Chapter 12: Science that Underlies the Northwest Forest Plan

INTRODUCTION

The long-term monitoring programs and research related to the Northwest Forest Plan (NWFP) provide an unprecedented opportunity to examine how the scientific basis and socio-ecological context of a major forest conservation and ecosystem management plan have changed (or not) in 22 years, and how well the goals and strategies of the plan are positioned to address new and emerging issues. The plan was developed through a political process that largely excluded senior managers and involved scientists in an unusual and controversial role: developing plan options directly for the President to consider. Since that time the role of science in planning has changed; it is now limited to synthesizing science in support of planning and management (USDA 2012), rather than conducting assessments and developing plan

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options, which is a task of managers. The implementation of the NWFP was followed by monitoring, research, and expectations for learning and adaptive management (FEMAT 1993). The goals for the NWFP were developed in the context of scientific understanding and values of the late 1980s and early 1990s. While some concerns and understanding about conservation and use of these forests have not changed, new science and concerns have appeared and are emerging, and the social and ecological context of the NWFP has changed. For example, since the plan was developed in the early 1990s, the frequency and extent of wildfires in the NWFP area have increased substantially in response to climate warming (Westerling et al. 2006, Reilly et al. In review), the invasive barred owl has become a major threat to populations of the northern spotted owl (chapter 4), and the forest products industry has largely moved away from the use and economically valuing large logs, and toward the use of smaller diameter trees from forest plantations (Haynes et al. 2009). The scientific assessment for the NWFP (FEMAT 1993) did not address other issues that are considered important today including climate change, invasive species, and effects of fire suppression on habitat diversity and forest successional dynamics.

In the early 1990s, wildfire was often viewed by stakeholders as a threat to plan goals instead of also being an important ecological process that can help achieve desired ecological outcomes. The social dimensions and approaches to the NWFP originally were not collaborative (Skillen 2015) and seen largely in terms of commodity-based economic development and support for maintaining stability of local and regional economies (Charnley 2006). We 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 or more about values and conflict resolution than they were about ecological science (Lange 2016, Spies and Duncan 2009).

The goals of the NWFP were broad and challenging. President Bill Clinton’s charge was to develop a “balanced and comprehensive strategy for the conservation and management of forest ecosystems, while maximizing economic and social benefits from forests” (USDA Forest Service & BLM 1994). Since this broad goal was established, scientific understanding of frameworks for integrating ecological and social systems has developed through the emerging science of coupled-human and natural systems or “social-ecological systems” (Liu 2007). This socioecological perspective goes well beyond the late-successional
ecosystem management framework that guided the development of the NWFP in order to more fully embrace social components and interactions between social and ecological systems that can lead to system complexity, surprises and unintended outcomes from policies (Spies et al. 2014). For example, the relationship of federal forests to community well-being has changed and does not necessarily depend on the economic contribution of the wood products industry (Charnley 2006). Furthermore, that industry also experienced changes in the NWFP region, that 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, we better understand that achieving forest restoration goals requires restoring organizational capacity of agencies, infrastructure, and business capacity in the private sector in the form of mills and a skilled workforce (chapter 8).

A fundamental scientific assumption of the NWFP was that the mix of biological and socio-economic goals and strategies were compatible and capable of meeting the conservation goals of the NWFP and other biodiversity policies, as well as the socioeconomic goal of maintaining community stability. Scientists and managers now have the perspective afforded by 22 years of research and field experience in implementing the Plan to evaluate this assumption through the lens of social-ecological systems. We have three major objectives in this chapter:

1. Set the broader context of the NWFP goals and conservation approaches in terms of the science of social-ecological systems and increasing awareness of the pervasive impact of human activity on forest ecosystems and species.

2. Characterize how the conservation, restoration, and socioeconomic strategies of the NWFP interact, and how well they meet the original goals and are set to address new issues

3. Identify key uncertainties, research needs and management considerations

**Guiding Questions**
The guiding questions for this chapter are:

1. What are the latest perspectives on how global environmental change is altering forest ecosystems and how relevant are these perspectives in the NWFP area?

2. What are the latest perspectives on conservation and use of reserves given our expanded understanding of ecosystem dynamics and influences of global environmental change?

3. What are the 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? For example, how compatible are fine-filter approaches based on species that use multi-layered old forests with coarse-filter approaches based on historical disturbance regimes or based on managing for resilience of forests and species to future climate change and disturbance?

5. 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?

6. What is known about the tradeoffs of restoration actions across a range of conservation and community socioeconomic well-being goals?

7. What are the regional scale issues and challenges associated with the goals of the NWFP?

8. What are the uncertainties, research needs and management considerations?

**Key Findings**
Increasingly, environmental sciences are using social-ecological system (also sometimes described as coupled-human and natural systems) frameworks to understand ecosystems (Liu et al. 2007, Spies et al. 2014) and human communities (fig. 1). This science seeks to understand how the human and non-human components of a social-ecological system interact at multiple scales, and influence human well-being and the condition of species and ecosystems. Scientists are giving greater consideration to the breadth, dynamism, and complexity of these interactions that they did at the time of the Forest Ecosystem Management Assessment Team (FEMAT). For example, ecosystems provide many life support services and benefits to human communities beyond timber production; and, the impact of humans on the environment in the NWFP area is much broader than the effects of timber production.
Figure 1. Major components and interactions in the social-ecological system in which the NWFP and federal forest management are imbedded. Interactions occur within social and ecological systems and between them.

In the sections below we explore these interactions and how they can affect the goals of the NWFP. We begin by setting the context for conservation in terms of current scientific thinking.

Perspectives on altered ecosystems and conservation in an era of global ecological change

The effects of humans on environments in the NWFP area go beyond timber management impacts within the region and often originate from processes outside the region. The impacts of human activity on the globe and forests have become so pervasive that many scientists are now arguing that we are in a new geological epoch called the “Anthropocene” (Steffen et al. 2007, Carey 2016, Lugo 2015, Wohl 2013, Sun and Vose 2016, Corlett 2015, Lewis and Maslin 2015, Creed et al. 2016), a period since the early 1800s when rapid industrialization, population growth, and global trade and transportation led to dramatic increases in atmospheric carbon, landuse change, altered disturbance regimes, and introduction of alien species, including pathogens.

Native Americans had managed landscapes in the NWFP area in prehistoric and historic times to create conditions that favored natural resources important for food and other cultural values; fire was their most important environmental management tool (Charnley et al. 2007). However, human activity since development of industrial society in the 19th century has wrought many large changes in species, habitats, forests, streams, and landscapes of the NWFP. Relatively little of the area of the NWFP could be considered largely uninfluenced by human activity. Forests and watersheds that have been least affected by human activity are in large blocks of unroaded moist forests and high elevation forests in areas where fire frequencies were longer than 200 years and fire suppression and management activity has had relatively less impact on the creation of early successional and nonforest vegetation (chapter 3, Hessburg et al. 2016). Such areas currently occupy a relatively small percent of the NWFP area. All other areas
have been altered from historical conditions by human activity to different degrees by logging, plantations, roads, trails, splash and other kinds of dams, fire exclusion, and tree invasion of meadows and shrublands. Fire exclusion in fire-dependent forests, which occupy over 50% of the NWFP area, has had a profound effect on forest structure and composition, native biodiversity and resilience to fire and climate change (chapter 3). The extirpation of top predators and invasions by others may have caused trophic effects on ecosystems (Beschta and Ripple 2009, 2008, Wallach et al. 2015). Sudden oak death is altering community structure and fire behavior across large areas of northern California and southern Oregon (Crowl et al. 2008). The wildland urban interface is expanding rapidly in the NWFP area creating challenges to balancing fire protection and fire restoration goals (Hammer et al. 2007). Anthropogenic climate change is increasing warming the region to levels that may exceed climate conditions experienced in the last 1000 years (chapter 2), which will alter hydrological and fire regimes (Watts et al. 2016, chapter 2) even more, and change the expected role of NWFP conservation strategies (chapter 6). Fire is increasing as well but fire-prone forest landscapes are still running a fire deficit in comparison with historical conditions (chapter 3, Parks et al. 2015), and burned area maybe less than would be expected under a warming climate (chapter 2, chapter 3). The decline of American Indian management influence is also part of altered disturbance regimes and ecosystems in many areas (chapter 11).

In summary forests, watersheds and biotic communities in the NWFP area have been influenced by native peoples for many millennia, and many have been profoundly affected by human activity during the last 150 years and before that. This reality has at least two major implications: first, some ecological conditions, even in many old-growth forests, that may be regarded as “natural” have been influenced by human activity, and second, restorative actions may help to achieve goals of managing for desired species and a sufficient level of resilience to fire, climate change, insects and diseases.

Unprecedented ecological shifts or alterations that have occurred across the globe have also been described through 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 or manage for some of these novel or “hybrid” (semi-natural) states where it is impractical to change existing conditions or where they provide values including local livelihoods, quality of life, and habitats of desired species that may not
have occurred there historically⁴ (e.g. fire excluded forests that support dense-forest species). This perspective does not mean that maintenance or restoration of native communities or historical dynamics could *not* be a goal—only that some scientists are increasingly recognizing the goals of restoring and maintaining ecosystem integrity based on the historical range of variation in ecosystems may not be attainable in some places for ecological and/or social reasons. Hobbs et al. (2014) recommend using landscape frameworks to identify where it is possible to retain or restore native biodiversity and where acceptance or management for some novel or “hybrid” (semi-natural) qualities or ecosystems might desirable.

Recognizing the realities of the Anthropocene and reality of altered ecosystems has implications for using the 2012 Planning rule (USDA 2012), which is based on managing for ecological integrity (ecosystems that operate in their “natural range of variability”), which is used interchangeably with “historic range of variability⁵” by the agency (Bone et al. 2016), among other ecological goals. Given the pace and scope of environment change, it may be tempting to assume that history or historical range of variation is no longer relevant to conservation and management, however, this is definitely not the case (Keane et al. 2009, Safford et al. 2012, Higgs et al. 2014). The main question in conservation and management is not the fundamental value of history but how it is used (Keane et al. 2009, Safford et al. 2012). There are many uses of historical knowledge in informing management including: 1) history as information for how ecosystems work, as a reference, and as a possible target; 2) enriching cultural connections; and 3) revealing possible futures (Higgs et al. 2014). History as precise reference information and targets, and quantitative models of range of variation may become less important and even have negative consequences (in the case of precise targets) with climate and landscape change but other types of historical information may become more important (Higgs et al. 2014, Hiers et al. 2016). Information about the historical range of variation may be derived from models or from general characterization of ecological history (Hessburg and Povak 2015), which are also useful (and more available than

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⁴ There’s a precedence for this. NFMA actually stated this. “…*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).

