosystem service that includes long-term storage of carbon; climate regulation; water filtration, purification, and storage; soil stabilization; flood and drought control; and disease regulation.

representativeness—The presence of a full array of ecosystem types and successional states, based on the physical environment and characteristic disturbance processes.

reserve—An area of land designated and managed for a special purpose, often to conserve or protect ecosystems, species, or other natural and cultural resources from particular human activities that are detrimental to achieving the goals of the area.

resilience—The capacity of a system to absorb disturbance and reorganize (or return to its previous organization) so as to still retain essentially the same function, structure, identity, and feedbacks (see FSM Chapter 2020 and see also "socioecological resilience"). Definitions emphasize the capacity of a system or its constituent entities to respond or regrow after mortality induced by a disturbance event, although broad definitions of resilience may also encompass "resistance" (see below), under which such mortality may be averted.

resistance—The capacity of a system or an entity to withstand a disturbance event without much change.

restoration economy—Diverse economic activities associated with the restoration of structure or function to terrestrial and aquatic ecosystems (Nielsen-Pincus and Moseley 2013).

restoration, ecological—The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Ecological restoration focuses on reestablishing the composition, structure, pattern, and ecological processes necessary to facilitate terrestrial and aquatic ecosystems sustainability, resilience, and health under current and future conditions (36 CFR 219.19).

restoration, functional—Restoration of dynamic abiotic and biotic processes in degraded ecosystems, without necessarily a focus on structural condition and composition.

riparian areas—Three-dimensional ecotones (the transition zone between two adjoining communities) of interaction that include terrestrial and aquatic ecosystems that extend down into the groundwater, up above the canopy, outward across the floodplain, up the near slopes that drain to the water, laterally into the terrestrial ecosystem, and along the water course at variable widths (36 CFR 219.19).

riparian management zone—Portions of a watershed in which riparian-dependent resources receive primary emphasis, and for which plans include Plan components to maintain or restore riparian functions and ecological functions (36 CFR 219.19).

riparian reserves—Reserves established along streams and rivers to protect riparian ecological functions and processes necessary to create and maintain habitat for aquatic and riparian-dependent organisms over time and ensure connectivity within and between watersheds. The Aquatic Conservation Strategy in the NWFP record of decision included standards and guidelines that delineated riparian reserves.

risk—A combination of the probability that a negative outcome will occur and the severity of the subsequent negative consequences (36 CFR 219.19).

rural restructuring—Changes in demographic and economic conditions owing to declines in natural resource production and agriculture (Nelson 2001).

scale—In ecological terms, the extent and resolution in spatial and temporal terms of a phenomenon or analysis, which differs from the definition in cartography regarding the ratio of map distance to Earth surface distance (Jenerette and Wu 2000).

scenic character—A combination of the physical, biological, and cultural images that gives an area its scenic identity and contributes to its sense of place. Scenic character provides a frame of reference from which to determine scenic attractiveness and to measure scenic integrity (36 CFR 219.19).

science synthesis—A narrative review of scientific information from a defined pool of sources that compiles and integrates and interprets findings and describes uncertainty, including the boundaries of what is known and what is not known.

sense of place—The collection of meanings, beliefs, symbols, values, and feelings that individuals or groups associate with a particular locality (Williams and Stewart 1998).

sensitive species—Plant or animal species that receive special conservation attention because of threats to their populations or habitats, but which do not have special status as listed or candidates for listing under the Endangered Species Act.

sensitivity—In ecological contexts, the propensity of communities or populations to change when subject to disturbance, or the opposite of resistance (see "community resistance").

sink population—A population in which reproductive rates are lower than mortality rates but that is maintained by immigration of individuals from outside of that population (see also "source population").

social sustainability—"The capability of society to support the network of relationships, traditions, culture, and activities that connect people to the land and to one another, and support vibrant communities" (36 CFR 219.19). The term is commonly invoked as one of the three parts of a "triple-bottom line" alongside environmental and economic considerations. The concept is an umbrella term for various topics such as quality of life, security, social capital, rights, sense of place, environmental justice, and community resilience, among others discussed in this synthesis.

socioecological resilience—The capacity of socioecological systems (see "socioecological system") to cope with, adapt to, and influence change; to persist and develop in the face of change; and to innovate and transform into new, more desirable configurations in response to disturbance.

socioecological system (or social-ecological system)—A coherent system of biophysical and social factors defined at several spatial, temporal, and organizational scales that regularly interact, continuously adapt, and regulate critical natural, socioeconomic, and cultural resources (Redman et al. 2004); also described as a coupled-human and natural system (Liu et al. 2007).

source population—A population in which reproductive rates exceed those of mortality rates so that the population has the capacity to increase in size. The term is also often used to denote when such a population contributes emigrants (dispersing individuals) that move outside the population, particularly when feeding a sink population.

special forest products—See "nontimber forest products."

special status species—Species that have been listed or proposed for listing as threatened or endangered under the Endangered Species Act.

species of conservation concern—A species, other than federally recognized as a threatened, endangered, proposed, or candidate species, that is known to occur in the NWFP area and for which the regional forester has determined that the best available scientific information indicates substantial concern about the species' capability to persist over the long term in the Plan area (36 CFR 219.9(c)).

stand—A descriptor of a land management unit consisting of a contiguous group of trees sufficiently uniform in age-class distribution, composition, and structure, and growing on a site of sufficiently uniform quality, to be a distinguishable unit.

