Chapter 3: Caring for the Land

Ecological Integrity and Resilience

Call-out box 8. Ecological integrity

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

The Forest Service 2012 Planning Rule incorporates ecological integrity[8] and directs forest plans to align approaches across the broader landscape for an all-lands approach to ecological sustainability. Planning for ecological integrity supports ecosystem resilience under changing conditions, and systems that can recover from disturbance (36 CFR 219: 21176). Integrity is a course-filter designed to maintain biological diversity.

Resilience (figure 26) is a concept applied throughout this assessment and is also defined in the Forest Service 2012 Planning Rule Handbook 1909.12.[9] (The term describes a state of being or a potential, not a specific end condition. Resilience is the ability of a system to regulate itself as it transitions among stable states (Gunderson 2000, Holling 1973) and can be especially powerful in our era of rapid change (Scheffer et al. 2015, Standish et al. 2014). Examples of these transition triggers, or disturbances, are fire, insects, disease, invasive species, and climate change (O'Hara and Ramage 2013, Puettmann 2011). Resilient ecosystems maintain keystone structuring processes, which are sources of renewal and function across multiple scales (Hessburg et al. 2015; Spies et al. 2018a, 2018b). One of these keystone structuring processes in the Bioregional Assessment of Northwest Forests is fire (Keane et al. 2009) (photo 8 and photo 9).

It is important to note that ecological resilience is not always a desired condition. In fact, ecological resilience may directly conflict with desired conditions. For example, homes and communities exist near an ecologically resilient forest where wildfire may occur within normal ecological ranges. In this case, a natural process that is part of maintaining ecological integrity may not be socially desirable for that community. We can use concepts

[8] This concept is defined in the scientific literature as a means of evaluating ecological conditions in terms of their sustainability. The concept of ecological integrity is required by use in National Forest Service management planning (36 CFR 219 §219.8(a)). “Plan components for ecological integrity would be required to take into account the interdependence of ecosystems, impacts from and to the broader landscape, system drivers and stressors including climate change, and opportunities to restore fire adapted ecosystems and for landscape scale restoration. Plan components would be also be required to maintain or restore air, soil and water resources, and to maintain or restore the ecological integrity of riparian areas” (36 CFR 219 §219.9(a)).

[9] Resilience: The ability of an ecosystem and its component parts to absorb or recover from the effects of disturbances through preservation, restoration, or improvement of its essential structures and functions and redundancy of ecological patterns across the landscape (USDA FS 2015b: 16).

like ecological integrity and resilience as anchors for management and desired conditions, but they have limitations in the context of communities and changes in climate and land use. Landscape resilience measures the stability and response of an ecosystem state to disturbance. Vegetation structure, species, composition, and pattern are ways to measure landscape resilience. It is used in this document without the integration of social values of those landscapes.

Ecosystem Conditions: Resilience

The comparison of current conditions to known resilient conditions generates powerful insights into how ecosystems function, developed, and even how they manifest the conditions seen on the ground today (Higgs et al. 2014, Hobbs et al. 2014, Safford et al. 2012).Often we use past resilient conditions as indicators of resiliency because they are known and measurable. The use of these measurements of the alignment or departure of ecosystems from past resilient conditions to assess resilience requires the assumption that past conditions point us in the right direction, toward ecosystem function. In addition, we need to consider predictions about future resilient conditions to prepare landscapes and ecosystems to cope with changing environmental conditions.

For these reasons, ecosystem conditions are compared here with both past and current condition, in addition to indices of future conditions, drivers, and stressors.

Future Ecosystem Resilience

Reference conditions providing guidelines for how to manage our ecosystems for resilience are essential to translate a concept of resilience into practice. Using historic reference conditions related to multiple aspects of our landscapes and forests is a critical foundation for understanding resilience. Given our current changing climate, particularly as it relates to wildfire behavior, extent and seasonality, projections of future conditions are also essential when managing toward forest resilience. The changes highlighted in future large fire suitability in the BioA are important to describe not only how the environment is projected to change, but to project and draw meaningful conclusions about the degree of change and impact to forests, specifically in terms of structure, species composition, and landscape patterns.

Subsequent sections of this chapter will highlight the ways existing land management plans promote ecosystem resiliency as related to forest ecology, wildlife, aquatics, and fire, and will provide recommendations to promote resiliency where it is lacking. The chapter ends with a climate change section, one that demonstrates how National Forest System Lands are equipped, to varying degrees, to cope with climate change, followed by concerns that will challenge ecosystem resiliency.

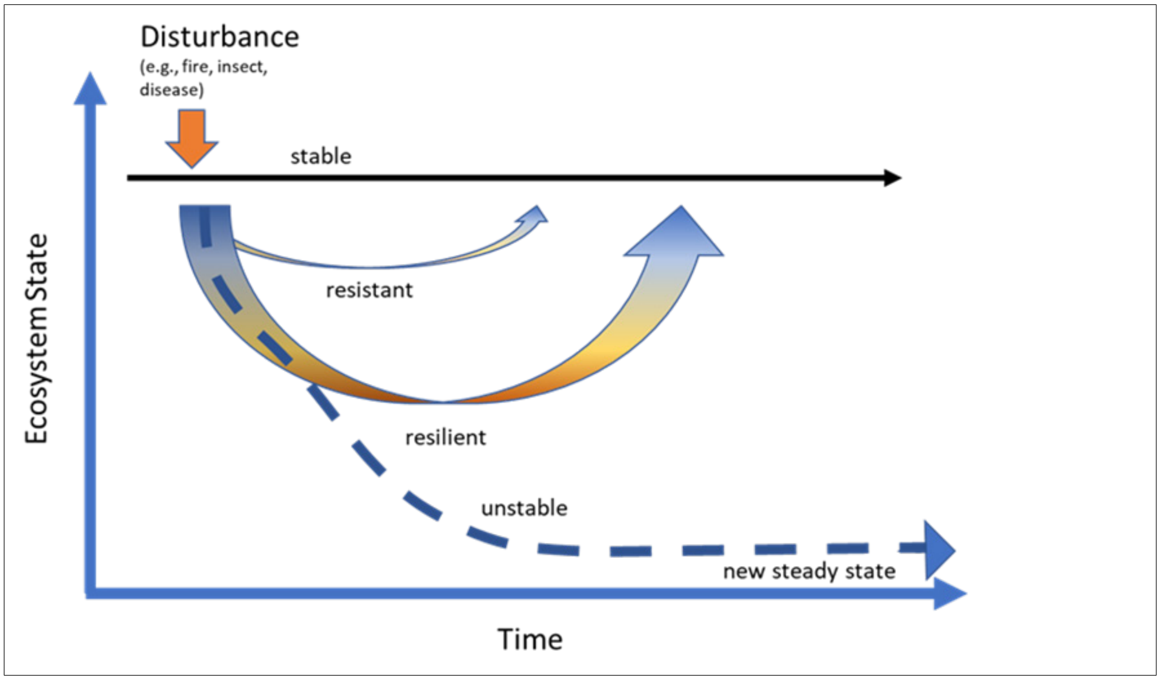


Figure 26. Ecological resilience diagram adapted from Franklin et al. (2018)

When a disturbance occurs, even a natural one such as fire, drought, insects or disease, an ecosystem responds in different ways. It can be resistant (very little change occurs, and the system stabilizes quickly), resilient (more change occurs but the ecosystem stabilizes eventually), or unstable (the ecosystem changes states completely). One example of this is a frequent-fire dependent forest historically dominated by ponderosa pine that now has dense stands of white fir or grand fir. The forest could experience a low-severity groundfire and change very little (resistant), or it could experience a mixed-severity fire and take years to recover, but eventually return to a state resembling conditions before the fire. Finally, a large high-severity fire could burn a large area of forest to the ground with the ecosystem unable to regenerate ponderosa pine, instead transitioning to a fir-dominated forest or a grassland or shrubland ecosystem (unstable). This figure does not incorporate climate change, changes in land use, or social factors.

Photo 8. Fire on the Rogue River-Siskiyou National Forest, 2018

Photo 9. Fire on the Olympic National Forest in the Hamma Hamma area, 2018

Forest Ecology

What is Working Well

What is Working Well 1—Reserve Systems

The reserve network of the NWFP, including late-successional reserves, riparian reserves, and congressionally reserved lands, is part of a designation-based landscape-scale approach that has worked well for conserving a network that supports many aspects of overall ecosystem health. This includes support for aquatic habitat and conservation of habitat for wildlife species that use dense, multi-layered old forest. The reserve network also ensures consistent management direction in each type of land use allocation.

Other plan amendments, such as PacFish, InFish, Eastside Screens (USDA FS 1995) and Sierra Nevada Framework (USDA FS 2004), have also been successful in achieving some desired network outcomes, including connecting and conserving aquatic habitat and dense, multi-layered forest.

While land use allocations and the reserve network have benefited multiple resources, some adjustments to create landscape resilience, especially in frequent-fire dependent and fire diverse (mixed severity) ecosystems are needed. Furthermore, to ensure a well-connected network of reserves that will persist, the application of best available science is needed to ensure that climate change refugia and fire refugia are incorporated into the reserve network.

What is Working Well 2—Conservation of Dense, Multi-layered, Old-growth Forests

The NWFP conservation strategies and other strategies, such as the Eastside Screens and the Sierra Nevada Framework, have been effective in stemming the loss of old trees and the type of old-growth forest that is a focus of the NWFP, mainly dense, multi-layered forest (Spies et al. 2018a). This type of old-growth forest is generally considered stable on federal lands and has increased slightly since 1993, providing the abundance, diversity, connectivity, and availability needed to support ecosystem functions and specific types of old-growth-dependent species in the BioA area *(*figure 27). This reversal of the pre-NWFP trend of old-growth loss is mainly a reflection of stopping clear-cutting practices and allowing trees to grow. Compared to preindustrial logging levels, old-growth forests are now described as islands of federally owned old forest among other land ownerships (figure 28).

While this old-growth conservation approach has been successful in some respects, old-growth forest types not defined or emphasized in the NWFP, Eastside Screens, or Sierra Nevada Framework are increasingly at risk of loss to fire (Spies et al. 2018a). These include old-growth forests in frequent-fire dependent and fire diverse (mixed severity) ecosystems. Loss of old growth from recent wildfires in California, southern Oregon, and east of the Cascade crest have been masked by gains in old-growth forest west of the Cascade Range where trees initiated after large 20th century fires have now grown into the old-forest category; when examining frequent-fire dependent ecosystems separately, acres of old growth have declined (Davis et al. in progress).

Regeneration harvest of old forest has been significantly reduced since the 1990s, particularly on federal forest lands in the Pacific Northwest, where the practice "virtually ceased in the early 21st century due to social objections and litigation." Currently, harvest systems that "retain significant structural elements of the pre-harvest stand have largely replaced clear-cutting" (Franklin et al. 2018:108).

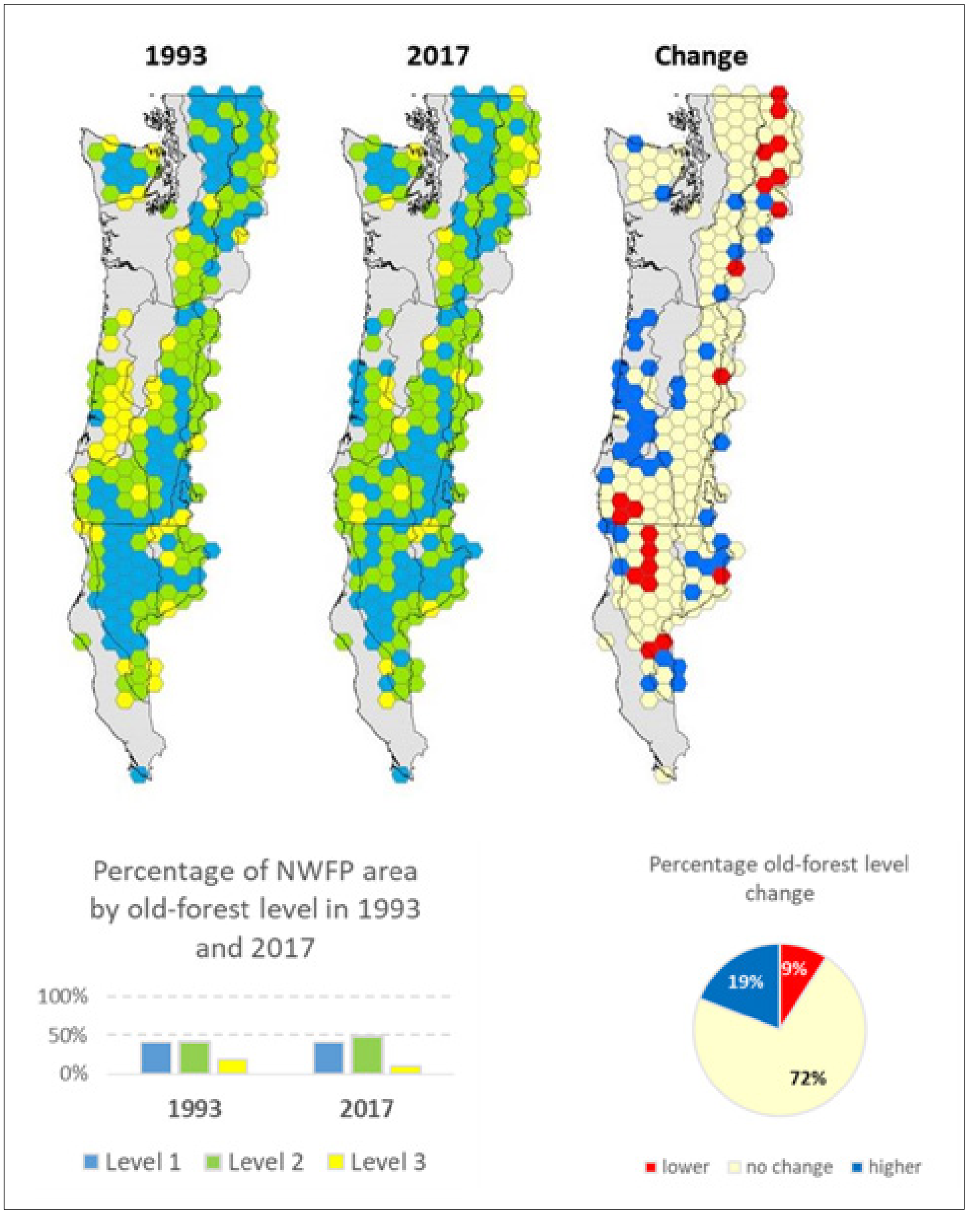


Figure 27. Snapshots (1993 and 2017) of old-growth abundance and change

Old-forest levels 1 and 2 represent areas where the amount of old forest on federal lands is at levels above (1) or within (2) the long-term average that occurred before logging and extensive fire exclusion. Level 3 represents areas where the amount of old forest is below the range expected for the area. No area with very low levels of old forest exists at this analysis scale. The "Change" map displays the percentage change in old-forest levels: Overall, old-growth habitat has remained stable but there have been changes in where the habitat is found through losses and additions.

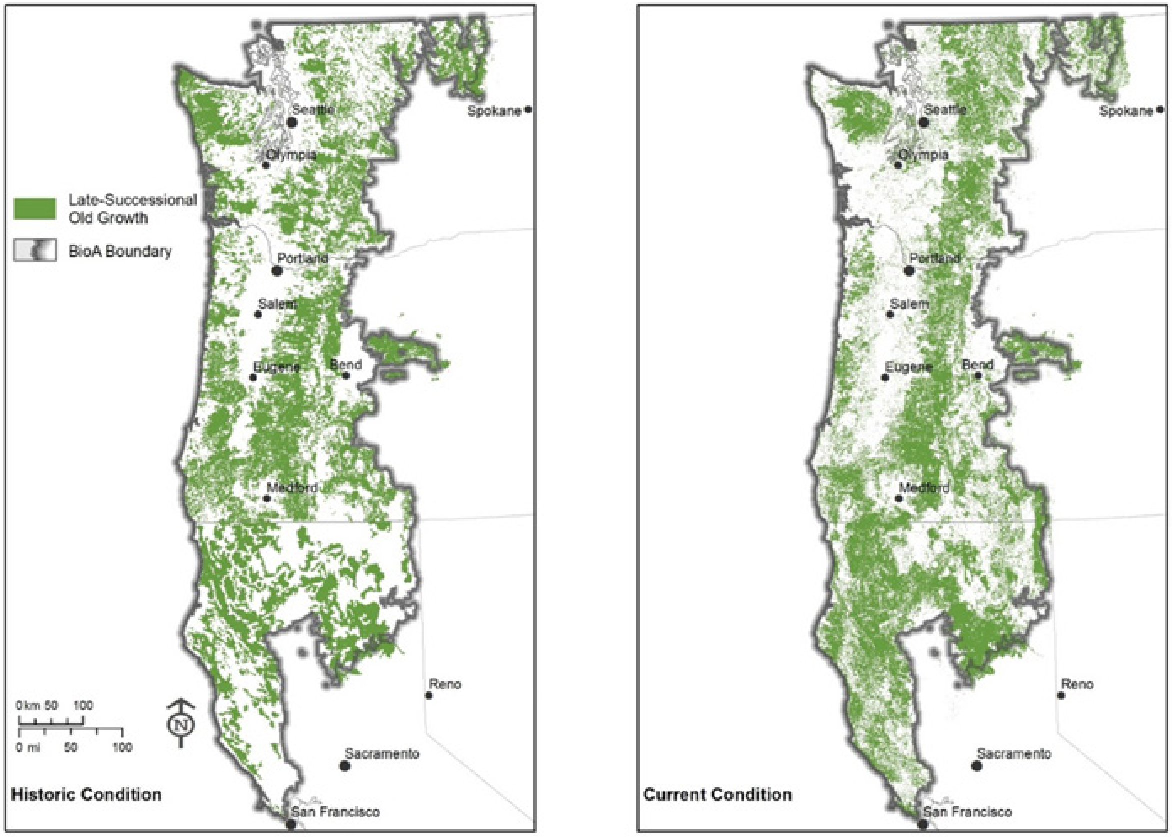


Figure 28. Historic and current amounts of old forests

Landscape portrait of how estimated levels of old forest have changed through the 20th century. Before industrial logging (circa 1940) much of the BioA area was old forest. Today, old forest tends to be better described as islands of federally owned old forest among other land ownerships and land uses. Current old-growth forest in the NWFP area was estimated here using Old Growth Structural Index 80 from the NWFP 25-year monitoring report. Outside the NWFP area old-growth was estimated based on large tree (greater than about 20 inches diameter at breast height) densities greater than 8 trees per acre based on Merschel and others (2019).

Key Change Issues

Key Change Issue 1—Landscape Scale Restoration is Needed

Restoration is needed to improve and maintain ecological function and resilience so that our national forests and grasslands can meet the needs of our communities and society now and in the future.

About 65 percent (17.8 million acres) of the national forests and grasslands across the BioA area lack historic structural diversity and resilience and do not adequately contribute to ecological integrity (map 8). Unless this issue is actively addressed, ecological integrity could continue to decline and the benefits from the national forests and grasslands could be reduced for future generations. For methodologies, see DeMeo et al. 2018 and Ringo et al. 2019.

Approximately 9.6 million acres within the BioA area need some type of forest structure restoration to improve and maintain ecological function and resilience. Of the 9.6 million acres that require restoration, about 2.2 million acres, primarily in our wettest, most fire infrequent ecosystems, need succession restoration[10] to enhance tree growth and snag development. Natural ecosystem processes and treatments that maintain and enhance old-growth forest are needed to develop and maintain ecosystem function (map 9).

The remaining 7.4 million acres have denser vegetation than they would have naturally supported, and they need either mechanical or fire treatment[11] or both to return to more natural, sustainable, and resilient densities (map 10). About 3 million of the 7.4 million acres also lack large trees, and therefore need a combination of disturbance and succession restoration to alter density along with time for the development of old-forest attributes.

Restoring riparian areas in concert with upland forests can be difficult because there is not necessarily synchronization of management direction between the two, even when best available science indicates needed restoration. Current land management plans offer descriptions of desired conditions for riparian areas that are too general and are not linked to landscape-level vegetation restoration or resiliency needs.

It is important to note that this analysis only focuses on the broad structural shifts needed across the BioA area. Specific forest restoration design occurs at the project level, based on site-specific data. The specific complexities of landscape and stand structures are not outlined here.