⁵ In this chapter we use “historical range of variability” and consider it synonymous with “natural range of variability” for our purposes. See Romme et al. 2012 for comparisons of definitions of historical range of variability and natural range of variability.
quantitative estimates of historical ranges) in using history to guide management. Safford et al. 2012 provide several recommendation 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.

- Ecological history is a key to understanding how ecosystems work, which is a prerequisite for conserving and managing ecosystems.

- Plan for the future, not for the past, but do not forget that the past provides our only empirical glimpse into the range of possible futures.

Managing for ecological integrity based on history can be an important way to set and achieve objectives for many ecosystems (chapter 3, Hessburg et al. 2016). However, there may be multiple possible alternative states for of ecological integrity based on realities of climate change, invasive species and the social range of variability, which determines the acceptability of the historical range of variation (Duncan et al. 2010, Romme et al. 2012). Given climate change other landscape-level changes and social influences, managing for social-ecological resilience to climate change and stressors (Carpenter et al. 2001, Folke 2006) and to sustain ecosystem services may be a more realistic approach than managing for a target based on historical range of variability (Safford et al. 2012, Stine et al. 2014). Managing for ecosystem resilience means focusing on overall ecosystem behavior and processes based on knowledge of ecological interactions that have occurred in the past and may occur in the future, e.g. future range of variability (Keane et al. 2009). It should be noted however, that “resilience” can be a useful goal only when clarified in terms of “resilience of what, to what?”(Carpenter et al. 2001). Given the expected limits of coarse filter approaches, fine filter (species) approaches are also key parts of conservation strategies.
However, focusing on individual species also faces similar challenges in the Anthropocene and over emphasis on just one component (e.g. a species) may have undesirable consequences for other species or components ecosystems (see section below on coarse and fine filter approaches in the NWFP).

The altered or novel ecosystem concept can be applied to some areas the NWFP area and goals. For example, uniform tree plantations of primarily of native tree species, which are now common across federal and private lands are perhaps the most well-known altered forest ecosystem in the region that provides economic values. While these may be restored on federal lands they are unlikely to change much on private lands in the future. However, one of the most pervasive and less appreciated anthropogenic effects is a major change to fire regimes in over half of the NWFP area as a consequence of fire exclusion and suppression (chapter 3). Lack of fire in the frequent and moderately frequent regimes has had cascading ecological effects on ecosystems and species. The effects include increased forest density, loss of open old growth forest types, an increased area of late-successional habitat that favors the northern spotted owl (chapter 3) and other species, altered disturbance regimes, successional pathways, and altered forest composition. The lack of fire also means a decreases in occurrence of diverse early successional habitats in some fire regimes (chapter 3).

The challenges to managing for ecological integrity, resilience and desired species in the NWFP area are both ecological and social. In the wetter forest types, where fire was infrequent, uniform plantations and time for succession (centuries) are the main ecological barriers to restoring dynamics based on history and historical diversity of these forests on federal lands. Social limits in these regimes may be mostly associated with funding to restore plantations, tradeoffs in values (e.g., dead wood or carbon and habitat diversity) associated with thinning in uplands and riparian areas, and lack of agreement on the need for management (chapter 3 and 7).

In moderately frequent and frequent fire regimes (chapter 3), the ecological limits include the fact that with build-up of fuels in historical fire frequent regimes, fire often cannot be reintroduced (e.g., as prescribed fire) without first reducing fuels often through mechanical means. And, more importantly climate change will continue to alter fire regimes and vegetation dynamics. The social and economic constraints to widespread restoration of fire to our fire-prone ecosystems are large and include budgets,
workforce, air quality, and the risk of losing other values (North et al. 2015, Ryan et al. 2013, North et al. 2012, Collins et al. 2010), chapter 8). It will be important to recognize that public support for restoring fire will be needed 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 beyond current annual fire suppression funding. For example, the current rates of restoration treatments in some areas of the western United States are well below what is needed for restoration (North et al. 2012, Spies et al. in press).

Another social challenge is that some altered conditions of ecosystems in the NWFP area may now be desirable to some people despite being highly departed from historical conditions. For example, the denser forests that have developed in high frequency and moderate frequency fire regimes now support more area of habitat for spotted owls and other dense forest species such as goshawks (chapter 3). Some groups may favor maintaining some of these dense stands; for example, the Klamath Tribes, expressed a concern for promoting mule deer by retaining dense tree patches as deer hiding cover within historically open ponderosa pine landscapes in their ancestral lands on the Fremont-Winema National Forest (Johnson et al. 2008). Based on interactions 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, multi-layered grand fir and white fir forests, which appear to fit an out-of-place old-growth forest ideal based on wetter old-growth types. Moreover, the tall, multi-layered forests that develop in moderate frequency fire regimes in the absence of fire in the western Cascades of Oregon may temporarily buffer climate change effects on the micro-climate for wildlife (Frey et al. 2016a, 2016b). Finally, such forests may be more desirable to some people simply because they occur without active management (except for suppression), which may be mistrusted (Dellasala et al. 2013) (See section on trust below).

On the other hand, these fire-excluded ecosystems can result in many undesirable outcomes, including altered successional pathways, biotic communities, and ecosystem functions (Keane et al. 2002, 2009). A particular example is increases in uncharacteristically large patches of high-severity fire in areas historically dominated by more frequent, less severe fires (chapter 3). Such patches may have undesirable effects in terms of accelerated upland erosion, stream sedimentation, insect and disease dynamics, and
reduction of services from mature forest stands including acorn production. Large patches of high severity fire in these ecosystems often kill large, old, trees, which are considered a regionally and globally significant keystone ecological structure (Lindenmayer et al. 2014), and can have negative effects on habitat for the northern spotted owl (Jones et al. 2016). The landscapes left following extremely large and uncharacteristically severe fires can pose significant management challenges, 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. Extremely large and unusually severe fires also have major social impacts through heavy smoke, evacuations, greenhouse gas emissions, costs of firefighting, and threats to lives and property.

The risks associated with fire-excluded forests concern many people including some stakeholders in the central Oregon forest collaboratives mentioned above. Many of the people in these collaboratives note concerns about the increased risk of widespread tree mortality due to 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 last 100 years in favor of fire-tolerant/drought-tolerant species (Andrew Merschel personal communication).

The rise of altered ecological conditions is also a concern where ecosystems are subject to multiple novel disturbance agents. For example, stands infested by sudden oak death (*Phytophthora ramorum*) may have increased potential for high burn severity (chapter 3), while rodenticides used in marijuana operations and the spread of barred owls may tax populations of sensitive fishers and spotted owls so that they are 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 but using landscape and social-ecological systems perspectives can help identify and implement the most effective ecological and social actions toward meeting the broad Forest Service goal (http://www.fs.fed.us/strategicplan) of increasing the
resilience of forests to fire and climate change while meeting the specific late successional forest goals of
the NWFP (Stephens et al. 2013, Fischer et al. 2016, Hessburg et al. 2015, 2016).

Species invasions have also changed the native biota of the NWFP region (chapter 6). The barred owl is
an example of an invasive species (some have called it a “native invader species” (Carey et al. 2012)) that
has become a major threat to the viability of northern spotted owls (chapter 4). While 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
populations have expanded as a result of human food waste and human disturbance of vegetation
(Marzluff and Neatherlin 2006, Peterson and Colwell 2014) and prey on marbled murrelet nests (chapter
5). The widespread expansion of true firs into pine forests where fire has been excluded could also be
considered an example of a native invasive species that was once uncommon in many fire prone-
landscapes but is now common and difficult to control now that seed sources exist across landscapes and
wildfires are excluded as often as possible (Hessburg et al. 2016, Stine et al. 2014).

The impact of the invasive barred owl on the spotted owl is profound but could in theory be reversed or at
least stabilized through efforts to remove barred owls. An on-going large-scale experiment will shed more
light on this future (USFWS 2013, Wiens et al. 2016) A program of removing an established species to
protect another is a major challenge to society from ecological, cost and ethics perspectives (Carey et al.
2012, Livezey 2010) but is not unprecedented (e.g. Wilsey et al. 2013). In the long run, the northern
spotted owl may be locally or completely replaced by the barred owl. From an ecosystem perspective
(e.g., productivity, food webs, trophic cascades) the effect of loss of the owl on the forests and vertebrate
communities is not known 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 expanding
populations of barred owls (Holm et al. in press).

The altered or novel conditions associated with the Anthropocene have sparked debate in the global
literature about the best strategies to conserve native and desirable non-native biodiversity as we explore
in the next section. Ultimately, innovative approaches will be needed that integrate social and ecological dimensions of the problem.

Recent perspectives on conservation and use of reserves in this period of global change

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). Some scientists have challenged traditional concepts and approaches in conservation (e.g., static reserves and using historical conditions or range of variation as a reference for ecological restoration) (Millar et al. 2007, Wiens 2016). Some indicate 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 require a new land management ethic (Keane et al. 2009). Others have advocated for a new science of conservation rooted in the integrated nature of socioecological systems and designed to promote human wellbeing, particularly among the poor, through judicious and sustainable use of ecosystems rather than strict preservation (Karieva and Marvier 2012). These new perspectives have received push-back from some conservation biologists. For example, Miller et al. (2014) and Doak et al. (2014) argue that conservation that centers on human values, often organized using the framework of ecosystem services, is an “ideology” that: 1) is not new (e.g., they are reflected ideas advocated by Gifford Pinchot a century ago), and 2) does not address the root cause of loss of biodiversity which they consider to be “unabated consumption and increasing human populations”. Instead, they emphasize preservation of biodiversity through large networks of protected lands arranged to foster connectivity. They devote little attention, however, to what protection means in disturbance-dependent systems and highly dynamic systems with a strong history of human impacts or in systems where invasive species are widespread.

Nature reserves (also termed “protected areas”) including wilderness areas remain key components of conservation strategies. The idea of a nature “reserve” is a cultural construct associated with EuroAmerican notions of humans as distinct from nature (Cronon 1996). Rules governing permissible
activities in protected areas or reserves vary across the globe and are often controversial (Brokington and Wilkie 2015). While there is strong support and scientific evidence of reserves as an immediate and clearly understood way to protect native biodiversity from land uses that degrade it, they have been criticized by some for threatening livelihoods by denying access to resources, and for not taking ecosystem dynamics into account. Often, the costs of reserves are experienced by local people while their benefits disproportionately accrue to people elsewhere. The 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) or negative (e.g., reserves that restrict access to commodities or subsistence goods and can increase poverty in rural areas (Adams et al. 2004)); 3) the goals for nature in the reserves can be ambiguous or difficult to achieve given that nature is multidimensional, not static, and often influenced directly or indirectly by human activity including recreation, inside and outside reserves (e.g., recreation, fire suppression, invasive species and climate change); 4) achieving biodiversity goals often requires management, especially given effects of past landuse change, invasive species and climate change, which can be controversial if stakeholders hold different values for reserves (e.g., no human intervention vs. restoration of habitat or processes); 5) reserves, which typically occupy a small part of most landscapes are not enough alone to provide for biodiversity (Franklin and Lindemayer 2009); and 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).