standard—A mandatory constraint on project and activity decisionmaking, established to help achieve or maintain the desired condition or conditions, to avoid or mitigate undesirable effects, or to meet applicable legal requirements.

stationarity—In statistics, a process that, while randomly determined, is not experiencing a change in the probability of outcomes.

stewardship contract—A contract designed to achieve land management goals while meeting local and rural community needs, including contributing to the sustainability of rural communities and providing a continuing source of local income and employment.

strategic surveys—One type of field survey, specified under the NWFP, designed to fill key information gaps on species distributions and ecologies by which to determine if species should be included under the Plan's Survey and Manage species list.

stressors—Factors that may directly or indirectly degrade or impair ecosystem composition, structure, or ecological process in a manner that may impair its ecological integrity, such as an invasive species, loss of connectivity, or the disruption of a natural disturbance regime (36 CFR 219.19).

structure (ecosystem)—The organization and physical arrangement of biological elements such as snags and down woody debris, vertical and horizontal distribution of vegetation, stream habitat complexity, landscape pattern, and connectivity (FSM 2020).

supporting services—A type of ecosystem service that includes pollination, seed dispersal, soil formation, and nutrient cycling.

Survey and Manage program—A formal part of the NWFP that established protocols for conducting various types of species surveys, identified old-forest-associated species warranting additional consideration for monitoring and protection (see "Survey and Manage species"), and instituted an annual species review procedure that evaluated new scientific and monitoring information on species for potentially recommending changes in their conservation status, including potential removal from the Survey and Manage species list.

Survey and Manage species—A list of species, compiled under the Survey and Manage program of the NWFP, that were deemed to warrant particular attention for monitoring and protection beyond the guidelines for establishing late-successional forest reserves.

sustainability—The capability to meet the needs of the present generation without compromising the ability of future generations to meet their needs (36 CFR 219.19).

sustainable recreation—The set of recreation settings and opportunities in the National Forest System that is ecologically, economically, and socially sustainable for present and future generations (36 CFR 219.19).

sympatric—Two species or populations that share a common geographic range and coexist.

threatened species—Any species that the Secretary of the Interior or the Secretary of Commerce has determined is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Threatened species are listed at 50 CFR sections 17.11, 17.12, and 223.102.

timber harvest—The removal of trees for wood fiber use and other multiple-use purposes (36 CFR 219.19).

timber production—The purposeful growing, tending, harvesting, and regeneration of regulated crops of trees to be cut into logs, bolts, or other round sections for industrial or consumer use (36 CFR 219.19).

topo-edaphic—Related to or caused by particular soil conditions, as of texture or drainage, rather than by physiographic or climatic factors within a defined region or area.

traditional ecological knowledge—"A cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes et al. 2000: 1252). See also "native knowledge."

trailing edge—When describing the range of a species, the boundary at which the species' population is geographically contracting through local extinction at occupied sites.

trophic cascade—Changes in the relative populations of producers, herbivores, and carnivores following the addition or removal of top predators and the resulting disruption of the food web.

uncertainty—Amount or degree of confidence as a result of imperfect or incomplete information.

understory—Vegetation growing below the tree canopy in a forest, including shrubs and herbs that grow on the forest floor.

use of wildland fire—Management of either wildfire or prescribed fire to meet resource objectives specified in land or resource management plans (see "Managing wildfire for resource objectives" and "Prescribed fire").

variable-density thinning—The method of thinning some areas within a stand to a different density (including leaving dense, unthinned areas) than other parts of the stand, which is typically done to promote ecological diversity in a relatively uniform stand.

vegetation series (plant community)—The highest level of the fine-scale component (plant associations) of potential vegetation hierarchy based on the dominant plant species that would occur in late-successional conditions in the absence of disturbance.

vegetation type—A general term for a combination or community of plants (including grasses, forbs, shrubs, or trees), typically applied to existing vegetation rather than potential vegetation.

viable population—A group of breeding individuals of a species capable of perpetuating itself over a given time scale.

vital rates—Statistics describing population dynamics such as reproduction, mortality, survival, and recruitment.

watershed—A region or land area drained by a single stream, river, or drainage network; a drainage basin (36 CFR 219.19).

watershed analysis—An analytical process that characterizes watersheds and identifies potential actions for addressing problems and concerns, along with possible management options. It assembles information necessary to determine the ecological characteristics and behavior of the watershed and to develop options to guide management in the watershed, including adjusting riparian reserve boundaries.

watershed condition assessment—A national approach used by the U.S. Forest Service to evaluate condition of hydrologic units based on 12 indicators, each composed of various attributes (USDA FS 2011).

watershed condition—The state of a watershed based on physical and biogeochemical characteristics and processes (36 CFR 219.19).

watershed restoration—Restoration activities that focus on restoring the key ecological processes required to create and maintain favorable environmental conditions for aquatic and riparian-dependent organisms.

well-being—The condition of an individual or group in social, economic, psychological, spiritual, or medical terms.

wilderness—Any area of land designated by Congress as part of the National Wilderness Preservation System that was established by the Wilderness Act of 1964 (16 U.S.C. 1131–1136) (36 CFR 219.19).

wildlife—Undomesticated animal species, including amphibians, reptiles, birds, mammals, fish, and invertebrates or even all biota, that live wild in an area without being introduced by humans.

wildfire—Unplanned ignition of a wildland fire (such as a fire caused by lightning, volcanoes, unauthorized and accidental human-caused fires), and escaped prescribed fires.

wildland-urban interface (WUI)—The line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetation fuels.

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