Restoration need is summarized in the *Synthesis of Science to Inform Land Management Within the Northwest Forest Plan Area* (Spies et al. 2018) and includes the following specific needs:

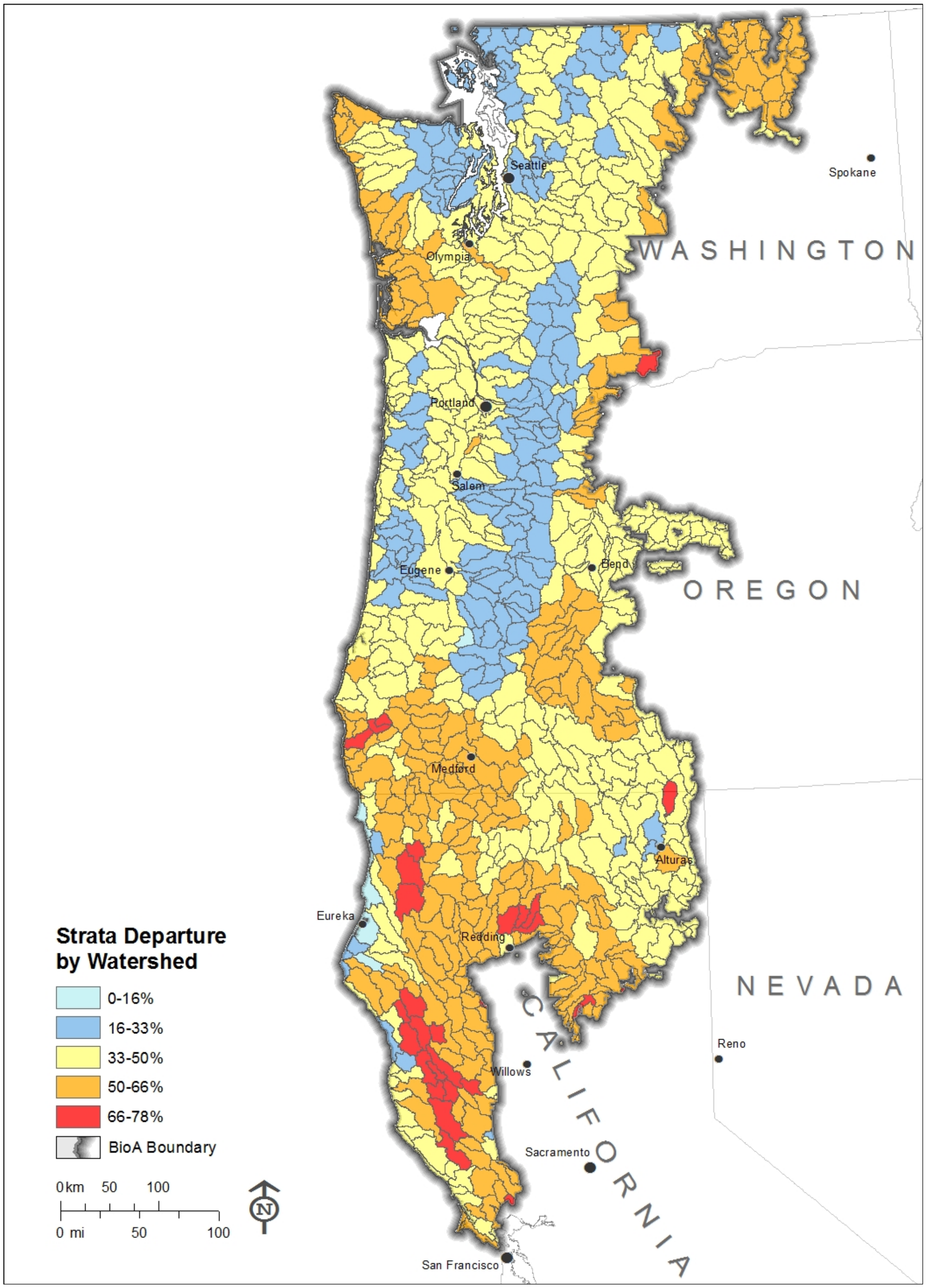
- Increase vegetation diversity in plantations and accelerate development of older forest structure and composition.
- Reduce fragmentation and increase connectivity of older forest patches.
- Create or promote early-seral vegetation where needed to provide seral stage and landscape diversity.
- Restore disturbance processes (for example, fire) where feasible.
- Restore low- and mixed-severity fire as key ecological processes where appropriate.
- Increase areas of open old forests where ecologically appropriate to promote resilience to fire and climate change and meet needs of species.

[10] Succession restoration essentially means to restore forests to resilient ecological conditions by allowing or culturing forests to grow into later seral stages. Later seral stages vary by forest type but generally include larger trees, more complex spatial arrangements, elements of dead and dying trees, and various ecologically appropriate species compositions.

[11] Disturbance restoration is needed when some elements of earlier seral stages are needed to restore forests. Some type of missing natural process, primarily fire, needs to be restored or mimicked through active management, or allowed to occur. Disturbance restoration treatments could take the form of some combination or independent application of mechanical treatment, prescribed fire, or wildfire management.

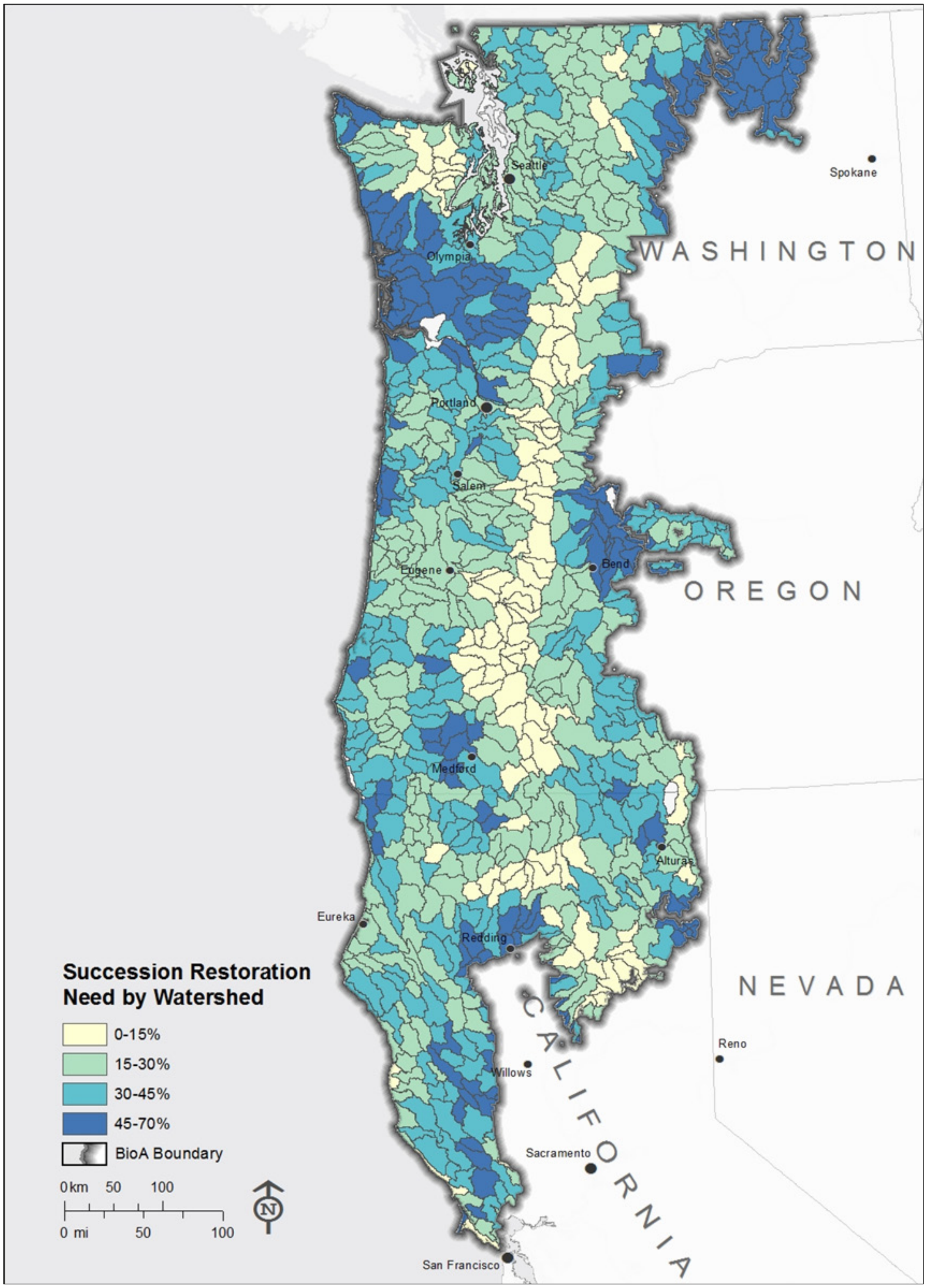
- Develop landscape-level strategies to create desired mosaics of open and dense old forest and to increase resilience and meet simultaneous needs of wildlife species and ecological integrity.

Road systems have also been shown to negatively affect terrestrial and aquatic biological diversity and ecosystem processes (Forman and Alexander 1998, Trombulak and Frissell 2000). So, although roads are a critical element of restoration implementation, reducing roads through decommissioning is important for meeting many biodiversity goals (Franklin and Johnson 2012, Trombulak and Frissell 2000). We acknowledge that conflict can exist between the use of roads and other objectives, such as habitat. No decisions have been made, and these tradeoffs will need to be addressed in upcoming planning efforts.



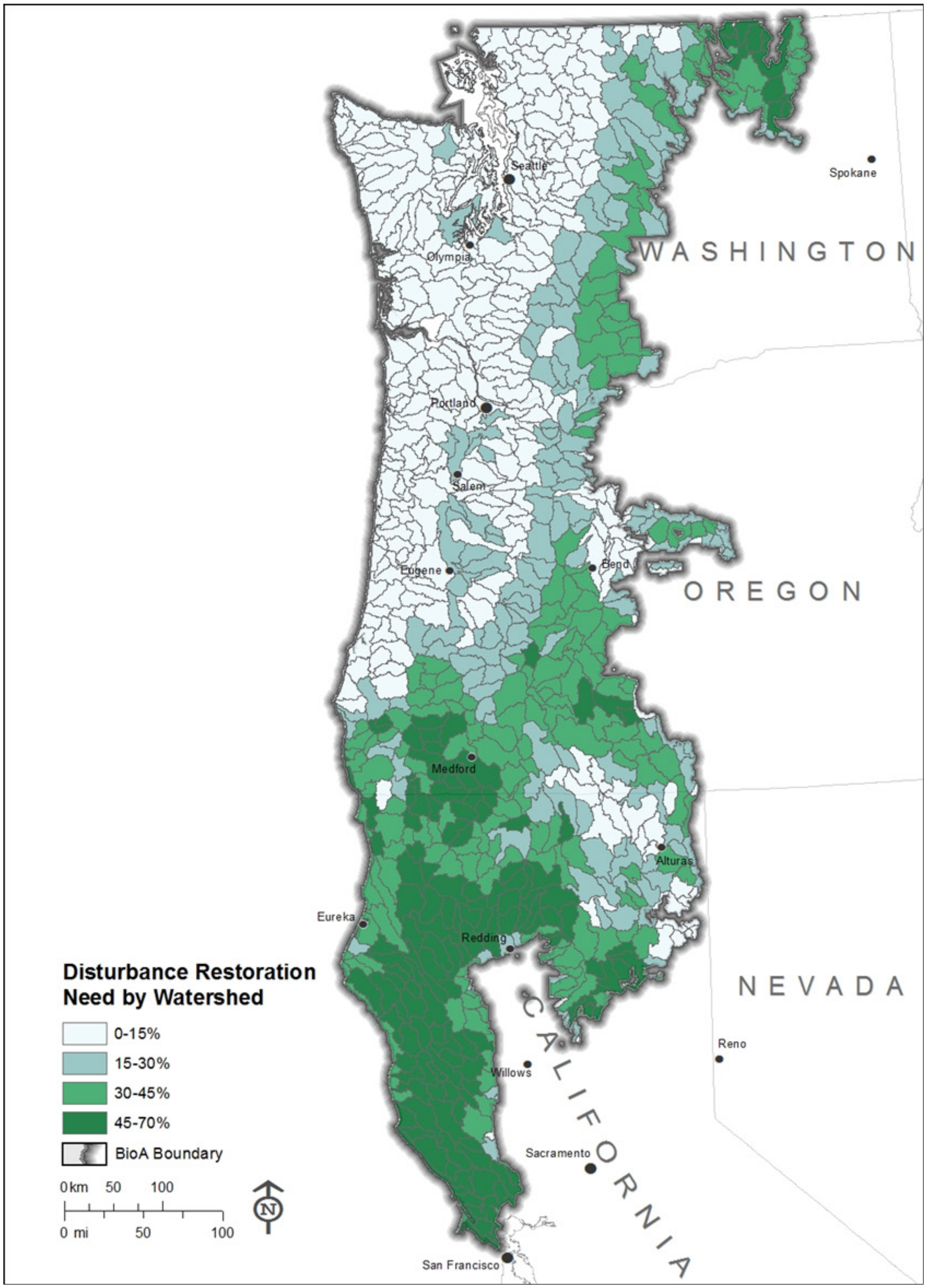
Map 8. Structural departure from more resilient reference conditions by watershed within the Bioregional Assessment area

Reference conditions are based on fire regime condition class assessment by vegetation type and landscape unit. Highest absolute departure occurs along the east Cascade Range slopes and foothills, Klamath Mountains/California high north Coast Range Cascade Mountains and northeast Washington, and the Coast Range (adapted from Ringo et al. 2019).



Map 9. Succession restoration needed within the Bioregional Assessment area

About 5.2 million acres within the BioA area need succession restoration, including tree growth and snag development. This includes 2.2 million acres of tree-growth-only needs (primarily national forests and grasslands west of the Cascade Range crest) and a 3-million-acre subset of lands where disturbance and succession are needed (for example, thinning, under burning, and tree growth) (adapted from Ringo et al. 2019.)



Map 10. Disturbance restoration needed within the Bioregional Assessment area

This map shows that 7.4 million acres within the BioA area need mechanical or fire treatments (for example, thinning or under burning) to reduce density and restore forests (disturbance restoration need). If a watershed has a 45- to 70-percent restoration need, that watershed needs urgent restoration to maintain ecosystem resilience (adapted from Ringo et al. 2019).

Figures 29 through 32 describe restoration needs in different ways using four factors that can be considered when creating strategies for forest plan modernization. They include 1) forest plan management emphasis (figure 29), 2) NWFP land use allocation (figure 30), 3) fire ecology category (figure 31), and 4) by national forest (figure 32). The first two factors are related directly to current forest plan direction, both in the underlying forest plans and in the NWFP amendment. This shows that forests generally have the most restoration need (both disturbance and succession) in areas where there is multiple, often conflicting, direction. In the NWFP area, the primary land use Allocation of adaptive management areas, congressionally reserved, administratively withdrawn, late-successional reserve, and matrix all have restoration needs, with almost equal amounts within matrix, late-successional reserves, and administratively withdrawn areas.

When examined in terms of fire ecology categories (frequent-fire dependent, fire diverse (mixed severity), and fire infrequent), restoration need is found mostly in frequent-fire dependent zones and is also apparent in fire diverse areas. This makes sense, because the structural effects of fire exclusion, historic timber harvest, and grazing have tended to be most apparent in frequent-fire dependent systems where tree density is much higher than historical reference conditions and old, large trees are less common on the landscape than they were historically, although younger shade-tolerant species continue to grow. Fire diverse ecosystems have had structural changes that are often less apparent as compared to species composition shifts, which are not measured in the BioA.

Restoration need is also summarized by national forest, and is an important consideration given that forest plan revision under the 2012 planning rule is completed at the forest level. Therefore, considering the amount of restoration need by forest could be a factor contributing to strategies to modernize forest plans. The Okanogan-Wenatchee, Fremont-Winema, Shasta-Trinity, Rogue River-Siskiyou, Deschutes, and Klamath National Forests each have more than 30,000 acres of disturbance-only or disturbance-then-succession restoration need.

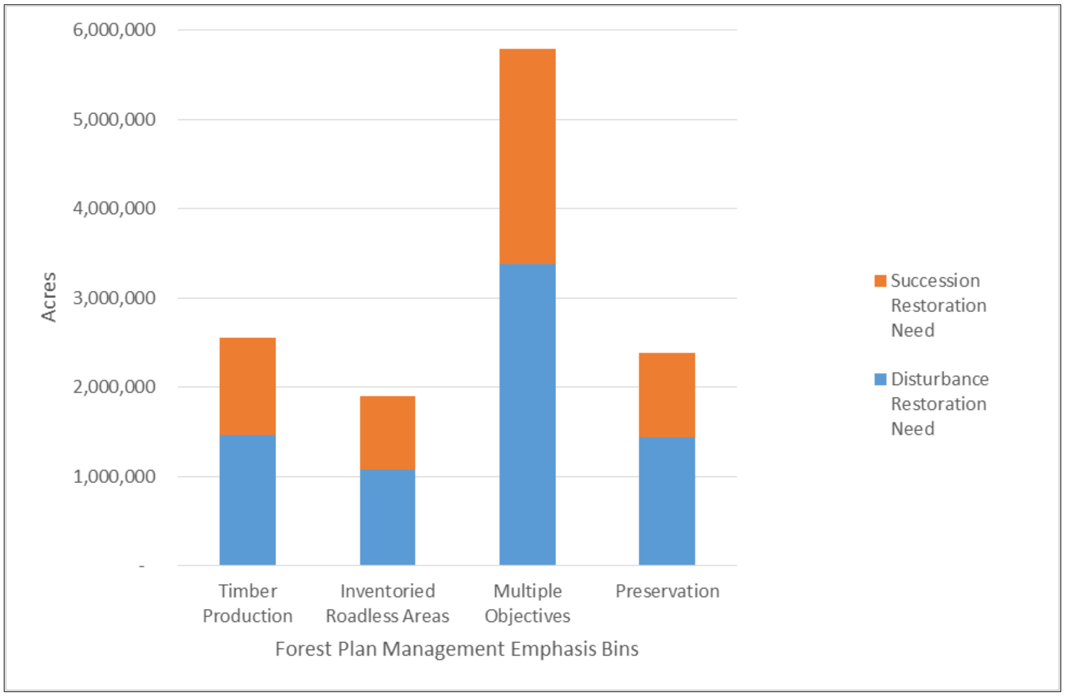


Figure 29. Acres of disturbance restoration and succession restoration need by forest plan management emphasis bin within the Bioregional Assessment area

Almost 3.5 million acres of disturbance restoration need is within lands that have multiple-objective management direction (Ringo et al. 2019).

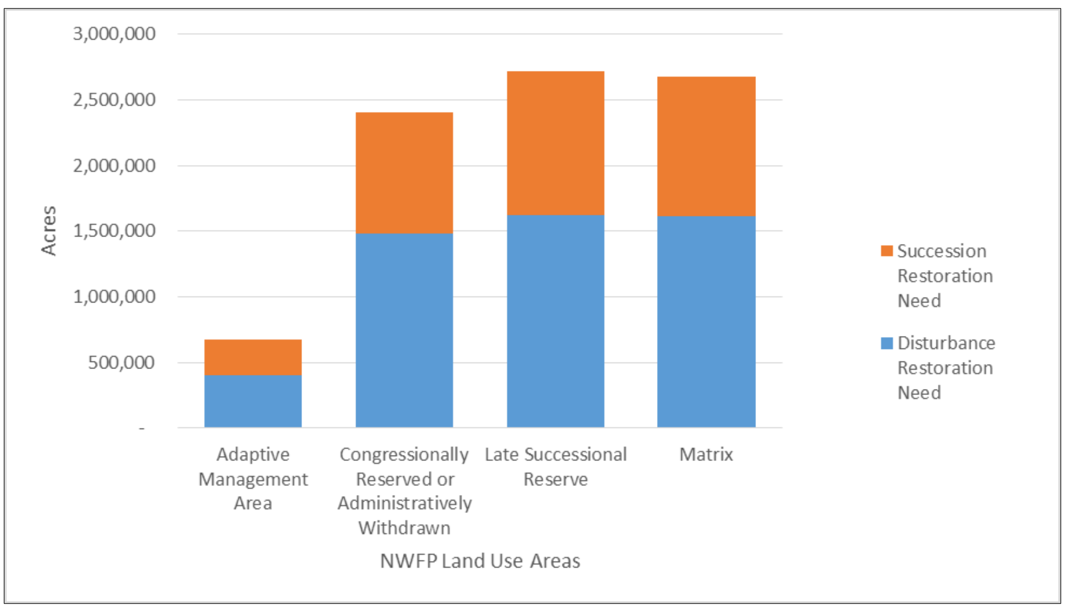


Figure 30. Acres of disturbance restoration and succession restoration need by Northwest Forest Plan land use allocation

More than 3.2 million acres of both matrix and late-successional reserve need some combination of fire or mechanical treatments to change forest structure (Ringo et al. 2019).