E. O. Wilson, in his book “Half-Earth, Our Planet’s Fight for Life” (Wilson 2016), challenges 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). While we are a long way from these goals (currently global estimates are 6 percent) the area of wildland reserves or protected areas for biodiversity is growing (Götmark 2013). In the NWFP area, reserves on federal lands constitute about 28%

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6 Designated wilderness areas account for about 42% of federal reserves, not including riparian reserves. Roughly 7.1 million acres (includes some national parks like Olympic and Mr. Rainier).
percent of total area of forest on public and private forest lands (chapter 3) and about 80 percent of the federal forest area. What is often missing from these proposals and assessments is what do reserves mean in dynamic systems and what management actions might be needed within reserves to meet ecological goals.

Under the NWFP, late-successional and old-growth forest and riparian reserves were established with the intention to protect older forest conditions from immediate adverse influences of commercial timber harvests, that is, harvests not intended to promote development of old-forest conditions, especially clear-cutting. The NWFP guidelines were clear in terms of what human activities the reserves were intended to be "reserved" or protected from. They were not designed or anticipated, however, to be reserved or protected from changes altered fire regimes, invasive species (especially barred owls), and from changes in the regional climate, which are now collectively posing increasing disturbance and stress on these old-forest ecosystems.

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 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. These categories vary depending on the amount of human activity and use that is considered compatible with the primary conservation objectives of the reserve (Lausche 2011). Reserves typically are defined in terms of objectives and management actions that are needed/allowed and, in turn, actions that cannot be allowed in order to achieve primary conservation objectives. As a result reserves tend to have a hierarchy of conservation goals; as demonstrated in the NWFP area where conservation of functional older forest and owl habitat are the top priorities in late successional reserves (LSRs) at least for the wetter provinces (Henson et al. 2013). Thus, reserves as they have been conceived and implemented globally are not just set aside from anthropogenic influence but rather exist along a continuum of uses and management approaches, based on goals and cultural context.
Conservation biologists and legal experts (Craig 2010) are beginning to recognize the problem of conserving biodiversity in small, fixed reserves in highly dynamic systems, where habitats, disturbances, climatic influences, and plant and animal communities are not static (Bengtsson et al. 2003, Lemieux et al. 2011, Alagador et al. 2014). However, little formal evaluation of dynamic reserve strategies—in which new protected areas are established and old ones decommissioned in response to changing environmental conditions—has occurred, and we are not aware of any efforts in the United States where a reserve was decommissioned and replaced with a new one or an alternative approach. However, dynamic habitat conservation approaches are being used for two other endangered forest species in fire-prone forests: the Red-cockaded woodpecker (Picoides borealis) which is dependent on fire to maintain old-growth pine (Pinus sp.) forests of the southeastern United States, and the Kirtlands warbler (Dendroica kirtlandii) which is dependent 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. Rayfield et al. (2008) simulated wildfire, industrial forest management and static and dynamic habitat reserve strategies for American marten (Martes americana), a species of mature coniferous forests in Quebec. 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 important implications: 1) if reserves are focused on just one successional stage or habitat condition, they may not be effective in fire-prone landscapes; 2) if dynamic conservation strategies are to be successful in the long term, the surrounding non-reserved areas must be managed in a way such that habitat replacement options 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.

A dynamic reserve system would be more difficult to implement, monitor and govern than a fixed area one, but may be more effective, depending on the objectives. Most importantly, it would likely require an ongoing and robust decision-making process that involved stakeholders, and rebuilding a high level of trust. While the idea of dynamic reserves may be relatively new, recall that the fixed reserve system of the NWFP is also a long term, experiment, and the results are mixed in terms of meeting species,
ecosystem and socio-economic goals (chapter 3, and see below). The assumption that we can sustain the
goals of the NWFP for old, multilayered forests in fire-dependent ecosystems requires careful monitoring
and critical evaluation, with the expectation that changes may be needed given future fire occurrence and
climate change and species movements or other ecological surprises. See below for more discussion of
NWFP reserves.

Key social components and drivers of the social-ecological systems in the NWFP area

Ecosystem Services

The ecosystem services concept, developed since the NWFP was initiated, recognizes that forests and
other natural systems provide many values and benefits to human communities. The recognition of these
values is not that new (Kline et al. 2013), however, efforts to explicitly recognize them within a broader
“ecosystem services” framework is new and in the process of being incorporated into federal forest
management (Smith et al. 2011, Long et al. 2014). e.g., Additional categories of ecosystem services that
are now explicitly acknowledged, 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), were typically taken for granted
until relatively recently. We now realize that our ecosystems have discernable limits to providing most if
not all of these benefits. However, ecosystem valuation, particularly in monetary terms, is at best difficult
and forest managers often have a difficult task in assigning appropriate worth to many features of their
forest in ways that can inform decision-making (Smith et al. 2011). Kline et al. (2013) indicate 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.
No published full accounting of ecosystem services has been conducted for the NWFP area, but some local efforts have been made (Smith et al. 2011, Kline et al. 2016). Key ecosystem services provided by federal forests in the NWFP area include, water, recreation, wildlife and plant habitat, wood products and carbon sequestration. The carbon sequestration potential of old growth forest ecosystems has received special attention (DellaSala et al. 2016, Hudiburg et al. 2009, Kline et al. 2016, Smith et al. 2013, Wilson et al. 2013) because 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. 2). The water supply from many watersheds in the NWFP area originates on national forests (Watts et al. 2016) and water quality can be especially high from undisturbed old-growth forests as a result of high nutrient retention and low erosion (Franklin and Spies 1991). Stream flow 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 expanded understanding of ecosystem services also reveals that synergies and tradeoffs can occur between and among biocentric and anthropocentric values (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 recreation or restoration jobs. 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 the job losses associated with protection of late-successional old growth habitats (Charnley 2006, 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.

Institutional Capacity

A key interaction in the social-ecological system lies between the desire to restore forest dynamics or create more resilient forests and the limited capacity of human communities for active management. While forest management on federal lands was often seen in the past (and still is by some) as threat to native biodiversity, it is now seen as important to restoration and conservation (Johnson and Swanson 2009). In the past, revenues from timber harvest often subsidized forest management, yet those revenues have declined with reductions in harvest (chapter 8), and drained budgets and reduced agency staff needed to conduct forest management. At the same time fire suppression costs have increased. This reality poses a significant challenge to promoting other forest management objectives such as ecological restoration, reducing wildfire risk to human communities and promoting habitat for wildlife (chapter 8). Federal
agencies lacked the necessary depth and breadth of institutional capacity (staff with the required skills, financial resources, management flexibility, and incentives) to fully implement the NWFPs ecosystem management goals (Charnley 2006). Efforts to maintain species and habitats and restore desired ecological conditions (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 frequent fire landscapes (North et al. 2012). The budget and agency capacity problem has led to innovative approaches to accomplishing restoration done, 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 not sufficient.

The NWFP represented a dramatic shift in social priorities from commodities toward biodiversity that has continued through a process that has been called “green drift” (Klyza and Sousa 2010) throughout environmental policy making in the United States. However, the idea that “working forest landscapes” can provide for conservation values, funding for restoration, and support for rural communities has also gained much traction in recent years (Charnley et al. 2014). 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 collaborative efforts that take into account social, ecological and financial considerations and legislative actions.

Trust and Collaboration

Trust among federal land management agencies and the public is key to restoration and landscape-scale management for multiple goals, but it is often difficult to find (chapter 9). Trust among interested parties is important 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 and 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. Trust held by community members for natural resource agencies is typically associated with increased public approval of management actions and decisions (Davenport et al. 2007). Trust building can also minimize resistance to planning efforts. Many types of trust exist and when one type of trust is damaged, having other types of trust can buffer the loss (chapter 9, Stern and Coleman 2015). Agencies can enhance public trust through transparency, consistency, reliability, and accountability over time, but also through formation of long-term personal relationships among stakeholders, citizens and agency representatives. A desire to build or expand trust is an important motivator for collaboration and conflict resolution (Wondolleck and Yaffee 2000). 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 find trust and build social license for 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 decision making (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 has been successful in encouraging stakeholders to work together to help plan and implement forest restoration treatments in dry forests at the landscape scale.

Two well established collaboratives fall within or immediately adjacent to the NWFP area, the Deschutes Forest Collaborative in central Oregon and the Tapash Forest Sustainable Collaborative in the Yakama Nation. The Western Klamath Restoration Partnership is another, more recent example that builds upon many years of collaborative efforts in northern California. In addition to large-scale collaboration, there has been a proliferation of community-based collaborative groups in the NWFP that are engaged in National Environmental Policy Act planning, stewardship contracting, and multi-party monitoring, on both sides of the Cascades (Davis, et al. 2015) and in northern California. Other types of collaboratives found 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 governance is viewed as an effective way to engage stakeholders, provide an opportunity for dialogue and deliberation, and to build trust and foster relations among groups that historically have worked in opposition. For example, the threat of high-severity wildfire in the interior and southern forests of the NWFP area maybe a “common enemy” that can enable environmental and timber groups to work together with the Forest Service to advance restoration projects on the ground. This 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 the blueprint for making meaningful progress on large-scale forest restoration.

The tremendous investment in collaborative processes promises to yield enhanced trust and improved ecological and social conditions, however, the long-term benefits of collaboration have not yet been documented.

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 both including utilitarian values, including use for timber as well as non-tangible cultural values. The perspectives held by native peoples of the Pacific Northwest, informed by thousands of years of place-based experience, helps to internalize many of the tradeoffs between use and preservation, as well to provide a long-term, broad spatial perspective about system dynamics. Some contemporary tribal communities are developing innovative forest management plans that many consider to be fulfilling the promise of the NWFP (e.g., Johnson et al. 2008). A key finding from chapter 11 is the recognition of fire as a critical process for maintaining ecosystem qualities that are highly desirable, even in relatively wet regions where natural ignitions are insufficient to maintain frequent fires.

Compatibility of the major goals and strategies of the NWFP and how well the objectives of the main ecological and social components have been met

Coarse- and fine-filter approaches to conservation
Coarse- and fine-filter strategies for conserving biodiversity are supposed to be complementary, but in practice and depending on ecosystem type, they may not be if one component (ecosystem or species) is given far more weight than another, and habitat relationships vary widely among focal species. The original focus of the NWFP was limited to late successional and old-growth forests (fig. 3A and 3B). The approach of using the spotted owl as a surrogate or umbrella for old forest ecosystems developed “unintentionally”, driven mainly by the Endangered Species Act and other federal policies (Mcslow 1993).

Earlier scientific debate on the pros and cons of single species (e.g., fine filter) vs. ecosystem (coarse filter) approaches to management (Simberloff 1998, Casazza et al. 2016, White et al. 2013) have been replaced by recognition that both approaches are needed and can be complementary (chapter 6, DellaSala et al. 2016, Hunter 2005, Noon et al. 2009, Simberloff 1998, Tingley et al. 2014, Reilly and Spies 2015) Meso-filter approaches (e.g., habitat elements like snags and large old trees) have also been included in the conservation approach hierarchy (Hunter 2005). The challenge now and source of some debate is to find an appropriate level or balance of both approaches (Schultze et al. 2013). If 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” maybe conserved but the “star actors may not show up”.

A multiple species conservation strategy approach was used to an extent in the NWFP. However, the focus was primarily on late-successional species (fig. 3), based on the distribution of the northern spotted owl, which occurs across a wide range of forest ecosystem types. The integration of fine and coarse filter strategies becomes more complex and challenging when the ecosystems that support the species in some areas are the product of recent human activities as they are in forests that have developed as a result of 100 or more years of fire exclusion (chapter 3). The congruence of fine filter and coarse filter approaches for species of older dense multi-layered forests varies by disturbance regime (fig. 4). The best congruence between managing for historical range of variation or ecological resilience) (i.e., a coarse filter approach) and managing habitat for species that use dense older forests is in regimes where fire was infrequent (i.e., frequencies of 200-1000 years). However, in regimes where fire was quite frequent (less than 35 years)
and landscapes were dominated by open canopy forests, these approaches involve greater tension. Congruence between fine and coarse filter approaches is intermediate in moderately frequent fire regimes (35 to 200 years) where high, moderate and low severity fire occurred at moderate frequencies and created mosaics of all forest and nonforest seral stages on the landscape, including early successional, dense older forests and mid successional forests, often with remnant old trees (chapter 3). The relative abundances and spatial patterns of different forest states under these regimes sets up inherently different capacities to support native habitats and species the region (fig. 5). The proportion of early and late-seral forest in owl home ranges varies along a north-south and west-east gradient throughout the owl’s range as a function of dominant forest types and associated prey species (Franklin et al 2000, Olson et al. 2004).
Figure 3. (A) Distribution of habitat (dotted line ellipses) in relation to tree canopy closure and tree size (A) and tree canopy closure and dead wood (B) for different biodiversity components in the area of Northwest Forest Plan. 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/Non Forest (shrubland, grassland). Aquatic habitat requires a range of vegetation states including older forest through time but is not restricted to old growth (chapter 7). Spotted owl southern range habitat includes a mosaic of closed and early-seral and nonforest vegetation. Many species require early successional and nonforest habitats.
Figure 4. Schematic diagram illustrating the degree of overlap between a coarse-filter and fine filter approaches to conservation in the three major historical fire regimes of the NWFP area. Coarse filter approaches (gray circle) are based on historical range of variation or management for resilience. Fine filter approaches are based on species associated with late successional, multi-layered old growth forests. Relatively little of the area of landscapes in the frequent, low-severity fire regime would be covered by old, multi-storied forest under that historical disturbance regime. The greatest compatibility between coarse and fine filter approaches based on multilayered forests is in the infrequent, high severity regime and the least is in the frequent, low severity regime. Other forest structural and successional stages are not shown.
Figure 5. Idealized spatial patterns of forest successional stages in the three major disturbance regimes of the NWFP area across time. Times are snapshots separated by at least 100 years. See chapter 3 for more information. Figure inspired by Agee 1998.

**Northern spotted owl**

The spotted owl was listed as threatened under the Endangered Species Act (ESA) in 1990. Despite extensive efforts of federal agencies to protect spotted owls, conserve remaining habitat, and set aside areas as future habitat for spotted owls, populations have continued to decline. When the NWFP was implemented it was predicted that spotted owl populations would continue to decline for as long as 50 years due to lingering impacts of previous habitat loss. Unknown at the time was the effects that
competitive pressure by barred owls would have on spotted owl populations, which have further
compounded the challenges faced by spotted owls and accelerated their rate population decline. Without
the protections afforded by the NWFP and ESA, spotted owl populations would likely have experienced
even steeper declines. Clearly, efforts to recover the spotted owl are facing multiple challenges related to
both habitat management and the barred owl invasion (USFWS 2011).

While old-growth forests and spotted owl habitat are similar in many ways, they are not synonymous
(Davis 2016) and strategies to conserve them may differ (fig. 4). Additionally, the owl does not function
as an umbrella for all or even most other species, a fact that was recognized at the time of the
development of the NWFP and lead to the development of aquatic conservation strategy and additional
species protections in the form of the Survey and Manage Program (Raphael and Marcot 1994, Thomas et
al. 2006, chapter 6). The limitations of the conservation strategy for spotted owls as a way to protect all
other species have been identified by others since then (Molina et al. 2006, Carroll 2010).

Marbled murrelet

The marbled murrelet has habitat needs that are nested to some degree within the range of northern
spotted owl habitats and are compatible with many definitions of old-growth forests (fig. 2). Thus, plans
and strategies that focus on the owl and old growth are likely to benefit the murrelet within its range.
However, it is clear that there are some distinctive habitat differences between marbled murrelets and
owls and requires special conservation considerations (chapter 5). For example, murrelet nesting habitat
occurs in coastal forests that typically had infrequent, high severity fire regimes. In addition, murrelets
preferentially select larger, more contiguous patches of forest throughout their range and tend to avoid
dge habitats where risk of nest depredation is greater (Raphael et al. 2015, chapter 5); therefore, unlike
the spotted owl, proximity of early seral forest is an undesirable habitat state because it can increase
abundance of birds that prey on murrelet nests. Efforts to restore fire resilient open old-growth forests in
the moderately frequent, mixed severity regimes in the range of the murrelet would likely reduce habitat
quality by increasing the exposure of nests to predators.

Aquatic habitat
Aquatic habitat partly overlaps with habitat characteristics of old growth, owls, and murrelets (fig.4). 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, multi-layered conifer canopies can intercept fog and deliver more moisture to streams than shorter dense forests, mitigating some of the effects of climate change (chapter 7). Decommissioning of roads can improve passage for fish and other species and help reconnect streams and floodplains and improve water quality. However, a reduced road network may limit the scope and scale of forest restoration management and recreation. Riparian environments and stream habitats are also dependent on geomorphic and hydrological disturbances that make many riparian areas a mosaic of older conifers, younger conifers, hardwoods, and shrub fields. This mosaic and the dynamic that drives it means that the range of variation of riparian vegetation habitats may include conditions that do not qualify as old growth or meet the habitat needs for the northern spotted owl and marbled murrelets. Fires burning through riparian areas and surrounding uplands may have reduced stream condition quality in the short term, but these events will often improve habitat quality as large dead trees fall into streams and post-fire floods reorganize streams into more complex habitats (chapter 7, DellaSala et al. 2015).

Other late-successional old-growth species

The Survey and Manage Program (chapter 6) identified and listed many fungi, lichens, bryophytes and other species groups that required specific surveying to help insure their conservation under the NWFP. Although the NWFP protects 80% of the remaining old growth forest in the region, this amount of old growth may represent only about 15% of the historical amounts of old growth that occurred in infrequent and moderately frequent fire regimes 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, and evaluating ecological conditions of other species for potential addition to the lists or for adjustments in the types of surveys and the degree of site protection needed for their conservation. Reduction in survey status or removal from the Survey and Manage species lists resulted from efforts locating species during "pre-disturbance surveys" before local harvests and other management activities proceeded. 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 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 near impossible administrative and financial challenge to the land management
agencies (Molina 2006). At present we recognize that alternative strategies to applying a fine-filter
approach to large numbers of species include a mesofilter approach that is based on functional groups and
habitat elements (chapter 6). If levels of intensive timber management from late-successional and old-
growth continues to be low as has been the case in recent years (fig. 6) and all such forests are protected
from timber management the program might not be needed (DellaSala et al. 2015). Most of the logging
that has occurred under the NWFP in older forests appears to have been associated with restoration and
fuel reduction activities in fire-excluded late-successional and old-growth dry forests (See Reserves
section above and below), which begs the question of appropriate conservation priorities in those
regions—species of dense multi-layered forests or species associated with more open fire dependent
forests? It is probable that fire exclusion has altered the habitats of native species in these regimes (Keane
et al. 2002, 2009, Dodson et al. 2008) however, the effects of fire suppression (e.g., forest succession) on
biodiversity have not received much attention in the NWFP area and broader evaluations of other
dimensions of biodiversity (e.g., population genetics, food webs, and ecological functions) have generally
not been made. In the absence of restoration activities, these forests are at higher risk of loss from large
patches of high-severity fire (chapter 3). Another tradeoff of the effects of the Survey and Manage
Program on forest management is the failure of federal agencies to meet the Probable Sale Quantity of
timber identified in the NWFP (see below).
Figure 6. Trends in area of OGSI 80\(^7\) harvested (A) and OGSI 200 (B) harvested by intensity class and percent of harvest of OGSI 80 (C) and OGSI 200 (D) by intensity class on all federal lands between 1994 and 2011: Low = 0-33 percent vegetation cover loss, Mod = 33-66 percent vegetation cover loss, High = > 66 percent vegetation cover loss. Note difference in scale between acres harvested in OGSI and OGSI 200. Based on analysis of annual thematic mapper satellite imagery. Data from Davis et al. 2015.

Forest carnivores, particularly those associated with old forest conditions, were not a primary focus of the original NWFP. Fishers, marten, and lynx were addressed in the Forest Ecosystem Management

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\(^7\) OGSI 80 and OGSI 200 stands for old growth structure index at 80 and 200 years, respectively. OGSI is an index of stand structure based on live and dead tree characteristics. It can be used to map the degree of old growth development across a landscape and is an alternative to classifications that simply define forests old growth or not. See Davis et al. 2015 for more information
Assessment Team report (FEMAT, 1993) to a limited degree with some modest suggestions including

closure to trapping of marten on federal land (until an incidental take of fishers is determined to be
insignificant), evaluation of the effects of poisoning porcupines, 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 (using higher
elevation, alpine and sub-alpine habitats) has increased significantly in the past 22 years. 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 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 1994a: 66). As mentioned above, the congruence of the old-growth forest
ecosystem goals with the other conservation goals varies by location within the NWFP region, and by the
definitions of old growth. In general, this NWFP goal, which is yet to be fully achieved, will still provide
a good foundation for reaching many of the other goals, but is not sufficient alone to meet all goals.
Moreover, meeting this goal has consequences for other components of forest biodiversity not considered
in the original NWFP (chapter 3, Hessburg et al. 2016), especially those dependent on fire of different
frequencies and severities. New understanding of the historical role of moderately frequent mixed
severity fire in many parts of the NWFP region, and of the effects of fire suppression suggest a goal of
conserving biodiversity associated with older forests requires a broad range of old forest reference
conditions including a focus on fire as an ecological process that sustains old forests and other important
successional stages in many parts of the region (see below).