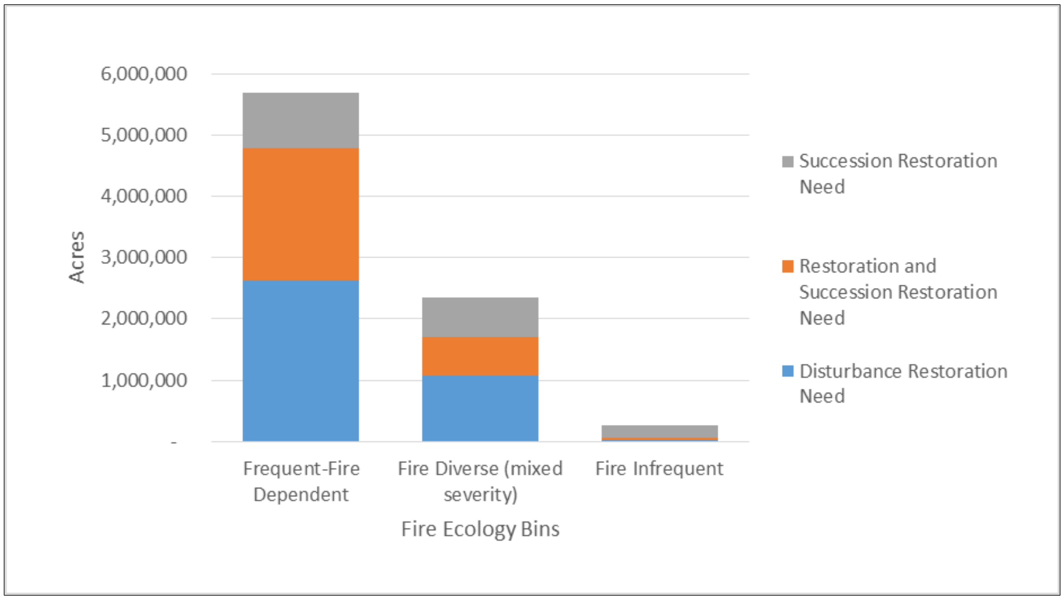


Figure 31. Forest restoration and fire dependency

Forest restoration need is categorized by fire dependency, including frequent-fire dependent, fire diverse (mixed severity) and fire infrequent. Both succession restoration and disturbance restoration are needed, sometimes in combination. Most current need can be seen in frequent-fire dependent landscapes and includes high levels of disturbance restoration need (Ringo et al. 2019).

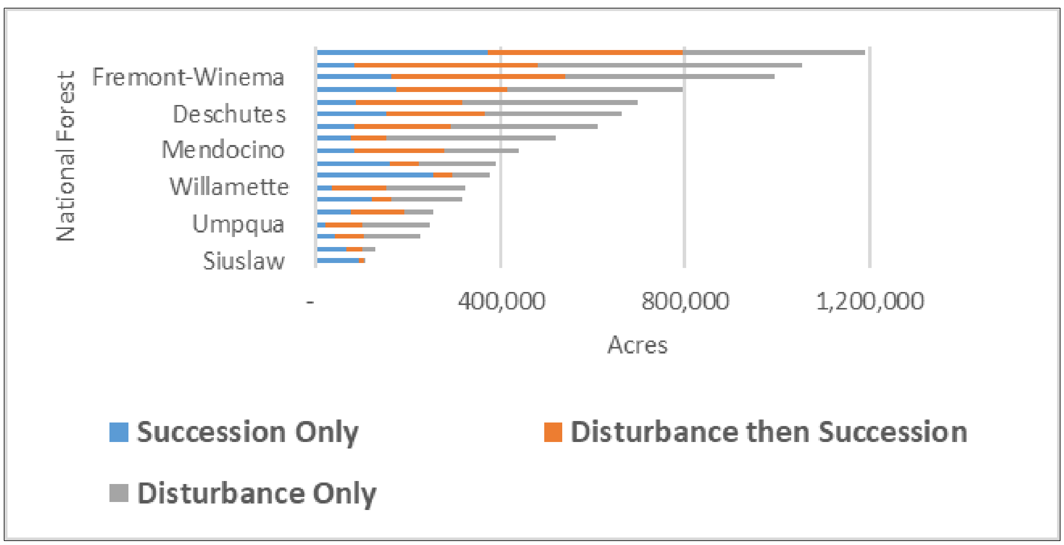


Figure 32. Forest restoration need by national forest within the Bioregional Assessment area

The Okanogan-Wenatchee, Fremont-Winema, Shasta-Trinity, Rogue River-Siskiyou, Deschutes, and Klamath National Forests each have more than 30,000 acres of disturbance-only or disturbance-then-succession restoration need. Number of acres of restoration need will likely increase through time. Given the sheer volume of current and future needs, modern forest plan direction related to restoration could help address this trajectory.

Current departure from resilient ecological function is also apparent when examining the abundance, distribution, and diversity of various tree species (species composition) and landscape pattern, primarily in frequent-fire dependent and increasingly in fire diverse (mixed severity) ecosystems. Recent research has taught us the following:

- An understanding of forest species composition, including the dynamic interactions between species composition and structure, is integral to gauging and managing for landscape resilience (Hessburg et al. 2016, Tepley et al. 2013) .
- Fire-dependent landscapes that historically were frequently disturbed by wildfire have had major shifts in species composition over about the past 100 years (Spies et al. 2018).
- In moister, fire-diverse landscapes, the effect of fire exclusion has been to significantly reduce the amount of early- and mid-successional vegetation that otherwise would now exist on the landscape as well as landscape-scale heterogeneity in forest composition, structure, and patch sizes (Haugo et al. 2019, Spies et al. 2018, Tepley et al. 2013).
- Some natural processes, including fire, are excluded across much of the BioA area (Balch et al. 2017).

Photo 10. **Disturbance restoration need on Deschutes National Forest**

Ponderosa pine overstory with grand fir understory.

Photo 11. Disturbance restoration need on Okanogan-Wenatchee National Forest

A typical dense, multilayered mixed-conifer patch in the eastern Washington Cascade Mountains. Note the relict ponderosa pine tree in the mid-ground (a remnant of a former forest); dead western larch—killed by dwarf mistletoe and inter-tree competition—fir-engraver bark beetle mortality, and western spruce budworm defoliation in the foreground; and a glut of pole-size trees that have grown into the understory during a period of fire exclusion.

Photo 12. Disturbance restoration in action on Okanogan-Wenatchee National Forest

A crew marks small Douglas-fir and grand fir in-growth for removal.

Photo 13. Disturbance restoration in action

After mechanical treatment, many areas also need prescribed burns to reduce surface and ladder fuels in addition to reinitiating ecosystem process such as nutrient cycling. Repeated burning favors the survival of medium- and large-size trees with thick bark and that are well spaced from neighboring trees.

Photo 14. Succession restoration need in fire infrequent forests

Larger trees and more complex structure are needed in this Olympic National Forest stand.

Climate Change Context

This section highlights the predictions that “environmental suitability” for large wildfires is projected to increase and the potential effects of that change on forest vegetation and landscape resilience. Environmental suitability for large wildfires is basically the measure of if conditions exist to support large wildfires. It is based on conditions under which large wildfires have manifested in the past and may be a predictor of when and where they might occur in the future. These conditions are associated with fire season precipitation, maximum temperature, slope, and elevation. Davis et al. (2017) projected changes in environmental suitability for large forest fires over the 21st century, and their methods have been applied across the BioA area (figure 33). Environmental suitability for large wildfires is described as low, moderate, or high and is displayed historically (1980) and as projected through the end of the century (2100).

Modelling indicates that the area that is highly suitable for large wildfires will steadily increase through time in the southern and eastern portions of the BioA area. Furthermore, the greatest increases in relative change in suitability for large wildfires is projected to occur in the higher elevation Cascades (fire diverse [mixed-severity] ecosystems), Coast Range (fire diverse [mixed severity] and fire infrequent), northern Cascades (fire diverse [mixed severity] and fire infrequent) and northern eastern Cascades (frequent-fire dependent and fire diverse [mixed-severity]).

Although changes discussed in the climate section (including fire season precipitation, maximum temperature, slope and elevation, and water-balance deficit) do not necessarily mean that fires will burn in these areas more frequently, as that depends on ignition, they do provide us with a good index of how much change these forests are likely to undergo in the coming decades. This will likely be increased fire frequency and seasonality, and changes in severity and patch size, as well as synergistic changes related to drought stress.

Climate change is likely to increase native insect and pathogen activity and affect population dynamics and geographic distributions of pathogen and insect species. Warmer winters and more intense droughts are expected to enable insects to move into previously unsuitable habitat (Bentz et all. 2016, 2010). Drought and insects may also interact to further stress trees and predispose them to mortality.

Climate change is not considered in our forest plans and is a primary reason for the need to create higher levels of ecological resilience to stressors and options for resilient ecological pathways. Climate change may continue to alter the composition, structure, and function of forested and non-forested ecosystems in the BioA area (Vose et al. 2012). Tree mortality is expected to increase (Allen et al. 2010, 2015). Tree growth and viability will also be affected by warmer winters, earlier snowmelt, and changing water availability.

Climate change is likely to compound, increase, and expand the departure of ecosystems from resilient conditions in the immediate, mid-term, and long-term future. The landscape is becoming increasingly vulnerable to uncharacteristic vegetation shifts in the face of climate change. Changes in temperature, precipitation, and effects on natural ecosystem processes such as wildfire, insects, disease, and windstorms, in addition to complex interactions with invasive species will be compounding factors for increasing the departure of ecosystems from resiliency (figure 35).

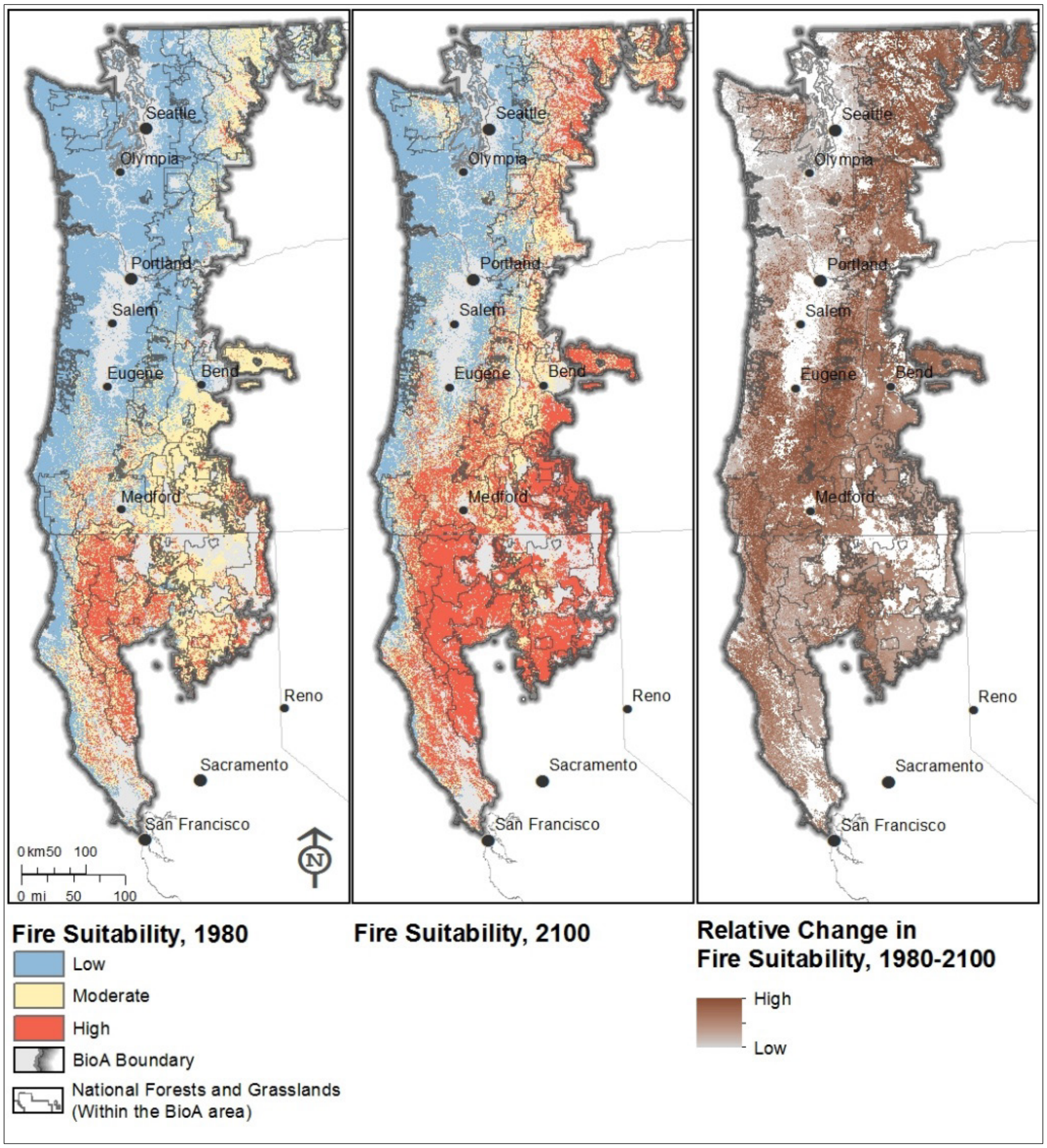
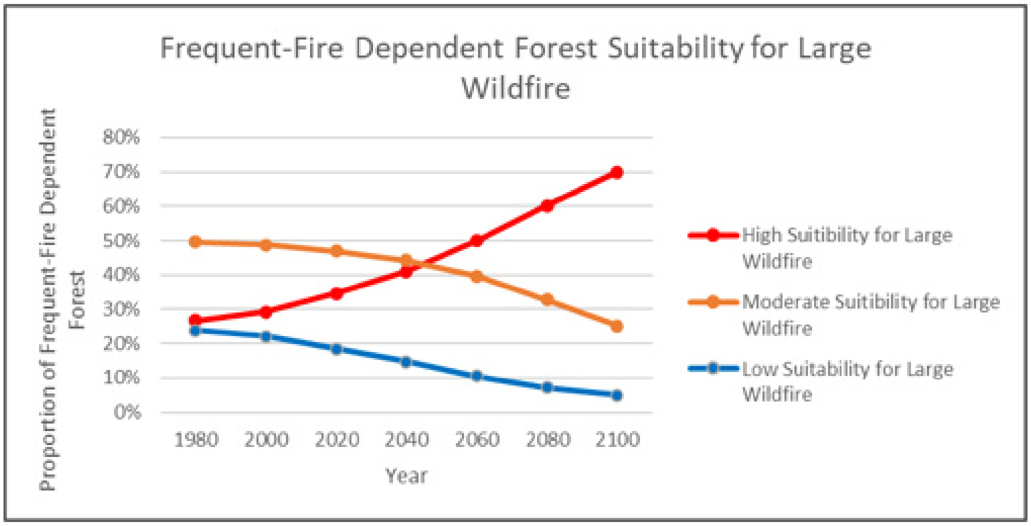


Figure 33. Past and future fire suitability in the Bioregional Assessment area

Past and future projected change in fire environment and relative change in fire suitability as an index of changes to resilient reference conditions (adapted from Davis et al. 2017). The area that is highly suitable for large wildfires (as measured by fire season precipitation, maximum temperature, slope, and elevation) steadily increases through time in the southern and eastern portions of the BioA area (comparing 1980 conditions to 2100 panels 1 and 2). Furthermore, the relative change in suitability for large wildfires increases most greatly in the higher elevation Cascade Range (moister fire-diverse [mixed-severity] ecosystems), Coast Range, northern Cascades and northern eastern Cascades (panel 3).

A



B

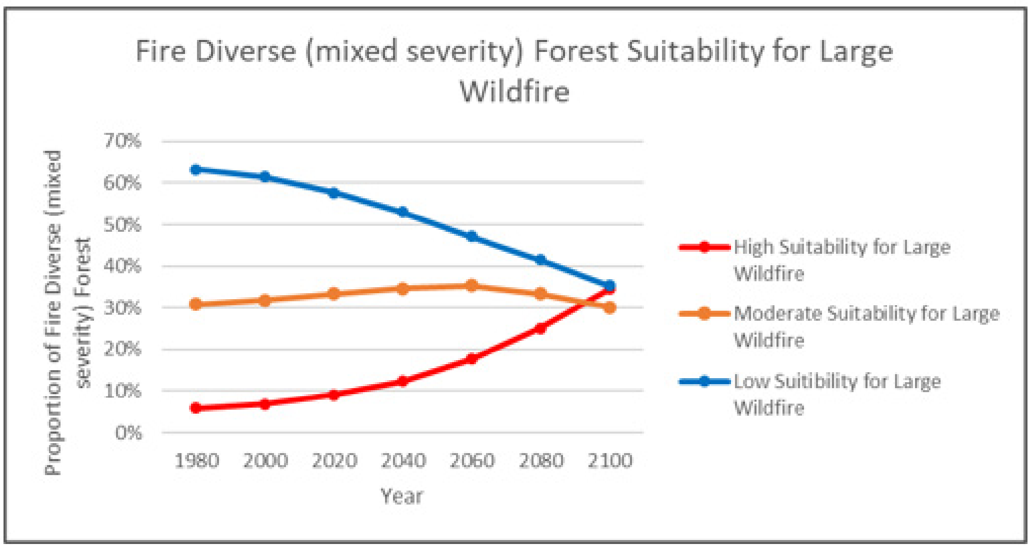


Figure 34. Past and future suitability for large wildfires in frequent-fire dependent (A) and fire diverse (mixed severity) forests (B)

In frequent-fire dependent forests, the area highly suitable to large wildfires grows from 27 percent in 1980 to 50 percent by 2060 and 70 percent by 2100. At the same time the proportions of moderate- and low-suitability to large wildfire declines. In fire diverse (mixed severity) forests, the areas highly suitable to large wildfires grows from 1980 levels at just 6 percent through 2060 at 18 percent and 35 percent by 2100. In fire diverse areas with low suitability to large wildfire decreases from 63 percent of the landscape in 1980 to 47 percent of the landscape in 2060 to 35 percent of the landscape in 2100. These charts both indicate an urgent need to address landscape conditions in a changing climate to limit the increase in large wildfire suitability. For variability of trends see Davis et al. (2017).

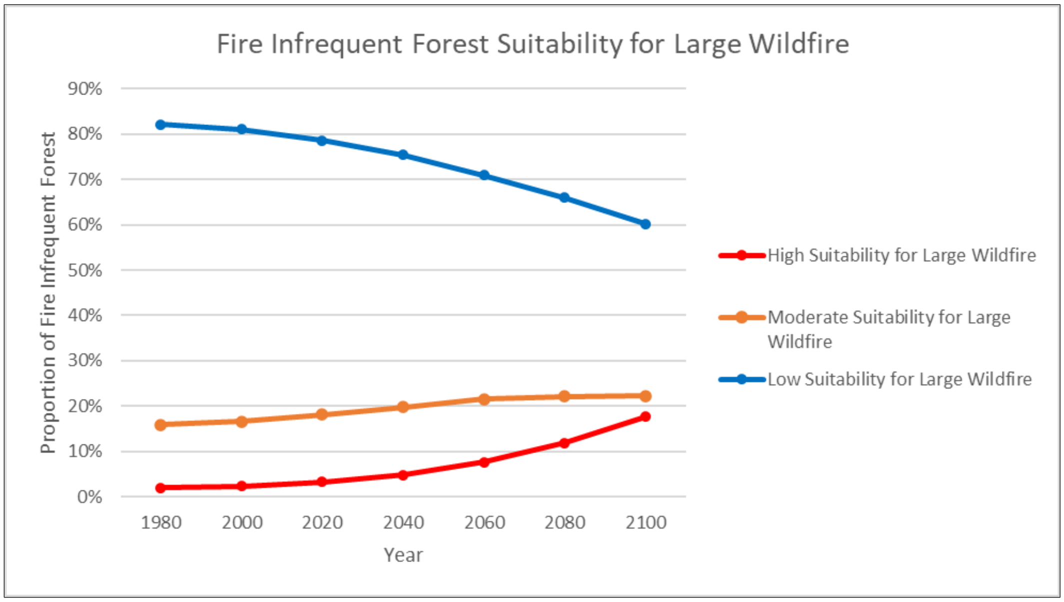


Figure 35. Past and future suitability for large wildfires in fire infrequent forests

In fire infrequent landscapes the highly suitability environments for large wildfires gradually increases through time from 2 percent in 1980 to 8 percent in 2060 and 18 percent in 2100. For variability of trends see Davis et al. 2017.

Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Recommendation 7: Expand the use of timber harvest as a restoration tool to provide economic and social benefits to communities.

Recommendation 8: Shift from single-species management to maintaining and restoring habitat for multiple species to help ensure we are managing our ecosystem to be resilient in the face of future change.

Recommendation 9: Promote active management in plant and animal habitats to restore and promote ecological resilience.

Geographic Considerations

As described in this section, based on best available information, we anticipate the area that is highly suitable for large wildfires will expand in the southern and eastern portions of the BioA area, with the greatest increases in suitability for large wildfires in the higher elevation Cascades, Coast Range, and northern and northeastern Cascades.

Key Change Issue 2—Management Options are Incompatible With Ecosystems

Current management options in forest plans are not always compatible with the unique ecosystems across the BioA area. This incompatibility creates situations where managers are working to restore and protect forests without helpful direction from forest plans. There is a need to eliminate current constraints that are no longer aligned with best available science and management objectives.

Fire exclusion has resulted in the exclusion of natural fire across much of the BioA area, leading to unintended ecological consequences, but the restoration work needed to address the consequences is difficult to plan because forest plans limit options. Loss of old forest from high-severity wildfire has been concentrated in frequent-fire dependent ecosystems were large wildfires have occurred, resulting in localized loss of old forest (Davis et al. 2015, in progress).

The amount of tree-density reduction and prescribed fire in frequent-fire dependent ecosystems to reduce risk of old-forest loss has been less than anticipated (Spies 2009). These activities would promote resilience to both climate change and fire within and outside late-successional reserves (Spies et al. 2018).

The use of timber harvest as a tool to achieve desired ecological outcomes is not broadly or consistently included in current plan direction. Plans tend to focus on timber outputs rather than desired landscape conditions and therefore do not often provide helpful direction on how to connect the two when they are complementary.

Harvest restrictions on lands within the NWFP reserve network and amendments such as the Eastside Screens management direction, which restricts the size or age of trees harvested, are not consistent with management recommendations based on the best available science. In the case of the Eastside Screens, this can limit our ability to capitalize on using timber harvest as a tool to reach ecological integrity.

One example of management direction that is not necessarily aligned with current best available science is the 80-year exemption associated with NWFP late-successional reserves. Spies et al. (2018) state the following:

> Somewhat arbitrarily, 80 years after conifer forest establishment has been used as the onset for “mature” (for example, OGSI 80) Douglas-fir forests…Eighty years was used as the threshold for late-successional/old growth in the NWFP (USDA FS 1994) because that is about the earliest time when such stands begin to resemble maturing forests in the moist forest (does not apply to the dry forest zone)…. The variability in structure with stand age indicates that at a regional scale, age or time alone is only a partial predictor of forest structure. The structural features of mature and old-growth forests would have included medium- to large-size (for example, greater than 40 inches) shade-intolerant tree species; smaller shade-tolerant trees of similar and lesser age in the mid to lower canopy layers; large standing and down dead tree boles; and horizontal and vertical structural heterogeneity of live and dead trees.

This exemption does not reflect our current understanding about many ecosystems within the NWFP area. In addition, under the NWFP, proposed forest management activities in stands older than 80 years in a late-successional reserve are subject to review processes, administered by the Regional Ecosystem Office, which tend to require more time and resources than activities in younger stands. Because it often requires higher levels of project management and project-related risk taking, needed restoration work in older stands may not be accomplished. In and of themselves, stand age or tree size are not the only, or necessarily the best, measures of ecological health. For example, forests more than 80 years old on lower productivity sites may be dense and lack understory diversity as a result of slow growth and development and exclusion of fires that would have contributed to structural variation; in this case, human intervention could help move the stand toward a more natural condition despite the age-based harvest limit. Consequently, needed restoration work in older stands may be hindered, or not accomplished. Looking across the diversity of forest habitats on the landscape, there is increasing recognition that stand age or tree size are not the only, or necessarily the best, measures of ecological health.

Another example is the 21-inch standard associated with the wildlife standards of the Eastside Screens. In this case, many relatively young shade-tolerant trees (for example, grand fir/ white fir) that need to be removed to work toward ecological resiliency purposes are overabundant on the landscape, but cannot be cut under current plan direction (without a forest plan amendment) because they have grown beyond 21 inches diameter at breast height.

Outdated management direction can hinder our ability to reduce the risk of insect and disease mortality in late-successional reserves, scenic corridors, and habitat managed for deer and elk cover; this is another example of the need to consider updating plan direction to reflect the best available science (figure 36 and figure 37; map 11).

Insect and Disease Context

In 2012, insect and disease risk was assessed nationally. On the National Insect and Disease Risk Maps, “risk” or “hazard” are defined as the potential that, without remediation, 25 percent or more of the standing live basal area of trees larger than 1 inch diameter at breast height will die over the next 15 years because of insects and disease (Krist et al. 2014). This risk assessment was updated in 2017. This assessment has identified geographic areas where prevention opportunities exist in synergy with forest plans (figure 61 and figure 62). It also shows how prevention opportunities intersect with national forests in the BioA area and fire dependency categories (figure 60) (see the “Forest Plan Management Emphasis” section and map 7). Current and near future risk (2012 to 2027) of forest mortality from insect and disease agents is particularly high in frequent-fire dependent and fire diverse (mixed severity) ecosystems.

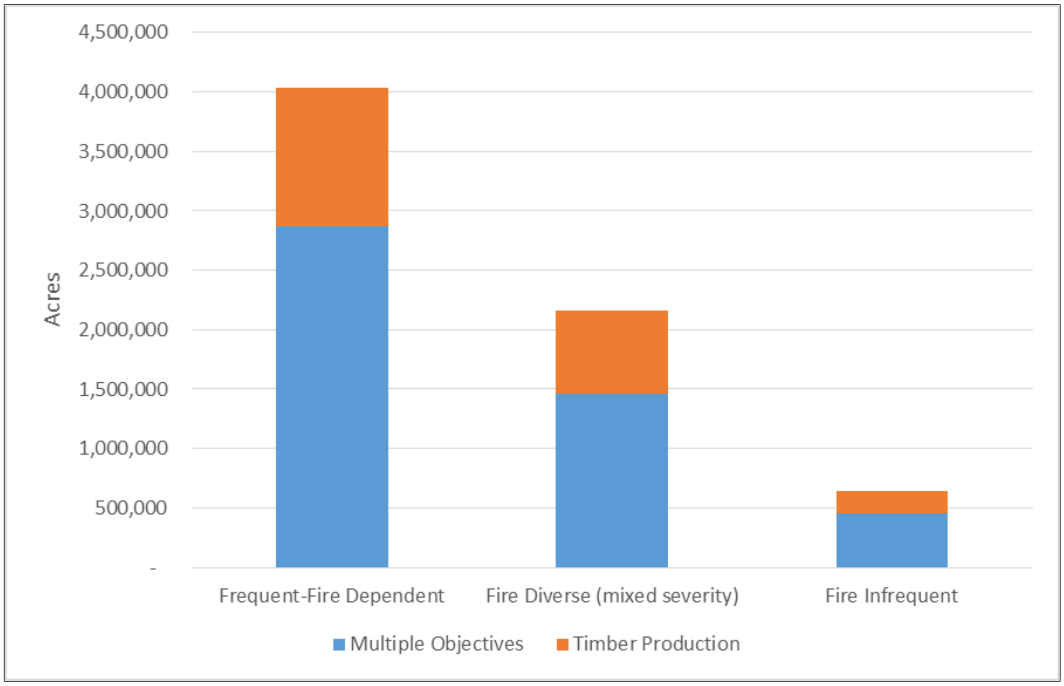
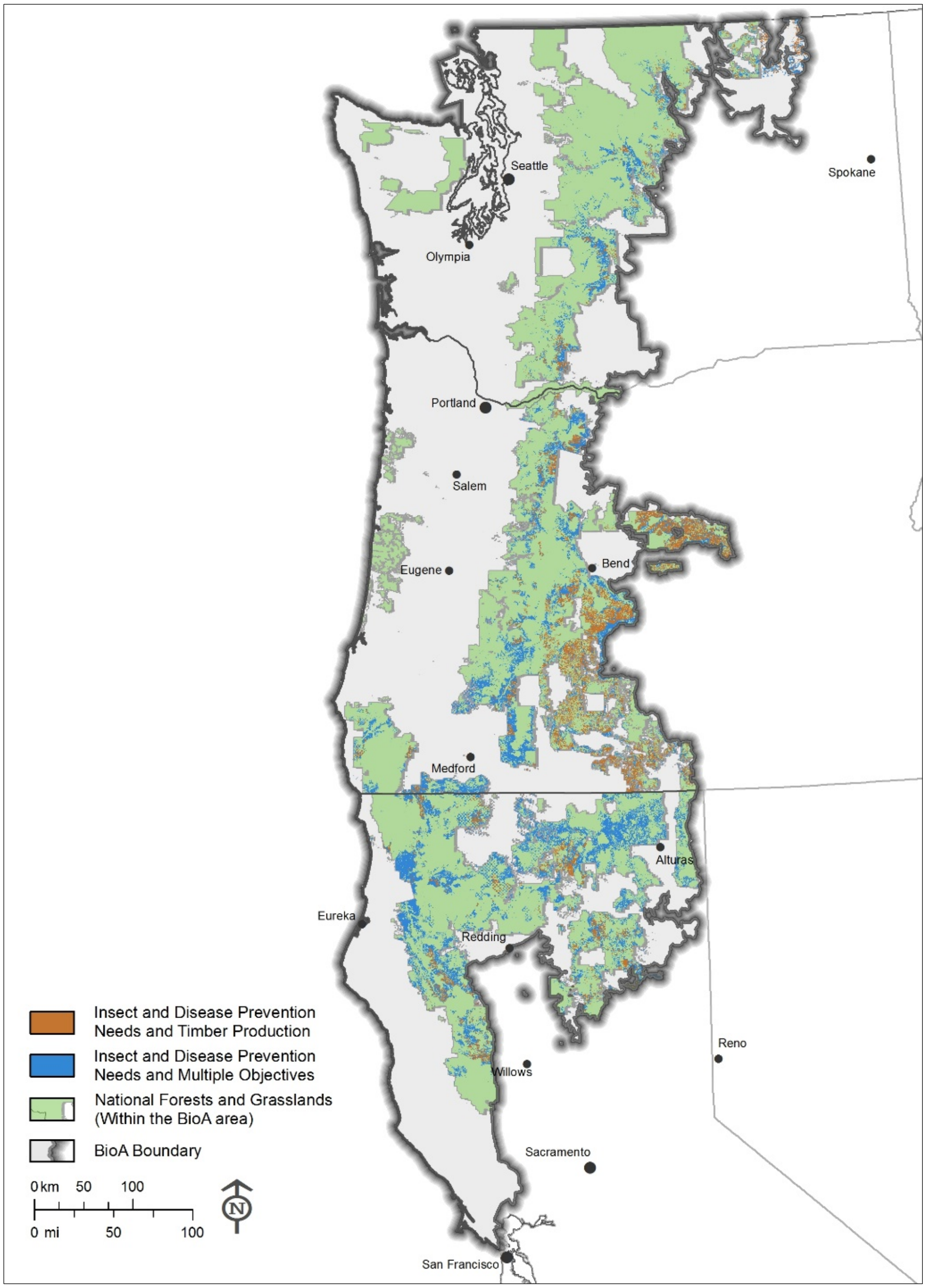


Figure 36. Insect and disease prevention need identified in 2017 as overlapping with Bioregional Assessment fire ecology categories and forest plan management emphasis areas

Forest health prevention needs about 4 million acres in frequent-fire dependent ecosystems and more than 2 million acres in fire diverse (mixed severity) landscapes. In fire infrequent landscapes, more than 600,000 acres need forest health prevention measures. Most of the need is in forest plan emphasis areas that have multiple objectives, including late-successional reserves, ungulate habitat, or viewsheds. See also the "Forest Plan Management Emphasis" section under "Sustainable Timber" in chapter 1.



Map 11. Intersection of forest health prevention needs with forest plan management emphasis areas within the Bioregional Assessment area

This map also displays all other forest health prevention needs outside of congressionally reserved areas. Risk, or hazard, in the National Insect and Disease Risk Maps (source of forest health prevention need) is defined as the potential that, without remediation, 25 percent or more of the standing live basal area or trees over 1 inch diameter at breast height will die over the next 15 years due to insects and disease (Krist et al. 2014). This risk assessment was updated in 2017. See also the "Forest Plan Management Emphasis" section under "Sustainable Timber" in chapter 1.

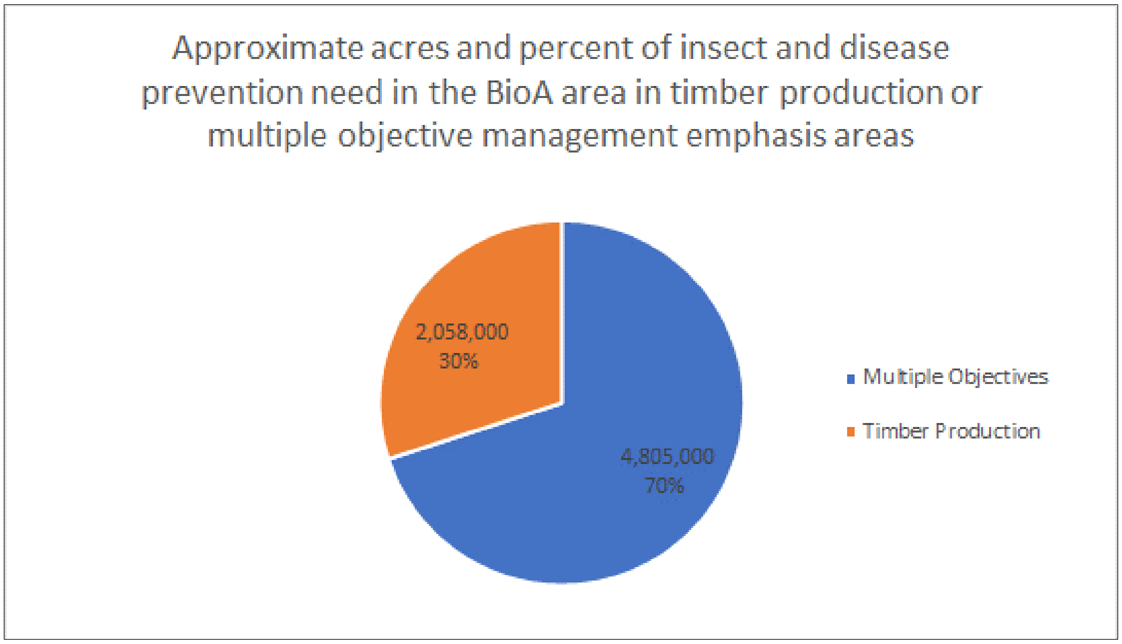


Figure 37. Insect and disease prevention needs in multiple-objective management areas

Acres and percentage of forest health prevention need that overlaps with current forest plan management emphasis categories of multiple objectives and timber production. Insect and disease prevention needs a total of more than 6.8 million acres in both forest plan multiple-objectives and timber production emphasis areas. See "Forest Plan Management Emphasis" section under "Sustainable Timber" and Map 7. Vegetation forest plan management emphasis categories for the Bioregional Assessment area.

Late-Successional Reserve Context

Late-successional reserves were designed to protect and enhance old-growth forest conditions. In combination with other land use allocations and standards and guidelines, late-successional reserves are intended to maintain a functional, connected, late-successional and old-growth forest ecosystem and create a network of habitat for old-forest-dependent species, including the northern spotted owl (USDA FS and USDI BLM 1994: 6–8). By design, timber harvest for purposes other than the development and protection of late-successional reserves or riparian reserve objectives is restricted through plan elements. Some of those elements are highlighted below.

Today, late-successional reserves, particularly in dry/fire-frequent/fire-dependent landscapes, are at risk of not fully meeting the purpose and need outlined in the NWFP to, "maintain and enhance late-successional forests…that are retained in their natural condition with natural processes, such as fire" The desired conditions of late-successional reserves generally identified in current forest plans do not capture old-forest structure, species composition, or development potential, depending on site conditions and history (Pabst et al. 2008, Reilly and Spies 2015). Our knowledge of the role of fire has advanced considerably from the early 1990s. The lack of fire in drier forests types over the past century has created hazardous, unsustainable conditions and treatments of some kind are needed in many of these forest types, including reserve areas, to restore resiliency.

The 2012 planning rule introduces a new ecological objective: ecological integrity and related resilience. This vocabulary was not part of the direction for the NWFP. This element changes the frame through which we see late-successional forests and emphasizes putting forests in the context of their ecosystem function. For the NWFP area, this is a significant change, especially for frequent-fire dependent forests.

Regional Ecosystem Office and Regional Interagency Executive Committee Review

Under the NWFP, national forests are required to prepare an assessment for late-successional reserves, or groups of small reserves. The late-successional reserve assessment describes the late-successional reserves' existing conditions, criteria for developing appropriate treatments, a fire management plan, and a monitoring plan. This document is then required to undergo review by the Regional Ecosystem Office (Regional Ecosystem Office) and Regional Interagency Executive Committee. Following the development and approval of the late-successional reserve assessment, proposed activities within the late-successional reserve must be consistent with the late-successional reserve assessment; if they are not, the late-successional reserve assessment or forest plan must be updated or amended, respectively, or a consistency review of the proposed activity is undertaken by the Late-Successional Reserve workgroup. Proposed activities that require a consistency review or amendment could include those designed for the beneficial creation and maintenance of late-successional forest in fire-dependent forests as well as activities that reduce the risk of large-scale disturbance. Depending on the complexity of the proposed activities, the late-successional reserve review process can add additional time to project timelines and may discourage national forests from proposing beneficial activities because of the time commitment. In recent years, the Regional Ecosystem Office and late-successional reserve workgroup have been working to expedite the amount of time it takes to conclude consistency reviews. The late-successional reserve Workgroup has identified many late-successional reserve assessments that may need to be updated to allow additional beneficial activities that would reduce large-scale wildfire risk and promote maintenance of late-successional forests. The standard for the consistency review is based on how proposed activities in late-successional reserves will protect or enhance old-growth forest conditions. This means that projects with multiple objectives (for instance, old-growth enhancement plus fire-risk reduction near the wildland urban interface) and projects that include portions of a late-successional reserve and other lands such as matrix, may not fully meet the standards set forth in the NWFP. In effect, late-successional reserves may be left out of otherwise "all lands" restoration projects and, if included, may add additional coordination requirements and increase the timeline for the completion of individual projects.

Under the 2012 planning rule, the overall ecosystem function as related to ecological integrity and resilience is emphasized where this concept was not part of the NWFP. This underpinning focus on ecosystem resilience may change how old-growth forest management goals and objectives are set in the future.

80-Year Exemption: Late-successional reserve standards and guidelines empower the Regional Ecosystem Office to create exemptions related to review of vegetation management in late-successional reserves. Certain precommercial thinning and reforestation activities were exempted from the Regional Ecosystem Office review process in 1995 and, in 1996, some commercial thinning activities were exempted from review. This 1996 exemption from Regional Ecosystem Office review for commercial thinning in stands under 80 years of age has become known generally as the “80-year exemption.” This means that for stands over 80 years of age, there is still a Regional Ecosystem Office review process needed in most late-successional reserves. Proposed management needs to be consistent with the late-successional reserve assessment and the NWFP. There is an exception in that the North Cascades adaptive management area/late-successional reserve stand age is 110 years, and additional activities are allowed east of the Cascades and in the Oregon/California Klamath Province.

The intent of this age limitation was to serve as a rough proxy for old-growth stand structure and development potential and was based on expert opinion informed by observations of natural forests (Spies et al. 2018). The 80-year exemption is applied across the NWFP area (with the exception of the North Cascades AMA/late-successional reserve where it is 110 years). This is also associated with Regional Ecosystem Office direction limiting harvest of trees to less than 20 inches diameter at breast height in late-successional reserves. Late-successional reserve criteria stipulate that,

> Individual trees exceeding 80 years in those provinces or exceeding 20-inches diameter at breast height in any province, shall not be harvested except for the purpose of creating openings, providing other habitat structure such as downed logs, elimination of a hazard from a standing danger tree, or cutting minimal yarding corridors (Knowles 1996).