Reserves
The LSRs and riparian reserves were a major and controversial component of the NWFP. Based on the monitoring results, the reserve strategy (i.e. keeping management for timber production out of older forests within LSRs and streamsides across the landscape) can be considered a success from the standpoint of stopping the logging of old growth, and associated habitat for northern spotted owl and marbled murrelets and other late-successional old-growth species (Davis et al. 2015, Davis et al. 2016, Raphael et al. 2015). In addition, although late-successional and old-growth forests have continued to decline somewhat across the NWFP area, the trends are in line with plan expectations (Davis et al. 2015, Davis et al. 2016). Similarly, clearcutting of riparian forests on federal lands has also come to a halt, contributing to watershed health (chapter 7).

The standards and guidelines for the reserves indicated a need for active management to restore ecological diversity to plantations in both wetter and drier forest types. Restoration activity has occurred in plantations in LSRs in wetter forests where novel approaches to thinning have been developed and apparently widely applied (chapter 3). The standards and guides for drier, fire-prone forests (east of the Cascades and in the Oregon and California Klamath provinces) were different (USDA and USDI 1994a). 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. It is not clear how much restoration activity has occurred in older forests in LSR’s or in riparian reserves in fire-prone forests but indications are that between 1993 and 2012 (20 years) less than 2% of older forest (OGSI 80) in the dry provinces had treatments that would reduce canopy cover and surface and ladder fuels that drive fire hazard (Davis et al. 2015). And, apparently, relatively little of the riparian reserves experienced restoration treatments in all fire regimes (chapter 7).

The late successional reserve strategy of the NWFP was neither designed nor implemented in a way that promotes or restores ecological integrity or resilience in fire-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 forest after a history of fire suppression and aggressive harvesting, without regard for their historical topographic positions, environments, or fire ecology context. The standards and guides for silviculture in fire-prone forests (USDA and USDI 1994a) are cautious with regard to restoration, and emphasize stand-level treatments to accelerate development of
late successional (i.e. dense multilayered) forests in younger forests that do not “degenerated suitable owl habitat”. They also suggest that treatment in older forests “may be considered” where they “will clearly result” in reduced risks. The standards and guides also lack a landscape perspective (e.g. Hessburg et al. 2015, 2016) that is now understood to be critical to achieving a mix of ecological goals in fire-prone landscapes, especially in mixed-conifer forests where there has been less experience with restoration (Stine et al. 2014). 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 Forest Service region 6 (Oregon and Washington) than any other region in the country (Miner et al. 2014). Other reasons may include, valuing multi-storied forests, the burden of survey and manage protocols, lack of trust in managers (Olsen et al. 2012), and possibly the perception by some members of the public that mixed-conifer forests do not need restoration (e.g. compared to ponderosa pine forests) or that reserves mean no-touch areas. Nevertheless, a review of the literature conducted for the ten-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 believe 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 enough active management had occurred during the first decade of the Plan, causing concerns about fire, insects, and disease.

If the broader goal is to build resilience to fire and climate change across fire-prone landscapes, the recent science indicates that the current NWFP conservation strategy (e.g. LSRs, matrix, survey and manage species) in fire-prone forests may not be the best approach. Landscape level strategies that restore fire as an ecological process based on topography and other factors, and consider the dynamics of successional stages would be more in line with the latest scientific thinking. Such an approach would also be more in line with the spotted owl Recovery Plan (USFWS 2011 and 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.”

The only explicit proposal that attempts to implement this vision for high-frequency fire forests is the proposed Okanogan-Wenatchee National Forest Restoration Strategy (USDA 2012) that 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. 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. 2011), and in the eastern Cascades of Oregon Spies et al. (in press) where scenarios of management for fire-resilient forests continued to provide habitat for spotted owls. Dynamic landscape approaches 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-cockated woodpecker). The habitats of these species are threatened by fire suppression rather than being promoted by it in the case of the owl. A dynamic landscape approach might still fit the broader definition of a “reserve” (e.g. exclusion of industrial level logging) but the current LSR-Matrix approach for high frequency fire regimes does not appear useful for high-frequency fire regimes in this context (management for resilience to fire and climate) and redesign could be considered. However, the science and experience with proposed changes to the NWFP conservation strategy in mixed-severity fire regimes 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 to conservation and restoration in moderate frequency, mixed severity fire regimes as well. Disturbance-based management can benefit aquatic habitats (Reeves et al. 1995) in these fire regimes. 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 regimes 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 a surrogate for partial stand replacement fire. However, the effort
was abandoned because of stakeholder concerns about cutting older trees in the matrix lands and stakeholder knowledge of these approaches and trust of the agency to implement them was lacking (Olsen et al. 2012).

Thomas et al. (2006) suggested changing the NWFP allocations to protect all remaining older forest whether or not in occurs in reserves or matrix. The U.S. Fish and Wildlife Service critical habitat designation recommend conserving spotted owl sites (recovery action 10) and protecting high quality habitat (recovery action 32) whether it occurs in LSRs or matrix lands (USFWS 2011, 2012). The science suggests that these actions will have ecological and social benefits but there will be tradeoffs associated with timber production.

The NWFP was intended to adapt to changes in knowledge and changes in the environment (USDA and USDI, 1994), which is consistent with the idea that conservation should be adaptive and an iterative process (Walters 1986, Carroll et. al. 2010), but has not done so for various reasons (see below). Hence although lines are drawn on maps and standards and guides are developed for reserves and other land allocations, conservation and ecosystem sciences suggests 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 and to addressing other interests across the wide range of forest environments and disturbance regimes that fall within the range of the northern spotted owl.

Socio-economic goals

The NWFP had four main socioeconomic goals (Charnley 2006): (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. The plan had limited success in achieving these goals. 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 timber sales have not been predictable or at the level envisioned. The probable sale quantity established by the plan was based on a number of assumptions: (1) older forests would contribute roughly 90 percent of the harvest 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, which often occurs by clearcutting (Charnley 2006). The area of regeneration harvest in OGSI 80 and OGSI 200 was 1,000 to 2,000 acres annually in the first 5 years of the plan but it declined to near zero by 2000 and has stayed very low since then (fig. 6). Most of the harvest since 2000 has been in the form of thinning and partial canopy removal, probably in drier, fire-prone forests (fig.6c and 6d), which would have generated less volume than intensive 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 probably sale quantity (Charnley 2006, Thomas et al. 2006). Another factor in the lack of cutting in mature and old growth forests was 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 (chapter 6).

Thus, the main source of the timber supply has shifted from 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. Timber as a by-product 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 cannot be sustained, because in 10 to 20 years most of the plantations will have been thinned once and most of them in the wetter provinces will become too old (80 years) to be treated again according to the record of decision (USDA and USDI 1994a) (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 to maintain resilience (Spies et al. in press). The sale of wood products
generated may not offset the costs of treatments. Thus, the longer-term outlook for timber production on federal lands in the NWFP area under current approaches is for a decline to very low levels of volume.

We now have new understandings of the relations between federal forest management and community socioeconomic well-being (chapter 8). For example, private forests currently contribute the vast majority of logs processed by mills in the NWFP area. Greater timber harvest on federal forests would increase the amount of logs available to mills and likely create additional work opportunities for loggers. Generally, increased federal harvest would reduce the prices paid for logs by mills, which in turn would make wood products producers and loggers better off, while making private landowners worse off because their logs will be worth less. However, there are exceptions where mills maintain capacity for processing resources in limited supply, including in dry forest regions with few mills.

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 can federal forest management 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 system.

Regarding long-term economic development and diversification, the Northwest Economic Adjustment Initiative and Jobs in the Woods programs had mixed results. However, alternate formulas for payments to counties, now embedded in the Secure Rural Schools Act, have made important economic contributions to NWFP-area communities, although the future of these payments remains uncertain. 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 decision-making from the local to the regional level (Charnley 2006). Since that time however, the number of forest collaborative groups has grown in the plan area and the agencies have emphasized the importance of collaboration as a way of doing business (chapter 9).
One way of minimizing tradeoffs between the social and biodiversity goals of the NWFP would be to do a better job of linking those goals through conservation strategies 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, and other activities that contribute to forest stewardship (Charnley 2006).

Adaptive management and monitoring

The NWFP was founded on the concept of adaptive management and learning, based on monitoring, adaptive management areas, and other forms of reactive, active and passive adaptive management. Bormann et al. (2006) provide an in-depth 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 adaptive management areas was generally not successful, as funding for the adaptive management areas 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 Adaptive Management Area 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). Four obstacles to adaptive management in the NWFP area were identified: 1) perceived or real latitude to try different approaches on adaptive management areas was limited; 2) some people saw adaptive management as only a public participation process and consensus on implementing ideas on the ground was not reached; 3) the precautionary principle (no action) trumped efforts to learn by doing and avoiding risk limited ability to increase understanding of systems; and 4) sufficient resources for management activities and the attending follow-up monitoring/research were not provided.

It is also important to note that the plan was not implemented as written, reflecting more of a reactive or passive adaptive management approach, resource limitations, and different interpretations at the ground level. The changes made in implementation of the NWFP include lack of timber production from older forests in the matrix, surveying for rare species, 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 difficult to discuss the “Plan” without qualifying which version of the NWFP is being discussed.

While 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, spotted owls, marbled murrelets, aquatic systems, socio-economic and tribal relations. Monitoring moved the implementation of the plan from opinion to evidence-based decision making, 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.

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 multiagency regional executives in guiding learning; 2) involving regulatory agencies; 3) accommodating reasonable disagreement among stakeholders; 4) committing to quality record keeping by managers; 5) developing long-term funding strategies and maintaining a critical mass of agency expertise; and 6) reshaping the burden of proof and the precautionary principle, and 7) allowing for management experiments to take place even if they don’t have total social license.

Plan goals and strategies in relation to new concerns

Since the development of the NWFP in the early 1990s new conservation concerns and issues have emerged that are directly related to meeting its original goals. We highlight two of them here: 1) the exclusion of wildfire as a keystone ecological process in many NWFP-area forest ecosystems, and 2) the role of climate change in affecting species, wildfire size and severity, and reducing the resilience of dense forests that have accumulated in the absence of fire.