The 80-year exemption, which applies to a diverse landscape, lacks the flexibility given our current environments and new insights around how old-forest composition, structure, and development proceed regardless of an age threshold. For example, the 80-year exemption applies to frequent-fire dependent, fire diverse (mixed severity), and fire infrequent systems although old forest develops and manifests very differently across all three of these categories.

New science about frequent-fire dependent and fire diverse (mixed severity) ecosystems (Spies et al. 2018) may suggest the need to modernize the 80-year exemption. Early-seral species such as white fir or grand fir have established primarily as a result of more than a century of fire exclusion; many of these trees are now more than 80 years of age. More trees regenerate through time and the ingrowth of these shade-tolerant and relatively fire-intolerant species has resulted in more acres of dense and multi-strata forests than historically existed (Camp et al. 1997, Hagmann et al. 2017, Merschel et al. 2014, Taylor and Skinner 1998, 2003). This changes the effects of fire and increases the risk of large patches of higher severity fire effects where historically they were not a major component (Spies et al. 2018).The 80-year exemption may be helpful to manage young, simplified stands, but the process associated with Regional Ecosystem Office review for management in stands more than 80 years of age may limit restoration needs in more complex stands.

Opportunities to use Timber Harvest as a Restoration Tool

Timber output predicted in forest plans does not necessarily incorporate modern desired outcomes for resilient landscapes, but opportunity exists to use active management, including timber harvest and prescribed fire, to achieve desired landscape and habitat conditions (figure 38). Implementation of ecologically appropriate landscape prescriptions based on resiliency, particularly in the face of climate change, could create a synergy where resiliency management and timber outputs both benefit. We acknowledge that even when the best available science indicates that active management for restoration and resiliency is needed, conflicting values around timber harvest or other types of active management still exist. During upcoming planning efforts, we will engage the general public, local and state governments, and American Indian tribes to help address this complex issue.

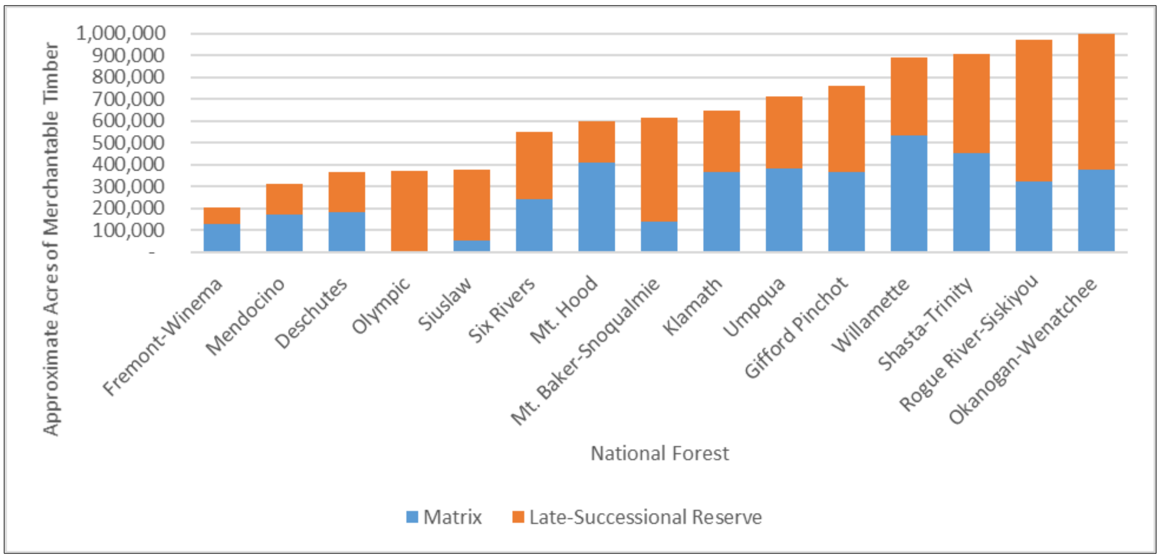


Figure 38. Merchantable timber acres in Northwest Forest Plan (NWFP) late-successional reserve and matrix

Approximate acres of merchantable size timber volume (more than 12,500 standing board feet per acre of standing tree volume) by forest and NWFP land use allocation: late-successional reserve and matrix. Not all forests have the same potential to sell additional timber volume based on future planning framework.

Eastside Screens Context

One component of the Eastside Screens that affects implementation of restoration and resilience projects and timber production is the restriction on harvest of trees greater than 21 inches diameter at breast height. The ecosystem standard requires a landscape-scale analysis of forest structure. If the results of this analysis indicate that there is a lack of late- and old-structure forest as compared with historic reference conditions (Scenario A), then no trees, regardless of species, greater than 21 inches diameter at breast height may be harvested within late- and old-structure forest. This component of the wildlife standard, intended to conserve large trees on a landscape where the largest trees were historically cut, can conflict with attaining desired conditions across the landscape. This is especially true where ingrowth of white fir and grand fir undermines the protection and culturing of ecologically desirable old trees and species fire tolerant species compositions in frequent-fire dependent and fire diverse (mixed severity) ecosystems. Currently, the only pathway for harvesting younger, shade-tolerate conifers more than 21 inches diameter at breast height under Scenario A of the wildlife standard, is with a forest plan amendment. We acknowledge that even when the best available science indicates that removal of trees more than 21 inches diameter at breast height is needed for restoration and resiliency, conflicting values around timber harvest or other types of active management still exist. Upcoming planning efforts will engage the general public, local and state governments, and American Indian tribes to help address this complex issue.

Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Recommendation 7: Expand the use of timber harvest as a restoration tool to provide economic and social benefits to communities.

Recommendation 8: Shift from single-species management to maintaining and restoring habitat for multiple species to help ensure we are managing our ecosystem to be resilient in the face of future change.

Recommendation 9: Promote active management in plant and animal habitats to restore and promote ecological resilience.

Geographic Considerations

The geographic considerations associated with the aforementioned key change issue “Management Options are Incompatible With Ecosystems” vary by ecosystem and interaction with management direction and are therefore complex. The section above highlights some of these considerations given fire, active management for landscape resilience, and timber output.

Key Change Issue 3—Dynamic Ecosystems Need Dynamic Plans

Our current forest plans are relatively static, but our ecosystems are not. There is a need to create planning mechanisms that integrate uncertainty and reduce risk of ecosystem or management failure in the face of anticipated change. This could include creating scenarios or processes that are triggered under various circumstances. Integration of upland forests with riparian and aquatic systems when planning is also needed for the overarching resilience of forest ecosystems. Ecosystem resilience, along with many ecosystem processes such as regulation of structure and nutrient cycling via naturally occurring fire, landslides, or insect and disease activity and habitats, can only be evaluated at a landscape or larger scale.

This dynamic need is also tied to evaluating and managing invasive species, including plants, insects, diseases, and animals; invasive species are increasing in diversity and extent across the BioA area and will have increased capacity to change forest ecosystem function and processes in the future. Invasive species generally reduce ecosystem resilience, which is of heightened concern in the face of climate change.

Planning Considerations

Integrate modern management concepts and tools to help us manage ecosystems toward resilient states and reduce risks associated with ecological and social uncertainty.

Refer to BioA Chapter 2 Management Recommendations

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 3: Update and consolidate the existing aquatic direction processes and analysis requirements.

Recommendation 4: Reduce the introduction and spread of plant, animal, and other invasive species.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Geographic Considerations

Within the BioA area, the effects of climate change are anticipated to be the greatest in northern California, southern Oregon, the eastern Cascades, and high elevation zones.

Key Change Issue 4—Ecosystem Restoration Tradeoffs

There is a need to strategically consider that some ecosystems will be more difficult than others to restore, stabilize function in, or proactively prepare for climate change. Turning the tide of rapid change in some frequent-fire dependent and fire diverse (mixed severity) ecosystems will be difficult given our current toolbox and ecological realities. Major, often irreversible, changes include broad landscape species composition shifts (for instance, shade-tolerate seed banks in large high-severity fire footprints), swings toward non-forest (for instance, rapid succession of fire in chaparral), or transition into novel states or landscape patterns (for instance, large-scale mortality of old-forest and legacy trees from a combination of insect, disease, drought and uncharacteristic fire (Franklin et al. 2018, Johnstone et al. 2016).

Under our new “Anthropocene”[12] epoch of human activity and climate change, “there are some historical ecological patterns and processes difficult or impossible to reestablish” (Corlett 2015 in Spies et al. 2018). The disproportionate increase in high-severity fire (without proportionate increases in low- and mixed-severity fire) in frequent-fire dependent and fire diverse (mixed severity) zones (Haugo et al. 2019) is contributing to the trend of moving frequent-fire dependent ecosystems toward novel alternative states (Lydersen et al. 2017, Prichard et al.2017), including non-forest and non-native (Hessburg et al. 2015).

---

[12] Relating to or denoting the current geological age, viewed as the period during which human activity has been the dominant influence on climate and the environment.

Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 4: Reduce the introduction and spread of plant, animal, and other invasive species.

For Further Consideration

Strategically consider that some ecosystems will be more difficult than others to restore or proactively prepare for climate change. Create regional and subregional strategies for ecological risk management. Balance investments for restoration and resilience management, given tradeoffs in value and opportunity cost related to (1) highly altered ecosystems, (2) ecosystems with inertia toward an altered state, and (3) ecosystems where there is opportunity and likelihood to create landscape resilience in the face of climate change.

Geographic Considerations

Fire infrequent forests are relatively functional and forest attributes that contribute to resilience are generally improving through time. These forests have a high capacity for carbon sequestration and the development of structural complexity. Currently, our most productive, fire infrequent and historically clear-cut forests (Coastal and Olympic) are still missing old-forest structural elements that are projected to develop through time and succession as trees grow larger. Within historic plantations, options to continue to enhance complex structural components, species composition or more complex landscape patterns through silvicultural methods are likely limited under current late-successional reserve management direction.

Frequent-fire dependent forest ecosystems do not currently reflect resilient reference conditions (East Cascades slopes and foothills, Klamath Mountains/California high north Coast Range) and are highly departed, given the metrics of forest structure, species composition, and landscape pattern. Frequent-fire dependent forests are becoming increasingly vulnerable to uncharacteristic vegetation shifts in the face of climate change. This includes the Cascades, Klamath, North Cascades, and portions of the Coast Range ecoregions. These areas are projected to continue to rapidly depart from resilient conditions because of interactions between fire exclusion, increased large fires with larger patches of high-severity wildfire, insects, disease, and changing climate.

There is a need to mitigate and adapt frequent-fire dependent landscapes to improve the ecosystem resiliency in the face of climate change. This could include assisted migration of plant species, creation of climate refugia, or landscape-scale planning for increased fire in transitional forest-grassland interface areas. In frequent-fire dependent ecosystems, multi-aged management, including the use of mechanical harvest, prescribed fire, and wildfire,[13] could help with retention of soil organic matter, microbial communities, and water storage to support long-term soil quality where shade-tolerant tree species dominate the landscape outside of reference conditions.

Fire diverse (mixed severity) forests are currently somewhat reflective of resilient reference conditions, but ecosystem function is becoming increasingly vulnerable to uncharacteristic vegetation shifts in the face of climate change—especially historically uncharacteristically large, high-severity wildfires. This is especially true in the Cascades, South Coast and portions of the north Cascades. Without proactive management to mitigate the effects of climate change, these national forests and grasslands will likely be measurably less reflective of resilient conditions soon because of interactions between changing climate, increased wildfire, insects, disease, and invasive species.

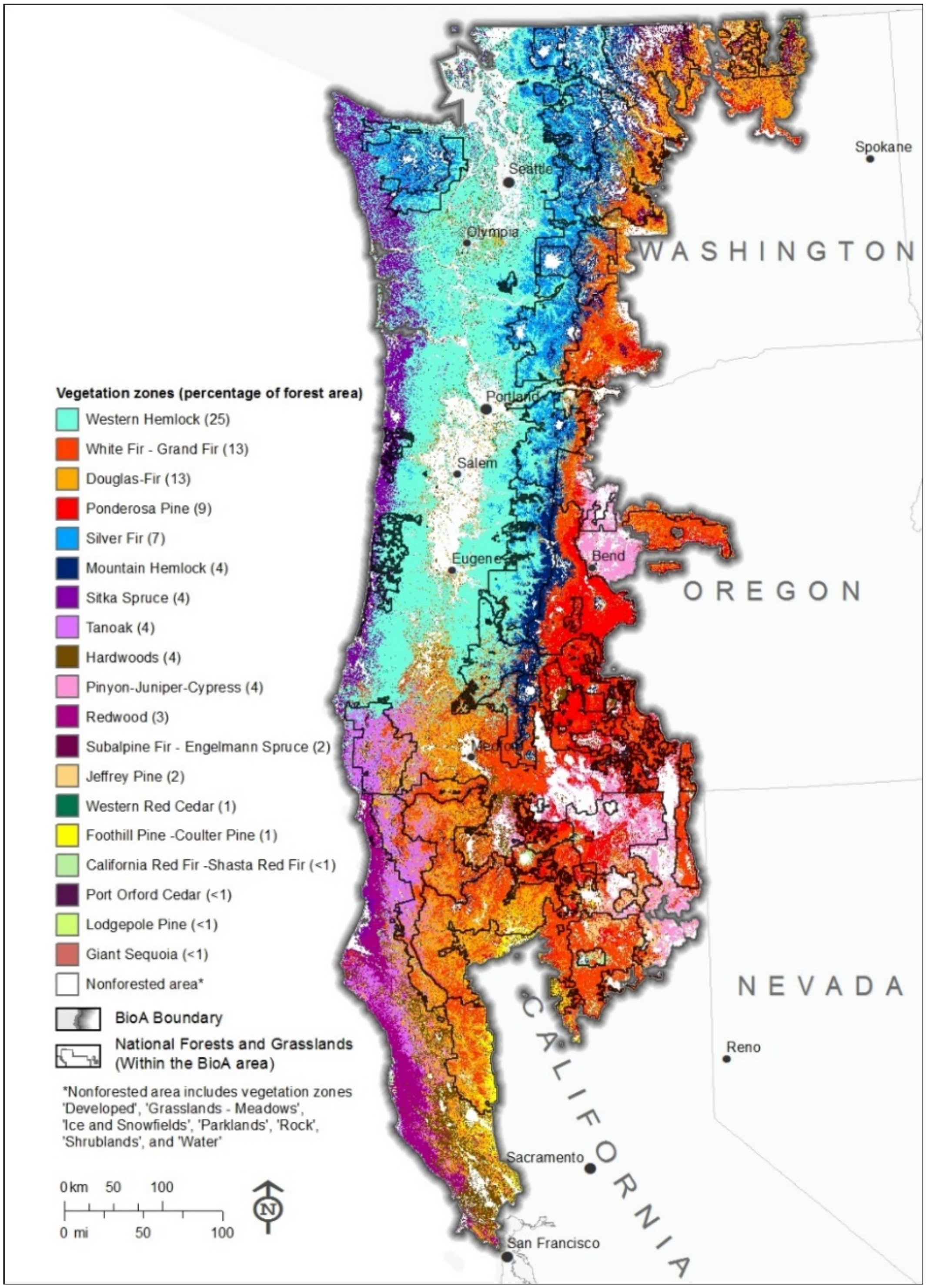
There is a need for strategic planning and ecosystem management direction related to proactively prepare for climate change. In fire infrequent forests there are special needs to manage in the face of projected increases in dramatic windthrow events, especially along the Washington coast. Across the BioA, there is a need to create strategic climate and fire refugia.

Soil types vary across the BioA, but in general, forest plan direction is similar across the whole area; it would be possible to address these needs at the BioA scale. There is variability, such as sandy or serpentine soils, which will need to be addressed on a sub-regional or forest scale.

Background Information to Support Key Change Issues

The BioA area is composed of highly diverse forest and non-forest ecosystems characterized by a broad variety of vegetation zones and species (map 12). In addition to providing a high-level characterization of the diversity of forests and ecosystem function and processes across this area, this document aims to describe how these forests have changed in the past 200 years, are changing now, and are projected to change into the future. Since European settlement, forest ecosystem conditions and functions have been considerably altered through a combination of fire exclusion, grazing, roadbuilding, invasive species, historic timber harvest, and other activities (DeMeo et al. 2018, Haugo et al. 2015, Keane et al. 2009, Landres et al. 1999, Morgan et al. 1994; Swetnam et al.1999; Wiens et al. 2012). Change is a continuing theme for our BioA ecosystems. The gap between resilient conditions and existing conditions is projected to continue to widen in the future, primarily as a result of climate change, the legacy of fire exclusion, and the interactions of these with insects, disease, and invasive species (Davis et al. 2017, Spies et al. 2018; map 12).

[13] Related terms: “let burn,” “natural fire management,” prescribed natural fire”; “wildland fire use for resource benefit,” also referred to as WFU or fire use (1995). Any natural fire could be managed for multiple objectives (2009)—“appropriate management response fires,” “multiple objective fires,” “managed wildfire.”



Map 12. Broad and diverse vegetation zones within the Bioregional Assessment area

These vegetation zones are named for the tree species representing land potential to support ecosystems and produce resources. The categorization serves as a framework for the intersection of climatic and productivity gradients across the landscape, including disturbance regimes (notably fire). Also represented on this map are Environmental Protection Agency class III ecoregions and Northwest Forest Plan physiographic provinces.

Photo 15. Complex early-seral forest after a stand-replacing fire in the Metolius Basin, Deschutes National Forest

Early-seral species that established after fire include manzanita, ceanothus, and conifers, such as ponderosa pine. Also pictured are fire-created snags and residual trees that survived the fire.

Photo 16. Forest in winter on Mt. Bachelor, Deschutes National Forest

Photo 17. South Fork Skokomish Trail on the Olympic National Forest

Photo 18. A meadow below Butler Butte lookout on the Umpqua National Forest

Call-out box 9. Non-forested lands

Non-forested ecosystems are found across the Bioregional Assessment area, and those landscapes provide resiliency, habitat, and a variety of culturally significant species. Major herbaceous and shrubland vegetation include grasslands, meadows, wetlands, vernal pools, chaparral, coastal and mountain scrub, sagebrush, alpine, and sparse vegetation.

These systems support high levels of diversity, provide habitat for wildlife, recreational opportunities, and important ecosystem services. Non-forested lands should be managed to maintain or improve wildlife habitat and rangeland conditions based on ecological parameters. Studies show that in many of our drier landscapes we have less non-forest and more forest than historically. In some cases, managing for national range of variation could mean reducing forest cover. There is a potential need to address desired ecological conditions in forest plans for terrestrial non-forested lands. "Essentially all natural temperate forest landscapes include areas that are not currently dominated by the tree life-form, although these historically may have varied widely in nature and extent with the forest region and disturbance regime" (Franklin et al. 2018).

Photo 19. Beargrass meadow on the Gifford Pinchot National Forest

Potential Vegetation

Potential vegetation serves as a useful integrator of climate, geomorphology, and soils to describe land capability to support ecosystems and associated resources. Whereas existing vegetation can vary with age and disturbance, potential vegetation serves to capture and describe the endpoint of where the sere (set of ecosystem stages over time) ends up. The modern view of potential vegetation focuses less on the ideal climax vegetation at the end of the sere, and more on land productivity, hydrologic and nutrient cycles, and disturbance regimes.

Natural Range of Variation

We can estimate if a landscape is resilient by comparing current forest structure, species composition, and landscape pattern to resilient reference conditions. Natural range of variation and historic range of variation are different names used for reference conditions. Understanding reference conditions is critical to putting resilience into management practice. For example, natural range of variation could provide percentages for how much old, mid-aged, young, and early-seral forest might be present on a resilient landscape. Reference condition values are usually predicted through modeling.

One of the most important applications of potential vegetation in recent years has been to serve as the framework for disturbance regimes, notably fire. Fire regimes are characterized by a recurring pattern of fire frequency and severity that can be described and quantified. For example, ponderosa pine ecosystems (potential vegetation) historically featured frequent low-intensity fire. In contrast, wet western hemlock potential vegetation is associated with infrequent but high-severity fire. Mixed-conifer vegetation is associated with a mixed-severity fire regime and has proven challenging both to describe and to manage on our landscapes. Through modeling techniques using tree-ring and other data, we can estimate what the range of historic fire frequency and seral stage abundance was for each potential vegetation type. By comparing this with current seral stages, estimates of ecological departure from natural range of variation can be developed. This becomes an important tool in planning restoration needs.

Past and Current Departure from Resilience

Naturally sustainable forest conditions, or natural range of variation, have been estimated for our forests. Departure or distance from this natural range of forest conditions is a measurement of how far and in what direction forests have moved away from resilient states.

A simplified analogy to help describe forest ecosystem resilience would be to the human body and overall health. When humans become weakened internally or externally, we become less resilient and less able to recover from disease, accidents, or normal stresses in our daily lives; we may become sick. This is akin to loss of forest ecosystem resilience. Forests ecosystem function can be weakened in a variety of ways and forests become less able to recover from forest disturbances, such as insects, disease, wind, and wildfire that forests would normally be able to bounce back from. Stresses that are a normal part of everyday forest life now can trigger ecosystem state changes. The healthy states defined in the natural range of variation were sustained for thousands of years and therefore give us a scientifically sound foundation for managing our forests toward more healthy and sustainable conditions into the future. The information in this section provides an ecological basis for how and where management could create more healthy forests. This ecological basis does not consider social acceptability as discussed in the introduction of this chapter.

Many ecosystems are currently departed from resilient conditions, and the gap between resilient conditions and existing conditions is projected to continue to widen in the future because of a variety of factors, including fire exclusion, the effects of legacy timber harvest and grazing, and climate change, and the interactions of all these with insects, disease, and invasive species. Shifts in forest structure and species composition and changes in disturbance processes have resulted in forests with too many trees, an unstable increase in shade-tolerant tree species, and systems that are out of sync with current and projected fire, insects, and disease conditions. The direction of change in a given ecosystem varies by primary drivers and productivity factors. Both restoration activities and succession support could be applied to move ecosystems toward more resilient reference conditions.

Current definitions of old forest are not reflective of the broad diversity of forests within the BioA and are not supportive of managing for resilient landscapes. Desired conditions (old-forest definitions) identified in existing land management plans are not fully aligned with resilient historical and future projected structure and composition, especially in systems that have been altered by fire exclusion, which include fire-dependent and more mixed fire diverse (mixed severity) landscapes (Spies et al. 2018).

Forest Structure

The term “departure” is used to describe how different current forest structural conditions are from historical or reference conditions. For this discussion we rely on standard Fire Regime Condition Class metrics (Barrett et al. 2010) to describe the natural range of variation. Current conditions that are less than 33 percent different than reference conditions considered within the natural range of variation. Conditions that are 33 to 66 percent different from reference conditions are considered moderately departed, and conditions that are more than 66 percent different than reference conditions are considered highly departed.

Current (2017) departure of forest structure from natural range of variation has been measured for the BioA. In addition, the need for forest restoration has been characterized. Restoration need has been described as (1) a need for succession restoration (that is, time to grow larger trees) and (2) a need for disturbance restoration (that is, reducing the number of trees via thinning or fire). Approximately 9.56 million acres in the BioA area currently need some type of restoration. This analysis is based on a comparison of current conditions to natural range of variation from LANDFIRE biophysical settings. About 7.4 million acres need some type of fire or mechanical treatment to reduce the number of trees; about 3 million of these acres also need succession restoration to grow larger trees. About 2.2 million acres within the BioA area currently need only succession restoration because the forests lack complexity and the trees need to grow larger.

Of the 7.4 million acres across the BioA area that need some type of disturbance restoration, about half are located within land management areas that restrict the implementation of mechanical forest restoration activities. About 46 percent of the identified area that needs disturbance restoration is in multiple-objective management emphasis areas, 20 percent is in forest plan timber production emphasis areas, 19 percent is in preservation, and 15 percent is in inventoried roadless areas. Of the acres in multiple-objective areas, about 470,000 are in riparian reserves.

Of the 2.2 million acres across the BioA area that need only succession restoration, 45 percent is in multiple-objective management emphasis areas, 20 percent is in preservation emphasis areas, 18 percent is in forest plan timber production emphasis, and 17 percent is in inventoried roadless areas.

Overall, frequent-fire dependent forests are consistently in need of disturbance restoration and are relatively highly departed from resilient conditions. About 4.8 million acres of the fire-dependent forests within the BioA area need some type of disturbance restoration and about 900,000 acres are also in of succession restoration. Fire-diverse systems are currently less departed, with only 1.7 million acres of departure needing some type of disturbance, and 650,000 acres needing succession restoration.

It is important to note that this departure analysis is an estimate that is likely under estimating departure in moister fire diverse (mixed severity) systems. Spies et al. 2018, find that, "Historical fire occurrence in these regimes (mixed severity) varied at centennial scales with climate and human population density (for example, Weisberg and Swanson 2003). Thus, given the occurrence of warm, dry conditions during much of the contemporary fire period, a rotation exceeding the upper end of the range suggests we are currently experiencing much less fire than would have occurred historically under a similar climate" (Spies et al. 2018 Vol. 1 p.139).

Vegetation Species Composition

Species composition of the forest, including the dynamic interactions between species composition and structure, are integral to gauging and managing for landscape resilience (Hessburg et al. 2016, Tepley et al. 2013). We know that species composition in fire-dependent landscapes historically were frequently disturbed and have had major shifts in species composition since the implementation of fire exclusion. For example, ponderosa pine, which thrive with and depend on frequent, low-severity fire, have declined throughout their range due to fire exclusion, while more shade-tolerant species such as white fir, grand fir, and Douglas-fir have expanded.

In moderately frequent or fire diverse (mixed severity) zones, species composition has shifted less dramatically since historical times, but has great potential for change owing to the inherent productivity of these areas. In moister fire diverse (mixed severity) landscapes, the effect of fire exclusion has been to reduce the amount of early-successional vegetation and change the quality and distribution of mid-successional forests that otherwise would now exist on the landscape. This has changed overall landscape-scale heterogeneity in forest composition, structure, and patch sizes (Haugo et al. 2019, Spies et al. 2018, Tepley et al. 2013).

Mixed-severity fires burning at intervals of 50 to 200 years would have created a mosaic of forest successional stages, including multi-cohort, old-growth stands. Differences and complexity inherent in mixed-fire frequency and severity have contributed historically to creating multiple development pathways for forests (Harvey et al. 2014, Stevens-Rumann et al. 2018). But because humans have altered fire frequency, seasonality (Balch et al. 2017) and severity, vast changes in ecosystem function and vegetation have also occurred (Haugo et al. 2019). This means that, in fire diverse (mixed severity) zones, fire exclusion has and will continue to reduce the variation of not only stand structure but also in the species composition and the dynamic roles these elements play in creating resilient forests now and into the future (Tepley et al. 2013).

Species composition is also critical when considering resilience to insects and disease. Species composition, in concert with forest density and structure (canopy layers), is the main driver of forest mortality from insects and disease. Species composition has shifted through time because of fire exclusion, extensive grazing, and selective harvest. Species such as Douglas-fir, grand fir, and white fir have moved down slope and into areas where their densities were historically kept low (large, fire-resistant individuals cultured) in a predominately ponderosa pine system (Hagmann et al. 2013, Heyerdahl et al. 2019).

Ecological Inertia

The inertia of species composition is also to be considered in the context of managing for resilient landscapes. Dry forests that have already had significant shifts in species composition are showing signs of changed successional pathways toward the regeneration of more shade-tolerant, less fire-adapted species. Under the new Anthropocene epoch of human activity and climate change, “there are some historical ecological patterns and processes difficult or impossible to reestablish” (Corlett 2015 in Spies 2018). “For example, field observations suggest that after recent wildfires, instead of regenerating to ponderosa pine or western larch, some areas now quickly regenerate to Douglas-fir and white fir, grand fir, subalpine fir, or lodgepole pine, despite intentional efforts (which often fail unless done well) to reestablish ponderosa pine or larch. The presence of abundant seed from shade-tolerant tree species (for example, firs) provides this inertia (Stine et al. 2014: 140).” Additionally, Franklin et al. (2018) give examples of frequent-fire forest ecosystems that, when disturbed after a long period of alteration (fire exclusion), are no longer able to return to their former state (Franklin et al. 2018: 352 and 378).

This is also the case with compounding disturbances (such as reburns) (Johnstone et al. 2016). Spies et al. (2018: 139) conclude that this “trend is likely to continue unless climatic changes alter the disturbance regime and the growth or survivorship of tree species.” Additionally, the disproportionate increase in high-severity fire (without proportionate increases in low- and mixed-severity fire) in frequent-fire dependent and fire diverse (mixed severity) zones (Haugo et al. 2019) is contributing to the trend of moving fire-dependent ecosystems toward novel alternative states (Lydersen et al. 2017, Prichard et al. 2017), including non-forest and non-native (Hessburg et al. 2015, Millar 2015).

Landscape Pattern

The pattern of patches of forested areas, along with their size, arrangement, juxtaposition, edge, and other descriptors, is another critical element to consider when measuring and managing for landscape resilience. Landscape patterns are made up of combinations of structure and species composition. The scale at which pattern is measured is important and ranges from fine-scale (tree clumps) patches or stands, neighborhoods, and landscapes (Hessburg et al. 2015). Landscape patterns can be influenced through use of mechanical and nonmechanical silvicultural systems, methods, and tools, including prescribed and natural fire, even- and uneven-aged silviculture and intermediate methods, such as variable-density thinning.

Focusing on landscape patterns as we develop strategies to increase resilience ensures that our efforts are consistent with the best available science, which supports increasing heterogeneity and forest structure and composition at multiple scales (Hessburg et al. 2016). Across the landscape, there appears to be a correlation between the loss of pyrodiveristy (diversity of fire size, frequency, and severity) and loss of habitat, biodiversity, and ecosystem resilience (Hessburg et al. 2016, Kelly and Brotons 2017, Perry et al. 2011, Spies et al. 2018; Tingley et al. 2016). Management of landscape patterns also has implications for wildlife habitat connectivity and juxtaposition (distance between suitable habitat patches) (Cansler and McKenzie 2014, Kolden et al. 2015).

Frequent-fire dependent ecosystems tend to have homogenization at the finest scales and largest scales, including trees clump and patches due to ingrowth and densification (Churchill et al. 2013, Fry et al. 2014, Lydersen and North 2012) and the impact of large wildfires (Spies 2018, Stine et al. 2014).

Patches in fire diverse (mixed severity) landscapes are naturally complex; however, much of this complexity has been lost through fire exclusion, historic grazing, and timber harvest (figure 39). Fire diverse (mixed severity) zones have experienced recognizable homogenization at all scales, but most recognizably at the stand, neighborhood, and landscape scales because mixed-severity fires operate at all these scales (Tepley et al. 2013). Disease and insects tend to operate at the finer sub-stand and stand scales when at endemic levels. Therefore, the effects of fire exclusion in fire-diverse forest tend to be less recognizable, but the effects are important. Unsuppressed fires of the past would have created more of a landscape mosaic of forest successional stages than exists today.

Although some stand level diversity exists in moister forests (for instance, clear-cuts from the 1980s next to older managed or unmanaged forest), these are not the same patterns or scale of disturbance that would have occurred historically. Fire exclusion has reduced landscape-scale heterogeneity in forest composition, structure, and patch sizes. This very complex mix is not easily measured or recognized. But, if we are to estimate the departure from resilient conditions, changes in fire diverse (mixed severity) landscape patterns needs to be acknowledged as divergent, where the changes have created less than desired levels of heterogeneity, and therefore resilience, currently and into the future.

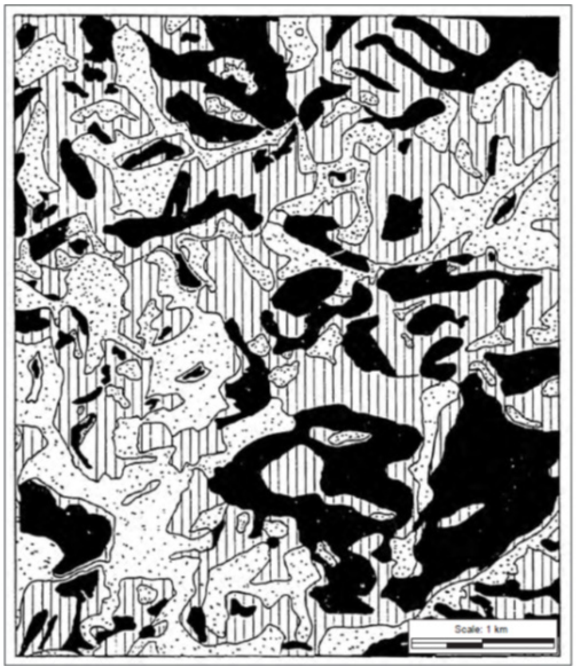


Figure 39. Patches in fire diverse landscapes

Patches in fire diverse (mixed severity) landscapes are complex. This complexity has been lost through fire exclusion. This example is from a Douglas-fir and western hemlock landscape in the western Cascade Range of Oregon. Black = a high mortality area (greater than 70 percent), vertical lines = moderate mortality (30 to 70 percent) and stippled = low mortality areas (less than 30 percent). From (Morrison and Swanson 1990).

Defining Old Forest

The interplay and connection between how we plan for and manage old forest and how we define and discuss old forest is important, especially when considering a definition for resilient old forest.

For example, the NWFP standards and guidelines provide the example that western Oregon Douglas-fir stands may begin the mature phase of stand development in around 80 years (p B-2) but offer little specificity on how to measure old forest among diverse physiographic provinces and ecosystems. Other general elements include live old-growth trees, snags, fallen trees, multiple canopy layers, small understory trees, canopy gaps, and patchy understories, with the caveat that all these characteristics will vary across vegetation types, disturbance regimes, and developmental stages. Distinctions between “older forests,” “late-successional,” and “old-growth forests” in forest plans, amendments, and subsequent guidance are also layered with either complexity or ambiguity.

Descriptions and definitions of old-forest structure and composition continue to be detailed in policy and scientific literature (Franklin et al. 1986; USDA FS 1989, 1992, 1993; Dunbar-Irwin and Safford 2016; Franklin and Johnson 2013; O'Hara et al. 1996; Safford and Stevens 2016; Spies et al. 2006; Youngblood et al. 2004). Since the implementation of the NWFP, our understanding and ability to measure and describe old forest and distinguish between the many types of old forest across the landscape have progressed, but most current definitions are still not reflective of historical structure and composition, especially for fire-dependent landscapes (Spies 2018).

The Old Growth Structural Index (Daviset al. 2015) has improved our ability to measure old forest; however, it is based on current forest conditions, not necessarily old forest as it would have looked before historic harvest, grazing, and fire-exclusion effects (figure 40, figure 41). Further work is needed to be able to measure and implement restoration of functional old forests across wet as well as frequent-fire dependent landscapes.

Call-out box 10. Old forest

The Northwest Forest Plan Science Synthesis defines old-growth forests based on live and dead structure and tree species composition. Old-growth forests in the plan area differ with age, forest type, environment, and disturbance regime (Reilly and Spies 2015, Spies and Franklin 1991). The variability and complexity of site conditions, forest succession, and disturbance processes make defining old growth difficult or impossible under a single definition. Current definitions of old forest also are not reflective of resilient conditions. This includes misalignment of desired conditions (old forest definitions) with resilient historical and future projected structure and composition, especially in frequent-fire dependent and fire diverse (mixed severity) landscapes. "Old forests are inextricably intertwined in space and time in a continuum of forest development, just as young, mature, and mixed-age forests are. Focusing on only one part of the continuum is like trying to understand light by examining only one color or wavelength, or like trying to understand a river by looking only at the deep, quiet pools and ignoring the rapids (Spies 2009).

Photo 20. Old-growth forest on the Gifford Pinchot National Forest

Photo 21. Old-growth forest on the Deschutes National Forest

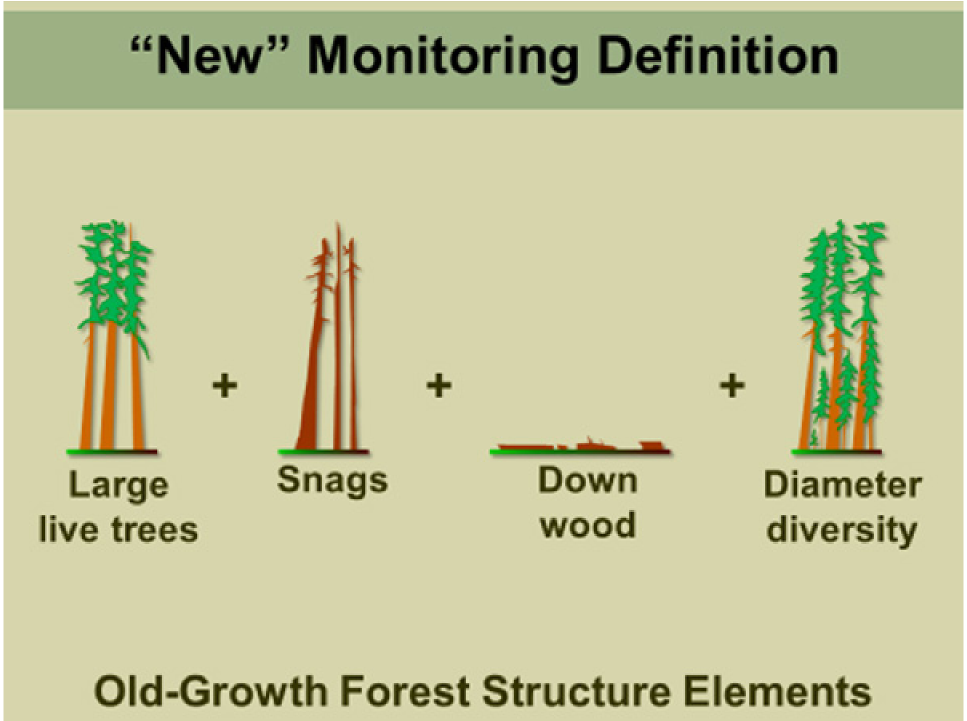


Figure 40. Old-growth structural index (OGSI) components

These components include large live trees, snags, down wood and diameter diversity.

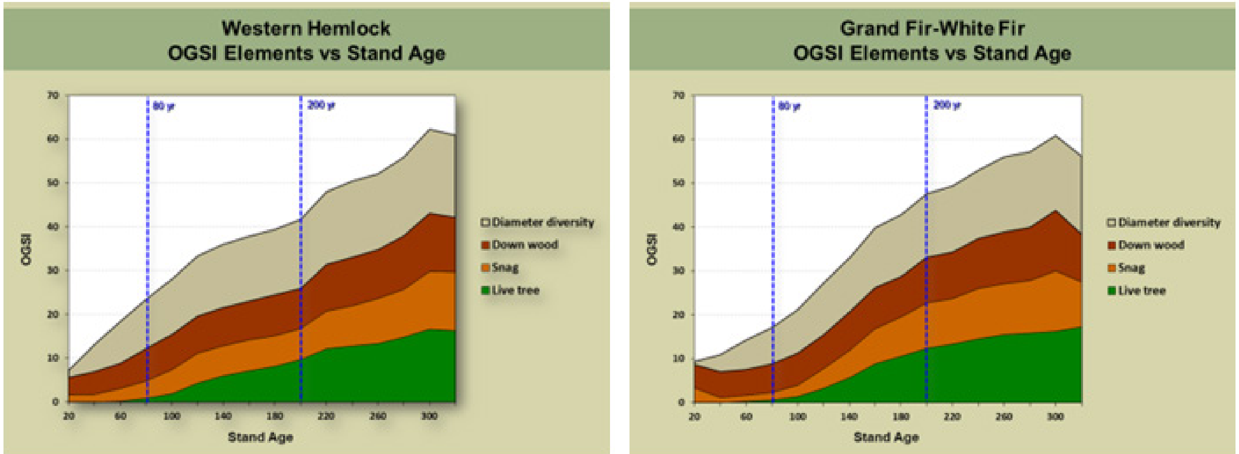


Figure 41. Forest types, old-growth structural index, age and compositional elements

These figures display how different forest types (here western hemlock and grand fir/white fir) differ in forest compositional elements, including diameter diversity, down wood, snags, and live trees at the different age thresholds of old-growth structural index and age including 80 and 200 years.

Other Vegetation Conditions, Including Quality Early Seral

Considering early-seral forest and habitat, along with all the other classes of forest structure and development, is part of whole ecosystem management (Spies et al. 2018). The NWFP Record of Decision (USDA FS and USDI BLM 1994: 47) points out that in 1994, there was more early-successional habitat within the NWFP area than at any other time in history, and did not necessarily create mechanisms for creating more, especially on federal lands, as early-seral conditions were assumed to be created on non-federal lands through timber harvest practices. An assessment of landscape-scale restoration needs in the BioA area indicated that from a restoration perspective, there is not necessarily a regional need for development of early-seral forest, as there is an abundance of relatively simple early-seral forest on private lands (DeMeo 2018: 26).