While not part of the original focus of conservation in the NWFP area fire dependent vegetation states are now recognized as ecologically interdependent with dense old growth in the sense that policies that
promote dense old growth (e.g., fire suppression) will reduce these other habitats and that in many cases old growth is connected to these other habitats through succession and disturbance. Chapter 3 highlights the ecological significance of open old growth forests, including as habitat for species such as the white-headed woodpecker (*Picoides albolarvatus*), a species that is on BLM and USFS sensitive species lists for Oregon and Washington as a result of loss of open ponderosa pine forests to logging, stand replacement fire and fire exclusion (Buchanan et al. 2003, Mellen-McLean et al. 2013). The design and implementation of the NWFP reserve-matrix strategy in fire frequent regimes will not likely lead to increasing resilience of forests to fire and climate change and increases in habitat to support of open old-growth forest species as mentioned above.

The lack of diverse early successional habitat has also become a major conservation concern (Swanson et al. 2011, Franklin and Johnson 2012, DellaSala et al. 2014, Hessburg et al. 2016). Many plant and animal species, including state-listed species, specialize in these early successional habitats (Swanson et al. 2011, 2014). Their life history traits would make them adapted to these environments and used to finding these relatively ephemeral and episodically occurring habitats in landscapes typically dominated by conifer forests. Whereas older forests can take centuries to develop, early seral forests 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 availability of these episodic and ephemeral habitats depends upon relatively frequent disturbance somewhere within large landscapes (Reilly and Spies 2015).

Despite increasing wildfire over the last 25 years the amount and frequency of high-severity across all NWFP fire regimes has been low relative to the historical regimes, the equivalent of a rotation of 550 to more than 1600 years across the three NWFP fire regimes (chapter 3). Large areas of early successional habitats would not have been common under historical regimes in which fires burned frequently (e.g., less than 20 years), because most fires in these regimes were low severity and maintained open old forest characteristics. Although fire area has increased with drought in the last 25 years, the amount of high-severity fire in moderately frequent and infrequent regimes may still be within the historical range given the large amount of climate and fire variability in the region (chapter 3, Reilly et al. in review Walsh et al. 2015, Hessburg et al. 2007). However, when climate is taken into account, the amount of early seral forest during warm periods of the past, such as we are experiencing currently, probably was at the higher end of...
its historical range. Thus, we hypothesize that given the current warm climate, early seral-post wildfire
habitats within regions of moderately frequent and infrequent fire regimes are deficient relative to the
historical range of variation.

Although early seral post-wildfire vegetation appeared to be historically uncommon in most areas of high
frequency, low-severity fire (chapter 3), large patches of nonforest habitats, such as savannas, grasslands,
shrublands, and even some wetlands would have been relatively common and maintained by fire (chapter
3). These nonforest habitats, are known to support unique biodiversity based on global-scale studies
(Veldman et al. 2015) and may be more limited 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.

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 intensity of climate change are still uncertain and
will likely vary among species, ecosystem processes and geography. In general, climate change adaptation
goals can be congruent or compatible with many of the original goals of the NWFP including flexible
boundaries for the LSRs. However, the degree of congruence varies with spatial and temporal scale (Spies
et al. 2010). For example, efforts to reduce tree density within forest stands and to increase resilience to
drought might conflict with development of dense multilayer forest habitat at stand or patch scales (e.g.,
less than 100 acres). Early seral habitats created by wildfire or through restoration management could
provide opportunity to plant or naturally establish more drought-resistant genotypes of key tree species.
Addressing fish responses to climate change will be especially challenging because of the prominent role
of ocean conditions and the importance of non-federal 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, but we
lack scientific assessments of how many species may respond to climate change and how management
strategies, including protection of climate refugia, silviculture to promote forest resilience, and possibly
even assisted migration might benefit at-risk species.
Mitigation efforts to limit releases of greenhouse gases and increase carbon storage can be compatible with many NWFP and other 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 it may or may not be consistent with reducing stand density in interior 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 and occurrence of fire (Ryan et al. 2010, McKinley et al. 2011, 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 and non-timber resources, including recreation opportunities, may shift under climate change as species abundance and distributions change (e.g., mushrooms important for commercial harvesting, fish and game species). Winter recreation associated with snow is already being affected by warmer winters. And, high-severity fire affects timber stocks and availability of non-timber forest products. 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).

Tradeoffs associated with restoration actions

Because the ecological goals of the NWFP are not necessarily consistent with addressing emerging conservation issues (e.g., the tension between managing for dense old forest species versus open old forest 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 socio-economic 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 1). Most of these effects are discussed in greater detail in other chapters of this report.

**Variable density thinning in plantations in all disturbance regimes**

Variable density thinning in plantations in uplands and riparian areas to increase habitat diversity now and accelerate 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 accelerate growth of larger trees, but it reduces dead wood amounts compared to the unthinned state unless at least some thinned trees are left on the site. Increasing spatial heterogeneity of the tree layer in plantations creates discontinuous fuel beds, increases habitat diversity, and restores some of the heterogeneity that would have occurred young post-wildfire stands. Similarly, thinning in riparian plantations can accelerate growth of large trees which 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). Thinning in plantations in riparian areas can also increase habitat diversity and shrub layers but reduce shading which can increase stream temperatures.

**Restoration of fire-excluded forests**

Thinning and prescribed fire to restore structure, composition and resilience to older forests in historically fire frequent regimes can have numerous site and landscape level benefits (chapter 3, Hessburg et al. 2016) (Table 1) 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 increase the heterogeneity of amounts and types of fuel can also reduce potential extent of large patches of high-severity fire that result in losses of denser forest habitat. But, this practice can have adverse effects on spotted owls and some species such as fisher and marten that use dead wood and hiding and den sites. The science of blending the goals of conservation of owl habitat and restoration
of fire dependent forest ecosystems at landscape scales is still in development and in need of more research and evaluation through adaptive management and collaborative landscape efforts.

Restoration of fire-excluded forests also has important 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.

**Early seral habitat in moderately frequent and infrequent fire regimes**

Given fire suppression, innovative silviculture (such as ecological forestry, Franklin et al. 2007), could be used to create openings in closed forests that provide enough light for early successional species and retain live and dead trees, and shrubs that typically would be found in higher-severity post-wildfire environments (Franklin and Johnson 2012, Franklin et al. 2007). The amount of retention of live trees would be variable to match variation in fire effects at patch and landscape scales. Prescribed fire would ideally 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 is probably most needed to meet diverse ecological and socio-economic goals in the moderately frequent, mixed severity regime, and it could target stands of any age because wildfire would occur across the full range of successional stages. The tradeoffs are both ecological and social (table 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. Consequently, some (Franklin and Johnson 2012) have proposed that this type of habitat creation focus on stands less than 80 years old, which may be more socially acceptable. It is important to note, however, that 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.

**Post-wildfire management**

Post-wildfire management typically includes both salvage logging and planting of trees, which may or may not be linked in management. The ecological effects of postfire salvage logging can vary 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). However, there may be some exceptions to this rule. Peterson et al. (2015) and Hessburg et al. (2016) identify situations—concerns about lack of seed sources or reburns that maintain undesirable shrub fields,—where postfire management might be used to meet ecological goals. These include: 1) fuel reduction treatments that reduces 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 and/or planting trees to reduce potential for high severity reburns and speed rate of forest succession where potential for large semi-stable 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 remove 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 likelihood of large patches of high-severity fire.

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 important for sustaining populations of early-successional species such as black-backed woodpecker (*Picoides arcticus*) (White et al. 2016). 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 habitat, 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

Roads have both beneficial and detrimental effects (chapter 7) relative to NWFP goals. They are needed for forest restoration management, recreation, access to tribal resources and non-timber forest products, timber harvesting, and fire suppression; yet, they have undesirable effects including acceleration of erosion, acting as barriers to migration of aquatic and terrestrial organisms (chapter 6), habitat fragmentation, and facilitating spread of exotic species. Decommissioning roads can help both reduce ecological impacts and reduce maintenance costs which can be significant, but some road system is 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. The costs associated with road decommissioning, which involves re-grading, removing culverts, and revegetation, often make this option impractical. Roads and road decommissioning are a prime example of tradeoffs associated with meeting competing goals for federal forests, including ecological restoration.

Regional scale issues and challenges associated with the goals of the NWFP?

The regional scale concerns related to the NWFP goals include: 1) the limits 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, and 3) the connectivity and distribution of federal lands as they related to capacity of organisms to respond to changing climate and vegetation dynamics.

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 aquatic conservation strategy. The marbled murrelet and northern spotted owl occur in coastal forests in southwestern Washington, Oregon and northern California where the proportion of non-federal forest land is relatively high (chapter 5). In these areas, continuing loss of murrelet nesting habitat may eventually
lead to a large gap in distribution of nesting habitat and thus a potential gap in the murrelet distribution, leading to genetic isolation of northern and southern murrelet populations (Raphael et al. 2016). Habitat for several species of fish is not well provided for solely on federal lands since these species find important habitat at lower elevations where most habitat is on private lands (chapter 7). With divergence of forest management intensity on 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 mean that no landowners will be providing for important habitats (e.g. hardwoods) that support 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 1994a). The need for a regional-scale strategy still exists for the listed species (chapters 5, 4, 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 guides for management under the NWFP (USDA and USDI 1994a) was too simplistic lumping fire-dependent ecosystems in parts of western Oregon and Washington into wet types where fire was considered uncommon and not a strong influence on successional dynamics between infrequent fires.

Another limitation of the regional perspective that underlies the strategy and implementation of the NWFP is the lack of characterization of regional variability in socio-economic conditions and the glossing over of local-level variability at the 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 their dependence on ecosystem services from federal lands. That information could be used to set priorities for meeting socio-economic objectives and finding areas where restoration needs and socio-economic 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, Spies et al. 2010, Carroll et al.
The distribution of federal lands and reserves appears generally favorable for species that needed to move upslope and northward (DellaSala et al. 2016, Spies et al. 2010). However, quantitative analysis of the effectiveness of the NWFP reserves and federal lands 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 suggest 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 climate models, vegetation dynamics models and models of species habitats, population dynamics, and landscape genetics.

Research Needs, Uncertainties, Information Gaps, and Limitations

Following its implementation, in 1994, the NWFP was supported by long-term effectiveness monitoring and ecological and social research, although little to no effectiveness monitoring has been conducted on biodiversity elements and Survey and Manage species. Still, we have learned a great deal about owl and murrelet ecology, fire and forest ecology, restoration management, aquatic systems, habitat needs of many rare species, and the socio-economic dynamics of the Plan area and impacts of federal forest management. Much of what we knew 22 years ago is still valid but we have also learned that the social-ecological system is more diverse and complex than was initially considered and we are now more cognizant of how much the social and economic component shapes management goals and influences our ability to implement management actions. As our awareness of social-ecological systems complexity increased and the boundary of our knowledge has expanded, so too has the frontier of our ignorance. Furthermore, we now have a better appreciation for how imperfect our understanding was in 1994 and how much our assumptions and knowledge today may be proven incorrect in the future.