However, there is a need for “complex” early-seral forest with higher ecological and habitat value. Complex early-seral habitat has been examined by Swanson et al. (2011), and in essence, complex early-seral forest differs from more simplified early-seral forest. Complex early-seral forest is often naturally occurring; it has high species diversity and is made up of legacies, including live and dead trees that provide habitat for surviving and colonizing organisms. Traditional forestry practices such as clear-cutting, salvage logging, and tree planting can reduce species richness and key ecological processes associated with complex early-seral habitat (Swanson et al. 2011). Phalan et al. (2019) found that early-seral habitat has remained stable overall on federal lands but declined on the Coast Range and in the Cascades ecoregions.

Old-forest conservation on its own will likely not be the only answer to conservation of old-forest habitat and there is a need to take a broader look at the balance of all structural and seral stages, their arrangement, and projected persistence through time (Spies et al. 2018).

Call-out box 11. Complex early-seral forest

While complex early-seral habitat was not a focus for the development of the standards and guidelines for the Northwest Forest Plan, there is now a compelling amount of scientific research documenting the importance of complex early-seral habitat for a variety of plant and wildlife species (Swanson et al. 2011, 2014; Phalan et al. 2019). Complex early-seral habitat is most often derived from stand-replacing forest disturbances, including wildfires, severe insect infestations, volcanic eruptions or extreme weather events, that leave behind residual large-diameter green trees, snags, and an abundance of downed wood, which are soon joined by understory grasses, hardwoods, shrubs and flowering plants (photo 22).

Photo 22. Complex early-seral habitat created by fire along the Fish Lake Trail 1570 on the Umpqua National Forest

Insects and Disease

Insects and disease are part of functioning ecosystems and can also be helpful indicators of ecosystems that are becoming less functional. Population dynamics and feedback loops between various disturbance agents like root diseases and bark beetles play an essential role in regulating, shaping, and driving our forested ecosystems. Insects respond when vegetative conditions move away from resilient conditions; levels of insect- and disease-caused mortality outside of natural ranges of variation or expected norms can indicate that forest structure, density, species composition, and landscape patterns are divergent from resilient conditions.

In combination with changing climate and wildfire, insects and disease will likely have changing effects across the region, especially where species like mountain and western pine beetles can broadly affect old forest by killing the largest relict trees. Nationally, Oregon tops the list in both absolute acres and proportion of risk (Idaho and Montana are also in the top three states). Primary agents of risks in the BioA area align in fire-dependent forests and include mountain and western pine beetles, along with a combination of root diseases, Douglas-fir beetle and spruce budworm (Krist et al. 2014).

Insects, Pathogens, and Climate Change

Biotic disturbances, such as insects and pathogens, can generally increase stand-scale mortality and may erupt into epidemic outbreaks with high levels of tree mortality (Raffa et al. 2008). They do not always result in immediate mortality, but instead depress tree growth and vigor and make trees less resistant to wind disturbance, predisposing them to stem breakage (Hansen and Goheen 2000, Larson and Franklin 2010, Manion 1981). Although mortality rates associated with insects and disease are generally much lower than those associated with fire in this region, insect activity has resulted in more loss of live carbon and canopy mortality than has fire in recent years at the scale of the BioA (Berner et al. 2017, Hicke et al. 2016, Reilly and Spies 2016).

Native insect and pathogen activity is likely to increase as trees experience more growing season drought; however, the magnitude of effects will likely vary geographically as well as among species (Chmura et al. 2011, Kolb et al. 2016, Sturrock et al. 2011). In addition to affecting host species, climate change will also affect population dynamics and geographic distributions of pathogen and insect species. Increases in insect activity are driven by drought and extreme weather events. Pathogen activity is likely to increase in areas where they typically infect drought-stressed host species, while the effects of climate change on pathogens that proliferate under moist conditions may be more variable and difficult to predict (Sturrock et al. 2011). Warmer winters and hotter droughts are expected to enable insects to move into previously unsuitable habitat (Bentz et al. 2010, 2016). Drought and insects may also interact to further stress trees and predispose them to mortality. Several nonnative pathogens and insects are of particular concern in the BioA area (see Reilly et al. 2018).

In 2012, insect and disease risk was assessed nationally. Risk, or hazard, in the National Insect and Disease Risk Maps is defined as the potential that, without remediation, 25 percent or more of the standing live basal area of trees over 1 inch in diameter will die over the next 15 years due to insects and disease (Krist et al. 2014). This risk assessment was updated in 2017 to reflect tree mortality in the current risk assessment period (2012–2027); the Forest Health Assessment and Applied Sciences Team recently updated the 2012 risk map to indicate areas where mortality has been averted through forest management, has already occurred, is ongoing, or has yet to be observed, associating those latter categories with opportunities for restoration, exclusion and prevention.

For the BioA area, we have identified areas where prevention opportunities exist in synergy with forest plan management emphasis categories and how prevention opportunities intersect with national forests and grasslands in the BioA and fire-dependency categories.

Call-out box 12. Non-native forest invasive insects and diseases

> *"Nonnative invasive plants, insects, and disease can have major economic and ecological effects on forests. …there are several species of plants and pathogens that are having or could have significant impacts on forests within the NWFP [Northwest Forest Plan] area" (Spies et al. 2018). Invasive diseases and insects with significant effects on forests of the BioA area include pine blister rust, Port Orford cedar root disease, sudden oak death, balsam woolly adelgid, and emerald ash borer. Adaptive land management direction has allowed for forests to address these changing threats to individual tress and forested areas across the Bioregional Assessment area. Including similarly adaptive planning components in future land management plans can help forests address current evolving and as-of-yet unknown risks.*

Harvest Methods Context

Timber harvest history has dramatically shifted over the life of the NWFP (photo 23, photo 24, photo 25). Timber sold volume levels on Forest Service lands within the NWFP area have totaled about 456 MMBF over the past 10 years (2009–2018), and 381 MMBF over the previous 10 years (1999–2008), with a low of 213 MMBF in 1995. The type of harvest method, or silvicultural method, has also shifted dramatically. The use of clear-cut regeneration harvest has been virtually eliminated.

Over the past 20 years, harvest methods have shifted primarily to commercial thinning. This is an intermediate type treatment meant to grow larger trees and increase stand health, but not to regenerate new trees. From a forest management perspective, this shift toward commercial thinning meets stand-level needs to grow larger trees; preserve and promote old-forest architecture and components; and, where appropriate, reduce stand stocking levels to promote forest health, individual tree growth, and reduce fuels. This shift has worked in many areas to both meet ecological needs and sustain the timber industry.

Photo 23. Historic clear-cut

This historic 1990s clear-cut in a mixed-conifer stand in California shows the shaded southern edge (left side of photo) of the clear-cut contrasted by the well-lit interior and northern edge.

Photo 24. Variable density thinning

A current example of ground-based variable density thinning on the Mt. Baker-Snoqualmie National Forest.

Photo 25. Prescribed fire-treated stand on the Fremont-Winema National Forest

Call-out box 13. Evolving timber harvest methods

Forest Service harvest methods have shifted from primarily clear-cutting in the 1980s and early 1990s to mainly commercial thinning for the past 20 years. In the 21st century, ecological forestry has become central to how foresters approach landscape planning. This includes the use of natural forest ecological models and natural forest development and disturbances such as fire in project design and harvest methods.

More diverse commercial thinning harvest methods such as variable density thinning; individuals, clumps and openings; multi-aged management; and variable retention harvest have evolved since 1994 and become broadly studied and implemented. The Forest Service is dedicated to supporting the study and use of these more diverse silvicultural techniques and systems to meet today's need for resilient landscapes and multiple land management objectives.

Ecological forestry, multi-aged management, variable retention and other modern harvest methods are likely our best options moving forward, especially in the face of climate change and social and ecological uncertainty.

"Silviculture carries the implication of active rather than passive human participation in the initiation and development of forest ecosystems. This has probably never been more appropriate than in the 21st century when humankind has altered so many of the fundamental conditions under which forest ecosystems have evolved. We believe forests in this century will often require human participation to assist them in their continued adaption to shifting environments and disturbance regimes (Franklin et al. 2018: 92)."

The summary here is based on definitions of silvicultural methods as historically and currently defined by the U.S. Forest Service Forest Activities Tracking System database (FACTS). As Franklin et al. (2018: 91) state, "Traditional terminology often fails to convey clearly the treatments that are being done, because over time, these terms have been used in many diverse ways." Although the Forest Service works to track activities within a historical database, one of the drawbacks of this method is that the details of silvicultural prescriptions are not necessarily conveyed. For example, variable density thinning is likely categorized simply as commercial thinning, although various levels of retention and removal occur across the broad range of prescriptions implemented in various ecosystems (figure 42 and figure 43). As Forest Service silviculturists have moved into the post-NWFP era, landscape ecology has become central to how foresters approach landscape planning; land managers now use ecological models from natural forest systems as a basis for managing forests, incorporating principles of natural forest development, including the role of natural disturbances, in the initiation, development, and maintenance of forests and forest landscape mosaics (Franklin et al. 2018: 92).

Desired ecological outcomes are unlikely to be met with commercial thinning alone. Generally, commercial thinning includes keeping the dominant trees in the stand, and may integrate forest health evaluations; however, intermediate thinning prescriptions do not include regeneration of any tree species as a primary purpose. This means that commercial thinning is an incomplete method for changing the dominant species composition of a forest in the long run, especially where more drought-tolerant and fire-adapted species are desired. For example, many forests that used to be dominated by ponderosa pine are now dominated by white fir or grand fir. Thinning in these forests will not necessarily recruit ponderosa pine back into the forest. If regeneration of trees does occur, the method promotes shade-tolerant (usually fire-intolerant) species. Even in variable density thinning, small created openings are not planned to necessarily regenerate a new cohort of trees, rather the purpose is primarily spatial heterogeneity. This means that when variable density thinning is applied as a part of a Forest Service silvicultural system, it is planned as an intermediate treatment and the tending and care of regenerating trees is not considered for the short or long term.

Regeneration of trees, especially sun-loving and relatively drought-tolerant Douglas-fir (in wetter sites), ponderosa pine and western larch, will not be successful with commercial thinning. Additionally, commercial thinning is meant to fit within a larger plan for how to work with forest succession. Since little mechanical regeneration of forests has occurred since about the mid-1990s, wildfire is currently the primary regeneration agent. Wildfires, especially uncharacteristically severe wildfires, often create more extreme regeneration conditions than would otherwise occur. This includes highly altered microclimates for tree regeneration and distance to seed sources, which may result in alternate pathways of forest development that may not be optimal, particularly in the face of climate change.

From a timber production and ecological restoration standpoint, relying solely on commercial thinning is also unlikely to be sustainable into the future, especially given existing limitations on vegetation management. The board-feet-per-acre volume production for a thinning from below (commercial thinning) project is generally much smaller than for another harvest method, such as single tree selection, group selection, or shelterwood harvest. When thinning from below, the smallest diameter trees are generally harvested. It takes many small trees to equal the volume of one larger tree, and the product may be completely different (for example, pulp or biomass for small trees and sawlogs for larger trees). The balance between logging operation costs, the value of the timber product, haul distance to mill, and market usually creates a situation in which smaller diameter tree thinning tends to be economically borderline. Depending on market values, timber sales can provide a profit or be a deficit. When even just a few larger trees are included in sales such as these, volumes and marketability increase, creating more stumpage value in the timber sale.

Skog et al. (2006) show that prescriptions that are not thinning from below can reduce the subsidy required for treating forests, increase the volume in the local market, and increase the value (sawlogs) of sold material. This increased public harvest volume benefits consumers, loggers/buyers, and mills, although private landowners may experience lower stumpage prices. Prescriptions that go beyond thinning from below can improve the value-to-cost comparison for a treatment and more volume can be produced. More diverse prescriptions that include tree species selection, gap creation, or various levels of regeneration such as single-tree selection, group selection, or shelterwood harvest can make some sales more viable and could benefit local wood processing infrastructure and workforce.

Furthermore, as forests continue to grow, the management direction in our forest plans, including age limitation on harvest within late-successional reserves (80-year exemption) and Eastside Screens 21-inch-diameter at breast height harvest restriction in old-forest-deficient landscapes, are increasingly broad. At a regional scale, these rules may not allow implementation of best available science on the forests for which they were designed. This is especially true when we consider desired conditions related to species composition, density, structure, and landscape pattern in old forests, and old-forest resilience through time. For example, shade-tolerant trees that are a product of fire exclusion in Eastside Screen areas will continue to grow larger than 21 inches diameter at breast height but would not be harvestable under current plans without forest plan amendment.

The integration of approaches such as ecological forestry (Franklin et al. 2018) and tools like multi-aged management harvest into the forest plans would help create modern desired outcomes across the landscape. Continued reliance solely on traditional intermediate commercial thinning at the current rates across the BioA area limits options for the creation of resilient landscapes through time. This could be especially valuable in frequent-fire dependent and fire diverse (mixed severity) ecosystems, where multi-aged silviculture and ecological forestry offer options for successfully coproducing timber and positive timber sale revenues where inherent productivity may limit the volumes produced per acre under traditional intermediate thinning practices.

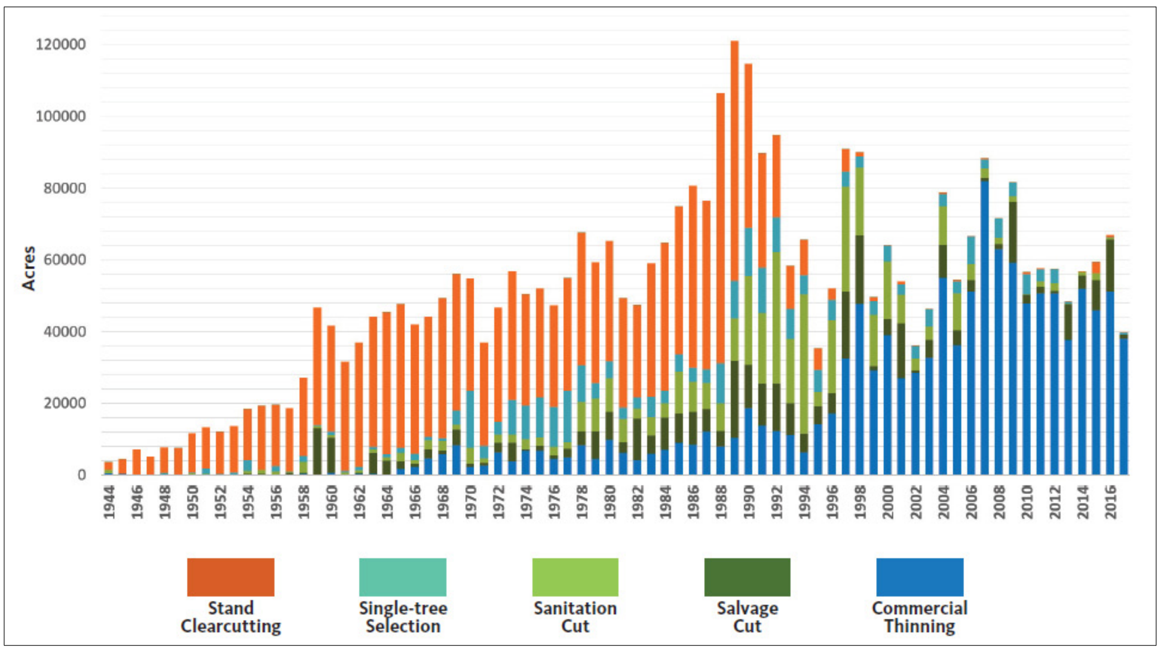


Figure 42. Acres of the primary harvest types within the Bioregional Assessment area from 1947 to 2017

Harvest types include clear-cutting, commercial thinning, salvage, sanitation, and single-tree selection. Peaks of activity include more than 75,000 acres of clear-cutting in 1988. In 2007 there was a peak in commercial thinning at just less than 82,000 acres. Timber harvest practices have moved to mostly commercial thinning, with almost no stand clear-cutting. Even with area harvested being similar to that in the 1970s, the volume is much lower due to the differing harvest types.

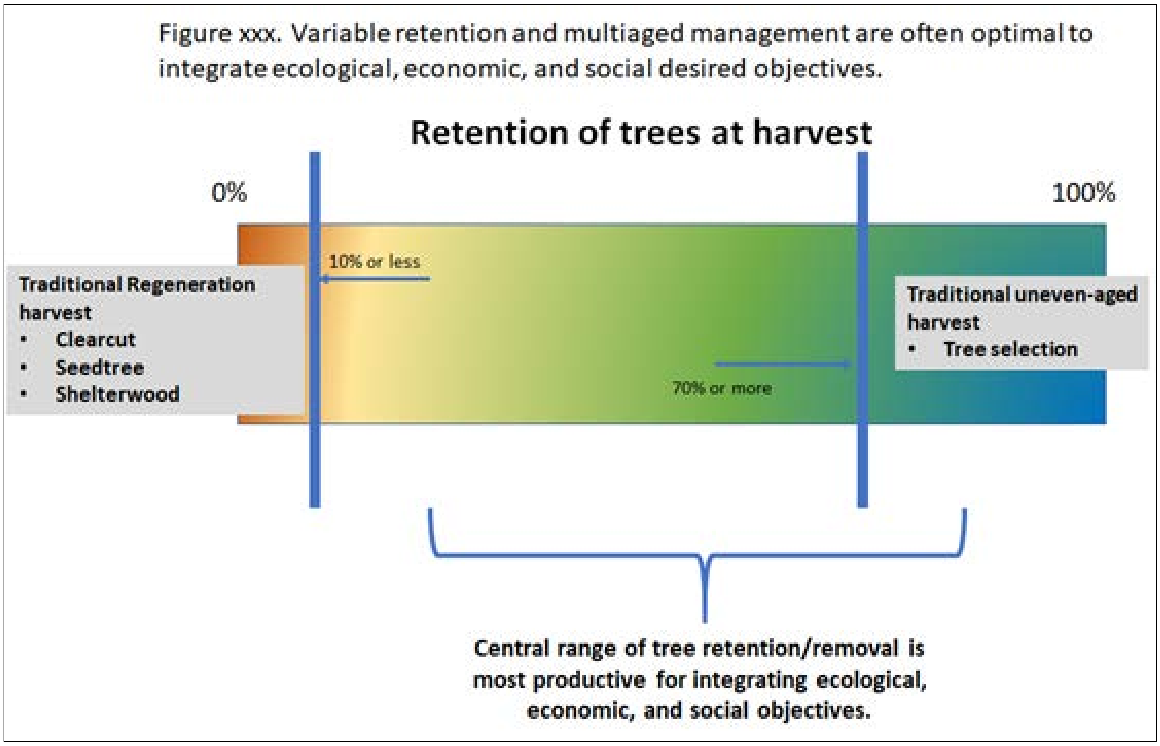


Figure 43. Variable retention and multiage management are often optimal to integrate ecological, economic, and social desired objectives.

Knowledge Gaps

Forest ecology, particularly landscape ecology, is a relatively new and rapidly developing field of study. Modern definitions of the discipline originated in the mid-1980s (Turner et al. 2001). Knowledge gaps, or topics of which we know there is incomplete understanding or lack of information, are common as they are with many aspects of natural resource management. We can point to knowledge gaps in places where new study and understanding are needed. We also know that knowledge gaps exist in locations where the public and land managers need to make recommendations and decisions based on the best information available in conjunction with strategic thinking, planning, and implementation. Primary areas discussed here with data gaps include the following:

- Mixed-severity fire regimes
- Moist and mixed-conifer forests
- Ecological forestry and multi-aged silviculture techniques
- Landscape patterns
- Vegetation species composition
- Forest structures, including complex early-seral and old forest
- Ecosystem resilience, reference conditions, and the natural range of variation

Call-out box 14. Uncertainty and risk in land management

Managing natural resources is especially challenging due to the inherent complexity of managing living things that are affected by randomly determined processes, such as fires and floods. It was important to consider uncertainty and risk in any projections and effects of land management decisions in this Bioregional Assessment, such as climate change and its impact on vegetation and disturbances. Not acknowledging uncertainties and tradeoffs can result in an underinformed decision. Incorporating uncertainty into decision-making and communications with the public to acknowledge risk can help update plans and meet new challenges nimbly.

Methods for dealing with uncertainty:

-Focus on ecosystem resilience

-Short-term and long-term goal setting

-Less focus on hypothetical desired future conditions and more on desired ranges that can be adapted to changing conditions.

-Plan for potentially dramatic changes in social, economic, and ecological changes

-Develop early warning systems

-Accelerate learning through communication and use of available technology

-Adaptive management

"The future has always been unknowable, but the levels of uncertainty about both future environmental and social conditions are extraordinary in this century" (Franklin et al. 2018).