We identify some of the key uncertainties and research needs below:

Monitoring

We lack sufficient 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 how restoration actions might be altering the dynamics of terrestrial and aquatic ecosystems over space and time. Effectiveness monitoring, has provided useful information but disinvestment in some aspects of NWFP monitoring over time (e.g., socioeconomic, implantation, Survey and Manage species species) has limited the amount and usefulness of the monitoring information produced. Research is need to determine how well the current set of monitoring metrics address important 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.

**Climate change**

Uncertainties about the effects of climate change on ecosystems including fire behavior are large and vary across the region. Silviculture, including tree planting, may help improve resilience of forests to climate change impacts we lack empirical information to fully understand the interactions and tradeoffs and to estimate how they might play out across time and landscapes under different climate scenarios. This lack of empirical information also limits our ability to implement climate change adaptation strategies in 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 tools are needed to identify stress and mortality in forests at landscape scales and to test hypotheses from simulation models.

**Ecosystems and species**

We lack information about how northern spotted owls respond to wildfires. We also need to improve our understanding about spotted owls and barred owls interactions and look for habitat niche separations to help determine areas for spotted owl conservation.

Effects of fire suppression (e.g., increased forest density and increased proportion of shade-tolerant trees) on ecosystem processes habitat for, and population response of, plants and animals are not well understood in the area of the NWFP. Relatively more research has been conducted on how changes in
stand structure and composition affect fire behavior than on how those novel forest conditions affect 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 managed wildfire) across diverse landscapes are not well understood. For example, it is unclear if we have passed tipping points (e.g., crossed ecological and socioecological thresholds that make it impossible to restore desired levels of resilience) in some landscapes that have been transformed by the cumulative effects of altered disturbance regimes. In addition the ecological and social impacts of using surrogates (e.g., mechanical fuels treatments) for fire are also not well understood, especially for biodiversity. 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.

Relatively little published research has focused on the capacity for the regional NWFP strategy of reserves and their associated management guidelines to meet biodiversity goals under changing climate and fire regimes. Research is needed to explore how alternative reserves designs, including the spatial pattern of alternative reserve objectives (e.g., single species versus multiple species and processes), management guidelines for reserves, dynamic reserves, or disturbance-based landscape meet multiple ecological objectives over time.

**Tradeoffs associated with management**

While we have some knowledge of the tradeoffs associated with restoration and conservation strategies to meet ecological and socio-economic goals, we lack knowledge of how those tradeoffs and interactions vary across the region, with scale and over time. Employing the precautionary principle may produce unintended outcomes because no action (e.g., not thinning a plantation or not using fire) may have undesirable effects (e.g., could result in less biotic community diversity compared to thinning). 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 ecosystem and how these actions interact with the social systems.

The current scientific literature is fairly clear on the benefits of salvage logging after wildfire: there are very few ecological benefits and most of the benefits are economic or pertain to reducing subsequent fire effects. However, we lack information on the long-term effects of salvage logging in burned forests whose density and composition were heavily altered by fire exclusion before the fire. In addition, we lack information on when and where planting might be needed and what kind of salvage might be needed if at all to insure recovery of desired forest composition following large high severity wildfire events. Finally, where salvage logging is conducted for economic objectives, we lack studies that quantify the level of ecological effects of salvage logging where managers seek meet both ecological and economic goals through carefully-planned landscape-scale approaches to post-wildfire management.

Social-ecological interactions and collaboration

Although ecosystem services have become widely recognized as a framework for characterizing the range of values on the federal forests relatively little quantification has occurred on federal lands. 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 best methods for quantifying ecosystem services, understanding tradeoffs, and using qualitative approaches in planning and management where quantification of ecosystem services does not exist.

We lack understanding of how increased socio-economic capacity within forest communities and within the agency could affect meeting ambitious goals for landscape restoration or management to increase resilience of forests to climate change, fire and invasive species. Few studies of the relationships between socio-economic capacity and restoration/resilience management have been conducted.
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 calls 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 around work (e.g., forestry services work, commercial NTFP harvesting). However, apart from recreation, little information is available about noneconomic relations between low income and minority populations and federal forests. 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 important to these populations.

The ability to undertake active management to achieve diverse ecological and socio-economic goals is constrained by many factors, but lack of trust in federal managers is among the most important, 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 mutual interactions among stakeholders and federal managers affects the ability accomplish management objectives for restoration and resilience. However, these collaboratives are relatively new and have not received much study. More information is needed about public responses to restoration management efforts as well as management for timber production using non-industrial, ecological forestry methods. We lack understanding of how trust at different organizational scales (individual, district, forest, national) affects social license of agencies for active management. Finally, we lack information about benefits of supporting community and agency capacity 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 important ways since the plan was implemented in 1994. For example, the capacity of the agency and forest industry to conduct restoration efforts across landscapes has declined,
the contributions of federal forests to ecosystem services (e.g., carbon sequestration and water supply) are now more widely recognized, but remain largely unquantified, and collaborative approaches to management are a high priority. Monitoring indicates that progress is being made toward meeting several of the long-term goals (e.g., 100 year time frame), namely maintenance of habitat for 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). However, other goals, such as a providing for a sustainable level of wood harvest to support rural communities, road decommissioning, and adaptation and learning through adaptive management (Borman 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 substantially realized. Finally, some Plan goals – such as providing alternative formulas for payments to counties most affected by the Plan to mitigate its impacts – have been realized in the short to mid-term, but their long-term viability remains uncertain. In addition, new concerns have emerged that were not part of the original plan including threats to populations of the northern spotted owl from the native invasive barred owl, the effect of fire suppression on fire dependent ecosystems (e.g., open old growth, early succession forests, nonforest communities), increased influence of exotic invasive species, and climate change.

Changes to forests, watersheds and species occurring on federal lands over the past 120 years have been significant, and many are both unprecedented and likely to persist. But, actions can be taken to move these ecosystems, forests, landscapes and species toward more desirable conditions that are better aligned 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 and to acknowledge that land managers can’t really restore these ecosystems to a particular historical period or all objectives on all lands, but we 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 the resulting forest conditions are altered relative to the pre EuroAmerican 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.

**Ecosystems and Species**
It is not clear if the NWFP alone will assure long-term persistence of the northern spotted owl. However, without the implementation of the NWFP, spotted owl populations would likely become moribund. Even in the face of losses due to wildfire and timber harvest, forests capable of supporting interconnected populations of spotted owls have increased or stayed relatively stable, which suggests the NWFP is on a trajectory for success for this component. The continued success of the NWFP for conservation of spotted owls rests on understanding how to minimize the impacts of barred owls and fine-tuning our ability to retain needed forest structure while also increasing resiliency of forests through strategic management focused on creating conditions compatible with historical disturbance regimes.

An emphasis on multi-layered old-growth conservation is still critical given their relationship to biodiversity, their reduced abundance, and the original NWFP goals, but it is also important to recognize that other vegetation conditions are valuable for maintaining overall regional biodiversity and human communities, including tribes with protected treaty rights. These habitats include open old growth, diverse early successional post-wildfire habitats, wetlands, oak-dominated forest patches and woodlands, shrublands and grasslands, and forest gaps.

**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 important, but it is likely not sufficient to reach the comprehensive goals of the NWFP. Contributions from streams and forests on non-federal lands are important to achieving NWFP conservation goals. Collaborative programs, financial assistance, more enabling policies or other and incentives might help to increase conservation on non-federal lands.

A restoration strategy will need to combine efforts to ameliorate anthropogenic impacts, such as culverts that are likely to fail in priority watershed areas, while also directing active management interventions, such as intensive thinning and use of fire, to restore departed systems or at least increase their resilience to climate change and fire. Such active management may be particularly important 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 LSRs occupying almost 70% of the USFS and BLM land base in the NWFP area, and protecting most of the remaining late-successional and old-growth forest and riparian reserves, rates of additional fragmentation of older forests from management activities on federal lands will be very low. Landscape level change will be dominated by succession in younger forests, with occasional losses of forest cover to wildfire. Concerns over connectivity among old-growth forests and LSRs will increasingly relate to climate-change effects and access to climate refugia. The effects of roads on species and ecosystem process remains a conservation concern.

The small amount of logging in most non-reserved spotted owl habitat and in mature and old growth forests over the last 15 years of NWFP implementation does not reflect 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 largely a result of the Survey and Manage Program. An implication of this change may be that some Plan components, such as fine filter conservation of survey and manage species, that were intended to mitigate logging non-reserved late successional and old growth forests, may now be less important.

Moderately frequent, mixed severity regimes, which were not recognized in the development of the NWFP, have also been affected by fire suppression which has reduced the amount of all severities of wildfire and the reduced the diversity of and resilience old growth forest types that were produced by and maintained by partial stand-replacement fire. Managers may want to consider trying ways to restore fire effects back into these systems through thinning, prescribed fire and managed wildfire. In theory such restoration actions could occur in forests with old trees (e.g., greater than 80 years old), but the ecological and social acceptability of this activity are uncertain and the issue is well suited for adaptive management studies.

A major challenge to management for historical range of variability or resilience to fire and climate change exists in historically frequent fire regimes of northern California, southern Oregon and parts of the
eastern Cascades of Oregon and Washington. Fires in these areas are have been much less frequent in recent decades but some recent fires have created larger patches of high severity fire compared to the historical regime. The denser forests and more shade tolerant species have increased the area of northern spotted owl habitat despite losses to fire in recent years (chapter 3). Landscapes including 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.

Scientists are beginning to consider that fixed reserves to conserve biodiversity may not be fully effective for maintaining dynamic biotic communities, ecosystems and landscapes under climate change. Many studies suggest that conservation strategies (and reserve design) should periodically be re-evaluated to determine how well they are meeting their original goals and to make possible changes to standards and guides and reserve or habitat conservation boundaries. This may include expanding reserves, shifting locations of reserves, or using landscape scale disturbance based management approaches. Using disturbance based management approaches to conservation is likely to require a robust social component to increase transparency, public understanding, and trust in mangers.

Social-ecological interactions

Historically, timber production was the central way in which federal forests in the NWFP area contributed to community socioeconomic well-being. Although it 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 may 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 and distinctive of these services. Efforts to quantify and communicate ecosystem services and characterize the associated tradeoffs are needed.

Efforts to sustain ecosystem services, conserve species, and promote ecosystem resilience to climate change and fire are 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 will be needed. Partnerships with NGOs and other agencies may help managers to meet their social and ecological goals. As outlined in chapter 11, emphasis on promoting tribal ecocultural resources, particularly as a means of upholding the federal trust responsibility, would likely also align with other objectives for ecological restoration, while enhanced engagement with tribes can provide additional mechanisms for accomplishing those objectives.

Collaborative groups may be part of the solution to increasing trust and social license for forest management. However, collaboration is relatively new and learning and adaptive management will be needed to determine the best way forward into an uncertain future. Also important will be efforts to collaborate with neighboring landowners in planning and implementing management activities for landscape-level treatments needed to increase forest resilience to climate change 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 system dynamics and tensions among competing goals by adopting a long-term and landscape scale perspectives.

Major disturbances such as large wildfires can open windows of opportunity to promote desired conditions and reestablish key 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 post-fire 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 likely to be limited by the
decline in overall staffing levels, limited infrastructure for processing wood products such as lumber and
biomass in many areas, and resource shifts toward fighting wildfires rather than restoring forests.
Managing natural ignitions for resource benefit appear to be a particularly cost-effective means of treating
landscapes.

Tradeoffs associated with management

All management actions 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 benefits the spotted owl and other species but may have a short-term negative impact on
habitat quality for other late successional species such as the marbled murrelet and can reduce amounts of
dead wood used as habitat elements by other species; 2) thinning and restoring fire to fire-dependent
forests can increase habitat for species that use more open older forests and increase resilience to fire and
drought but eliminate habitat for species that use dense older forests; 3) maintaining road systems to
conduct landscape scale restoration and support recreation can negatively affect native species and
ecosystem processes. Many of these tradeoffs can be ameliorated through landscape-scale planning and
using best practices for decision making.

In the long run, thinning in plantations less than 80 years old will not sustain wood production for local
communities (chapter 8). If the future involves further decline in provisioning services and economic
return based on commodities, it will be even more important to demonstrate how other ecosystems
services contribute to the values of the forests and how effectively active management meets habitat and
other ecosystem service goals.

Monitoring and adaptive management

The long term monitoring program and complementary research efforts of countless agency, university,
tribal, and nongovernmental organization scientists have provided managers, researchers, and
stakeholders with an enormous amount of information on how these species, ecosystems and social
systems interact and have changed in 22 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, but agency
capacity is flat or declining. 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 challenge assumptions but improves the ability to set and
meet attainable goals for our forests and other ecosystems. These forest and social systems will
undoubtedly change in the next 22 years and 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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Table 1. Summary of possible (known and hypothesized) major tradeoffs (effects) associated with current management activities and original ecological and socio-economic goals. Effects in black are generally consistent with a goal; effects in red are generally not consistent with goal or have negative effects on other goals not emphasized in the NWFP. Effects may vary 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 effects of extreme fires. For detailed discussions of these see individual chapters.

<table>
<thead>
<tr>
<th>Management Activity</th>
<th>Closed canopy Old growth Structure and function</th>
<th>NSO</th>
<th>MAMU</th>
<th>Other late-successional old-growth species</th>
<th>Aquatic habitats</th>
<th>Timber and non-timber supply</th>
<th>Local economies</th>
<th>Tribal eco-cultural resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suppression of wildfire</td>
<td>Increases shade tolerant tree species and canopy cover</td>
<td>Protects existing old growth trees from loss</td>
<td>Reduces open old growth types and landscape diversity</td>
<td>Reduces area of diverse early successional forest</td>
<td>Reduces resiliency in some fire regimes</td>
<td>Reduces</td>
<td>Protects habitat in northern part of range</td>
<td>Protects habitat for species that prefer dense multi-layered canopies, variable and poorly understood effects</td>
</tr>
<tr>
<td>Variable Thinning plantations in uplands and riparian areas</td>
<td>Accelerate large trees, Increases vegetation heterogeneity, diversity and understory layers</td>
<td>Accelerate development of large nest trees and multiple canopy layers</td>
<td>Accelerate development of crowns with thick limbs</td>
<td>Variable effects some positive and negative short term and longer term effects</td>
<td>Accelerate large trees, Increases vegetation heterogeneity, diversity and help support local</td>
<td>Can provide wood products and bioenergy and help support local</td>
<td>Can provide short term economic benefit to communities near wildfire</td>
<td>May promote recreation in unburned forests</td>
</tr>
</tbody>
</table>

(Note- this table will be reformatted to be more readable)
<table>
<thead>
<tr>
<th>Action</th>
<th>Effect</th>
<th>Effect</th>
<th>Effect</th>
<th>Effect</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can reduce dead wood if trees removed</td>
<td>May reduce populations of red tree voles, a prey species, in the short term</td>
<td>May create habitat for predator species</td>
<td>Effects likely variable with location in stream network</td>
<td>Can reduce dead wood inputs to streams if trees removed</td>
<td>Can reduce shading and increase stream temperatures</td>
</tr>
<tr>
<td>Thinning to restore resilience to fire suppressed forests</td>
<td>Can help to maintain large old fire resistant trees,</td>
<td>Can protect patches of nesting and roosting habitat from large fires</td>
<td>May reduce loss of large nest trees to wildfire</td>
<td>May create habitat for predator spp.</td>
<td>Same as above</td>
</tr>
<tr>
<td></td>
<td>Can increase old-forest diversity in fire dependent disturbance regimes</td>
<td>Reduces habitat quality at site level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can reduce fire spread rates and reduce sizes of high severity fire patches</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Prescribed fire</td>
<td>Same as above</td>
<td>Same as above</td>
<td>Same as above</td>
<td>Can provide wood for local communities</td>
<td>Jobs for local communities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>May not sustainable in long run because restoration may shift toward prescribed fire as stands are repeatedly treated</td>
<td></td>
</tr>
<tr>
<td>Early seral creation in closed forests to mimic wildfire effects</td>
<td>Can increase habitat diversity and provide habitat for species dependent on open, habitats and dead trees.</td>
<td>Not compatible with habitat in part of the range, maybe compatible at landscape scales in southern parts of range</td>
<td>Likely reduces habitat but some species may benefit from juxtaposition of old and young habitats</td>
<td>Can increase light to streams and stream productivity</td>
<td>Can provide wood products and help support local mill infrastructure</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Can increase habitat diversity and promote longer-term integrity of stream ecosystems</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Can decrease shade and increase stream</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Can provide ecocultural resources associated with less dense forests, including large nut-bearing trees</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Can enhance ecocultural resources associated with less dense forests, including various understory plants and game animals</td>
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</tbody>
</table>

**Notes:**
- NTFPs: Non-timber forest products.
- WUI: Wildland-urban interface.
- Early seral: Early successional.
- Compatible: Forest types that can coexist.
- Incompatible: Forest types that cannot coexist.
- Variable: Effects may vary depending on site conditions.
- Jobs: Employment opportunities for local communities.
- Recreationists: People who enjoy outdoor activities in the forest.
- Smoke: Effects on health and safety related to smoke production.
- Habitat: The environment in which an organism lives.
- Connectivity: The ability of habitats to support wildlife movement.
- Stream: A natural or artificial body of water.
<table>
<thead>
<tr>
<th>fire or occur in older stands</th>
<th>temperatures in some contexts</th>
<th>May benefit long-term recovery of habitat</th>
<th>Can benefit long term recovery of forest resources</th>
<th>Some work for local communities</th>
<th>Recovery of conifer forest may benefit some resources,</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting after wildfire</td>
<td>Planted of key tree species may benefit forest recovery</td>
<td>May benefit long-term recovery of habitat</td>
<td>Planted of key tree species may benefit longer term recovery of habitat</td>
<td>Can benefit long term recovery of forest resources</td>
<td>Some work for local communities</td>
</tr>
<tr>
<td>Salvage after wildfire</td>
<td>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</td>
<td>NA</td>
<td>Removal of dead wood likely not compatible with habitat for some of these species</td>
<td>Can provide timber timber and support local mills</td>
<td>Can provide jobs for local communities, 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</td>
</tr>
<tr>
<td>Road removal</td>
<td>Can reduce spread of invasives to older forest blocks, Can reduce edge effects, Can reduce access for restoration management</td>
<td>Unknown</td>
<td>May reduce corvid populations that prey on nests</td>
<td>Reduces erosion potential, Reduces risk of landslides and debris flows, Increase fish passages through stream networks</td>
<td>Can reduce access for timber management and NTFP gathering, Can reduce access for recreation and other forest uses, May improve water quality</td>
</tr>
<tr>
<td>Managed Wildfire</td>
<td>Can increase diversity of old forest types, Can increase landscape resilience to future fire, Can destroy old growth forests and large old trees</td>
<td>Not well known, but likely similar to spotted owl response</td>
<td>Can increase habitat diversity and promote longer-term integrity of stream ecosystems, Can decrease shade in increase stream temperatures</td>
<td>May damage and reduce value of trees that were scheduled for wood production, Can reduce fuels and lower risk of loss of unburned forests</td>
<td>Can increase area of habitat for game species and increase hunting use, 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)</td>
</tr>
</tbody>
</table>
Table 2: Summary of Socioecological Impacts of Post-Fire Management (salvage and/or planting)

<table>
<thead>
<tr>
<th>Issue</th>
<th>Cons</th>
<th>Pros</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>Carbon in dead trees may be slowly released as wood decays, and some may enter long-term pools in soils or in streams</td>
<td>Burned trees can be used as harvested wood products or offset energy from more carbon-intensive energy when burned in biomass facilities; replanting of trees has potential to accelerate long-term carbon storage in areas where natural regeneration is poor</td>
</tr>
<tr>
<td>Wildlife habitat</td>
<td>Negative impacts of removing biological “legacies” such as standing and down wood on wildlife communities, particularly “early-successional” species that depend on standing snags</td>
<td>Planting of trees can accelerate forest development and reestablishment of late-successional habitat.</td>
</tr>
<tr>
<td>Erosion</td>
<td>Mechanical activity poses risks of increased erosion and runoff</td>
<td>Residual materials can be used as source of ground cover</td>
</tr>
<tr>
<td>Wood loading to</td>
<td>Removal can interrupt important process for storing sediments and</td>
<td>Reducing excessive wood loading could less risk of debris jams and downstream culvert/bridge failures</td>
</tr>
<tr>
<td>streams</td>
<td>reforming aquatic habitats</td>
<td></td>
</tr>
<tr>
<td>Fuel loading/fire</td>
<td>Salvage can increase loading of fine fuels, leading to increased severity upon reburn; planted stands are highly vulnerable to fire for decades.</td>
<td>Removal of excessive fuel load can moderate future fire severity and fire behavior in some contexts.</td>
</tr>
<tr>
<td>Forest development</td>
<td>Salvage has potential to impact natural revegetation by trees and shrubs</td>
<td>Salvage + replanting can accelerate return to forest conditions in areas</td>
</tr>
<tr>
<td>--------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------</td>
</tr>
<tr>
<td>Economic returns</td>
<td>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.</td>
<td>Timber from burned areas has high economic values, and returns can be used to offset costs of hazard reduction and long-term restoration. Replanting can accelerate regrowth of timber-producing forests.</td>
</tr>
</tbody>
</table>