Terrestrial Wildlife

Introduction

The Forest Service has a critical role in contributing to biological diversity by managing habitat for a broad array of species. Land management plans provide direction and a framework for habitat management. Maintaining or restoring ecological integrity provides for the habitat needs of species and the diversity of plant and animal communities ("coarse-filter" approach). Sometimes, when this is not enough, there is a need for additional, species-specific management that focuses directly on one organism's population and habitat ("fine-filter" approach).

Although the protections created by the NWFP reserve networks have been effective in stemming the loss of old-growth forest, dependent species continue to decline, and new species have been listed since the amendment was enacted. There is a need to evaluate the effectiveness of the current reserve network in providing habitat for northern spotted owl, marbled murrelet and other old-forest-dependent species, while also recognizing the value of healthy and well-represented forest types of multiple successional and seral stages, including complex early seral, and maintaining habitat linkages and corridors.

Call-out box 15. Benefits of wildlife

The importance of a biologically diverse ecosystem is difficult to quantify but should be acknowledged. Diverse ecosystems are generally thought to be more resilient to change than nondiverse systems. Communities of plant and animal species are interdependent.

Besides the clear relationship to a healthy ecosystem, wildlife provides a variety of social and economic values to humans. For example, some species provide inspiration (aesthetic values), some provide information and resources (economic values), and for some people, wildlife have inherent value. In recent years, the value of wildlife to Northwest Forest Plan-area communities has been estimated in terms of the economic benefits that wildlife-based recreation provides. Spending by anglers, hunters, and wildlife watchers on National Forest System lands within the Bioregional Assessment area contributes considerably to both local and regional economies (USFWS 2011b, 2016).

For example, a 2011 survey conducted by the U.S. Fish and Wildlife Service found that 2.7 million people age 16 or older in Washington, 1.7 million people in Oregon, and 7.8 million people in California participated in fishing, hunting or wildlife viewing. The revenue generated from these activities was $24.79 billion in Washington, $21.7 billion in Oregon, and $7.58 billion in California.

What is Working Well

What is Working Well 1—Reserve Network

Much of what is working well for terrestrial wildlife habitat and biological diversity is closely integrated with ecological integrity. The reserve network, including late-successional reserves, riparian reserves, and congressionally reserved lands, is part of a landscape-scale approach that has worked well in supporting the conservation of habitat for wildlife species. Creation of designated areas and land use allocations that focus on species recovery has included clear and effective management direction in the context of habitat protection.

What is Working Well 2—Conservation of Dense Multi-layered Old-growth Forests

The NWFP conservation strategies and other strategies, including the Eastside Screens and the Sierra Nevada Framework, have effectively stopped the loss of old trees and old-growth forest on federal lands from timber harvest, mainly in dense, multi-layered forest (Spies et al. 2018a).[14] Old-growth forest is generally considered stable on federal lands and has increased slightly since 1993, providing the abundance, diversity, connectivity, and availability needed to support ecosystem functions and specific old-growth-dependent species in the BioA area (Davis et al. 2015; Davis, in progress).

[14] The “working well” of “Conservation of Dense Multi-layered Old-growth Forests” may seem like a dichotomy as the “Forest Ecology” section (“Key Change Issue 2”) outlines how many types of old forest, other structural stages, and overall ecosystem resilience is declining across much of the BioA area. In many respects, the NWFP has been successful in conserving old-forest ecosystems. However, conservation of a specific types of older forests does not necessarily ensure ecosystem resilience and integrity across the diversity of landscapes in the planning area. Threats to old-growth forests vary, depending on forest type and geographic location, but are heightened due to changing climate.

The northern spotted owl, listed as threatened under the Endangered Species Act (ESA) in 1990, is one of many species that relies on old-growth forest habitat. The reserve network established by the NWFP has been effective in stemming the loss of old-growth habitat from timber harvest on federal lands (Lesmeister et al. 2018); however, the owl population continues to decline. The reserve network has also been effective in maintaining and enhancing marbled murrelet habitat on federal lands; however, the birds continue to experience population declines in the northern portion of the BioA area (Raphael et al. 2018). Since the NWFP was adopted, additional conservation focus has been placed on other species, including marten, fisher, wolverine, and other mammalian carnivores who also depend, in part, on late-successional forest habitats.

What is Working Well 3—Survey and Manage

The survey and manage guidance in the NWFP requires that surveys for certain species be conducted before initiating management actions, and actions are limited based on the results of the surveys. Survey and manage has added much to our knowledge about rare and uncommon late-successional and old-forest-dependent species in the NWFP area (Marcot et al. 2018) and has resulted in species not being listed under the ESA. Also, some species have been removed from the survey and manage list after the increased survey efforts resulted in the discovery that they are more common than previously expected. Survey and manage mitigation measures help us focus on certain species and contribute to the modernization of forestry practices, such as leaving more dead trees, downed wood, and refugia habitat. However, the survey and manage program has not been without its challenges, and improvements and updates are needed.

Key Change Issues

Key Change Issue 1—Northern Spotted Owl Habitat and Planning Direction

When critical habitat was designated for the northern spotted owl in 1992 under the ESA, the habitat was designed to be consistent with the late-successional reserve network. However, under the 2012 critical habitat designation, some matrix lands were identified as critical habitat. There is a need for land management plan direction that better aligns with the U.S. Fish and Wildlife Service’s northern spotted owl recovery plan (USFWS 2011a) (figure 44 and map 13) and critical habitat final rule (Spies et al. 2018b). Better alignment is needed between designated critical habitat for spotted owls and the late-successional reserve network; this could help simplify management direction and better protect high-quality habitat for owls and other species that depend on dense, multi-layered, old-growth habitat, such as marbled murrelet. Additionally, better alignment with northern spotted owl recovery plan guidance, specifically recovery actions 10 and 32, and land management plan components could help streamline project planning and consultation (recovery action 10 involves conserving spotted owl sites and high-value spotted owl habitat to provide additional demographic support and recovery action 32 calls upon land managers to maintain and restore all high-quality northern spotted owl habitat that has large diameter trees, high amounts of canopy cover, and decadence components such as snags, downed wood, and broken-top live trees). In addition, management direction that is consistent with both the recovery plan and critical habitat final rule and that calls for active management to restore and improve ecosystem resilience could help conserve and develop northern spotted owl habitat in the long term.

The protections created by the NWFP reserve networks have been effective in stemming the loss of northern spotted owl habitat from timber harvest on federal lands (Lesmeister et al. 2018). National Forest System lands serve as the primary federal habitat for the northern spotted owl due to the large areas of connected suitable habitat and regulatory mechanisms that are protective of threatened or endangered species. There is a need to ensure the reserve network continues to function as intended in the face of a dynamic and ever-changing ecosystem, including addressing the alignment of designated northern spotted owl critical habitat and the current distribution of late-successional, old-growth habitats across the entire planning area (map 14).

Call-out box 16. Northern spotted owl

The historic range of the northern spotted owl stretches from southwest British Columbia through the Cascade Mountains and Coastal Ranges in Washington, Oregon, and northern California. A key component of northern spotted owl habitat is structurally complex older forest, especially for nesting and roosting. Early-seral habitat (for example, openings) is also important, especially in the drier portions of the northern spotted owl range. The Northwest Forest Plan and the Endangered Species Act have helped protect and enhance spotted owl habitat on federal lands, but habitat protection will not be enough to ensure long-term viability of the species (Lesmeister et al. 2018). Despite current protections, the species' population continues to decline each year throughout its range. This decline is thought to be driven by continued reduction of nesting and roosting habitat, particularly on non-federal lands, increasing habitat loss from wildfires, and competition with expanding populations of barred owls. Climate change projections indicate that suitable habitat for spotted owls will shift northward and to higher elevations (Carroll et al. 2010). The complex topography of the Cascades and Klamath Mountains could provide extensive refugia in shaded canyons and other microclimates. Future management considerations should include northern spotted owl competition with other species as well as the complex and dynamic habitat within the Bioregional Assessment area.

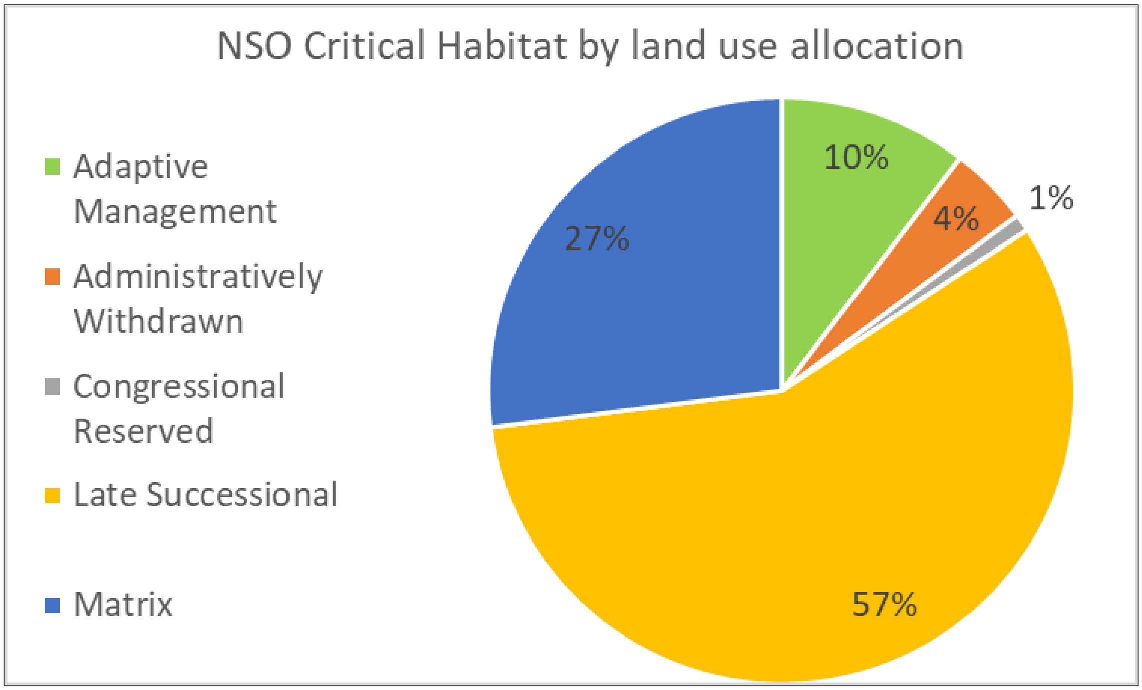
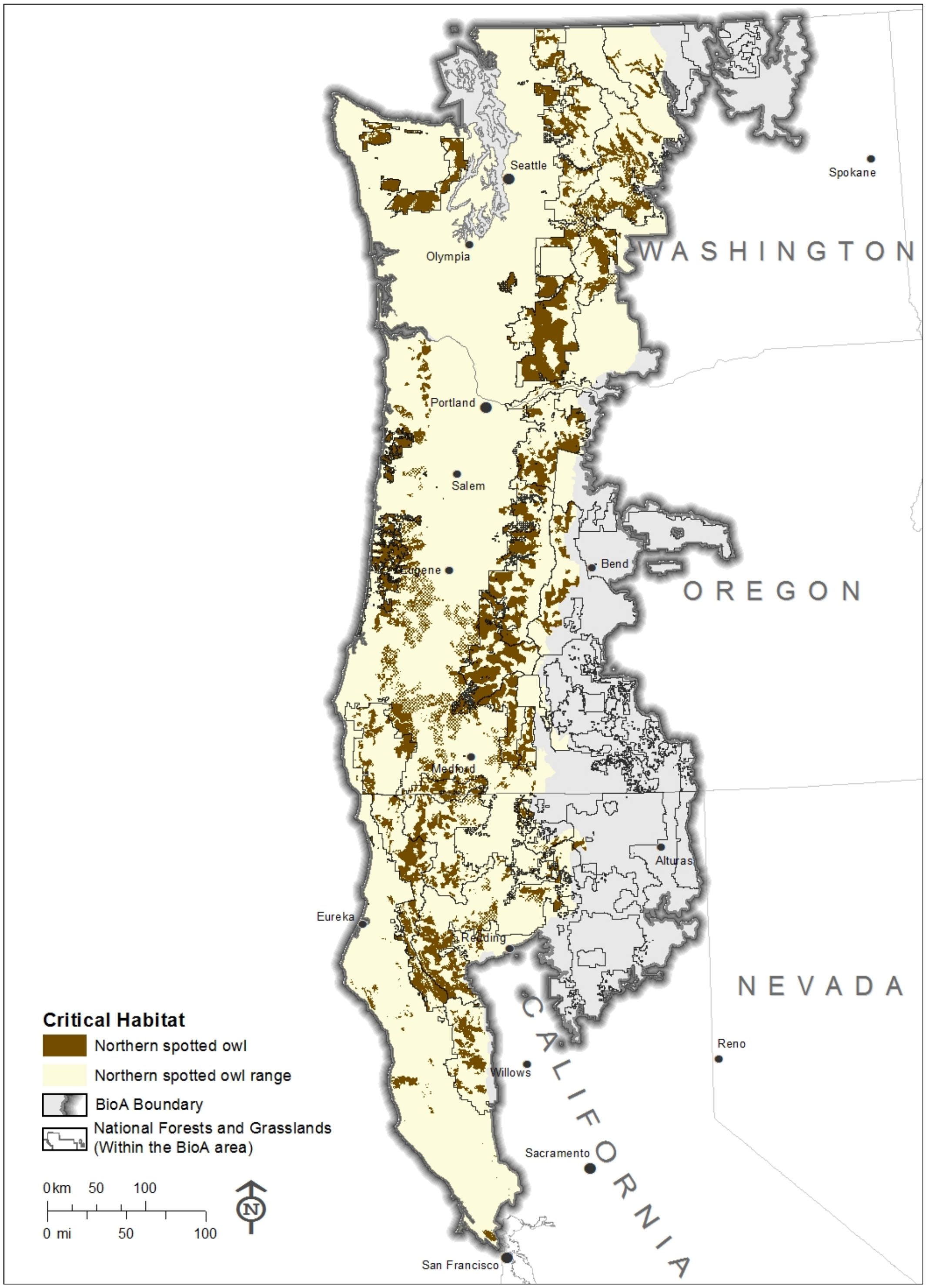
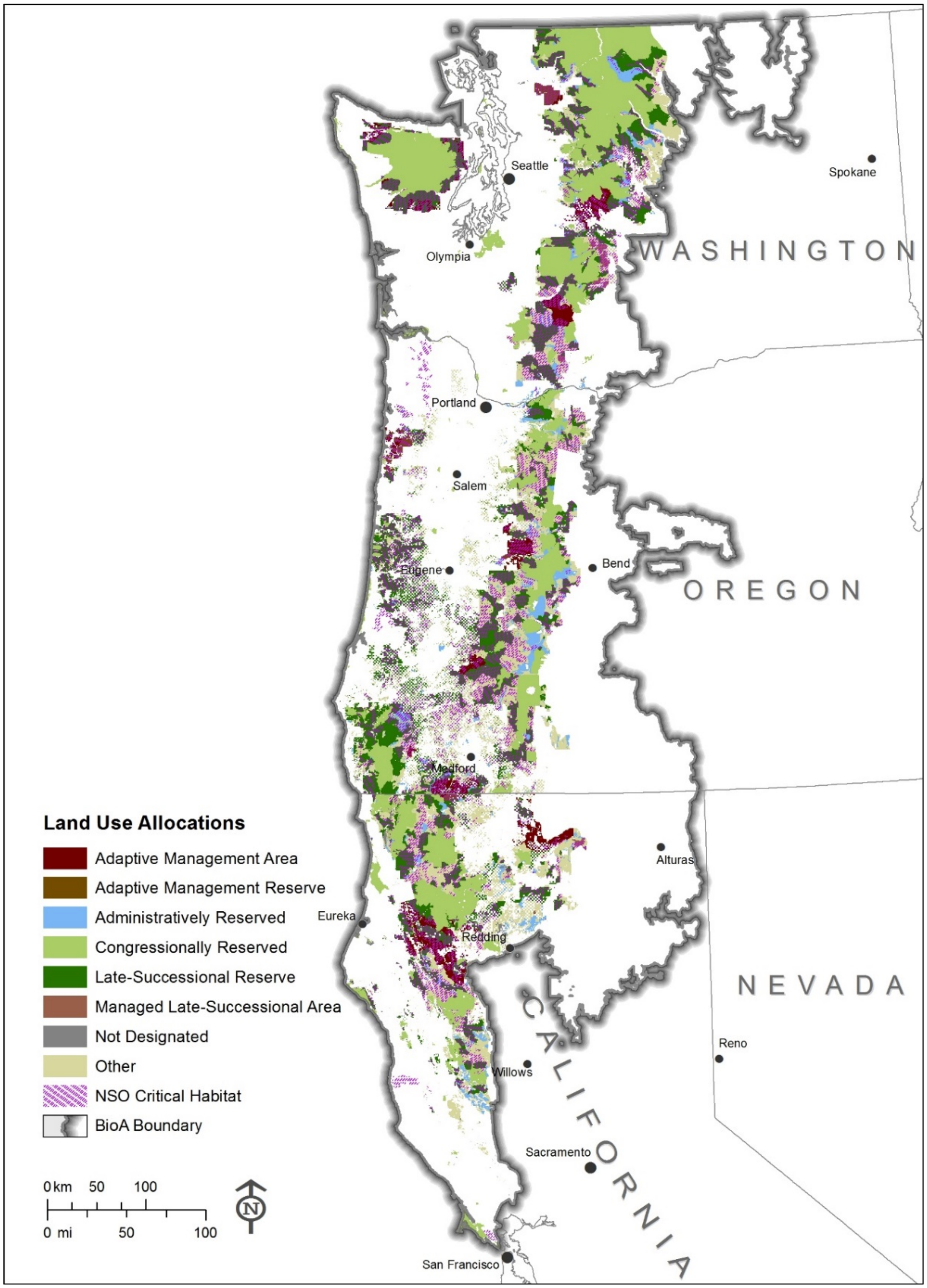


Figure 44. Designated critical habitat in each Northwest Forest (NWFP) land use allocation

Designated critical habitat for the northern spotted owl is most in line with late-successional reserves, congressional reserves, and administratively withdrawn allocations.



Map 13. Northern spotted owl designated critical habitat and range within the BioA area



Map 14. Northern spotted owl critical habitat overlaying Northwest Forest Plan land use allocation

Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Recommendation 7: Expand the use of timber harvest as a restoration tool to provide economic and social benefits to communities.

Recommendation 8—Shift from single-species management to maintaining and restoring habitat for multiple species to manage for ecosystem resilience under future uncertainty.

Recommendation 9: Promote active management in plant and animal habitats to restore and promote ecological resilience.

Geographic Considerations

The proportion of northern spotted owl designated critical habitat is least aligned with late-successional reserves in the Mt. Hood, Umpqua, Six Rivers, and Willamette National Forests (see figure 44)[15]. Plan direction that allows active management to restore and improve ecosystem resilience could help enhance and protect northern spotted owl critical habitat where it overlaps frequent-fire dependent and fire diverse (mixed severity) forests (map 15).

Key Change Issue 2—Northern Spotted Owl Habitat and Need for Active Management

Modification of land management plan desired conditions associated with old-forest management in drier, frequent-fire dependent ecosystems is needed. Loss of old forest from high-severity wildfire has been concentrated in frequent-fire dependent ecosystems (Spies et a. 2018a). It will be important to update land management plans to reflect ecological resilience and expected ecosystems in these areas.

The current capability of National Forest Service lands to provide late-successional forest habitat is strong; however, that capability is threatened by uncharacteristic wildfire, climate change, and invasive species. Uncharacteristic disturbances that broadly alter stands can remove features critical to northern spotted owl survival and reproduction, including sufficient canopy cover, large trees and snags. Climate change is projected to have a significant impact on the agency’s ability to maintain and sustain ecosystems and associated habitats in their current distribution.

[15] As in figure 18, northern spotted owl critical habitat designation is most proportionally aligned with late-successional reserves on the Mt. Baker-Snoqualmie, Siuslaw, Olympic, Fremont-Winema, Mendocino, and Deschutes national forests with more than 60 percent of northern spotted owl critical habitat within such reserves on these national forests. Nonalignment of northern spotted owl critical habitat with late-successional reserves and other reserves indicates a potential need to adjust land allocations in coordination with designated critical habitat for northern spotted owl and other species.

While the NWFP acknowledges the dynamic nature of fire-prone landscapes, there is a need for active management consistent with the Northern Spotted Owl Recovery Plan and Critical Habitat Final Rule that promotes the resiliency and ecological integrity of current and future cover types in the more fire-prone portions of the species range.

Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Recommendation 7: Expand the use of timber harvest as a restoration tool to provide economic and social benefits to communities.

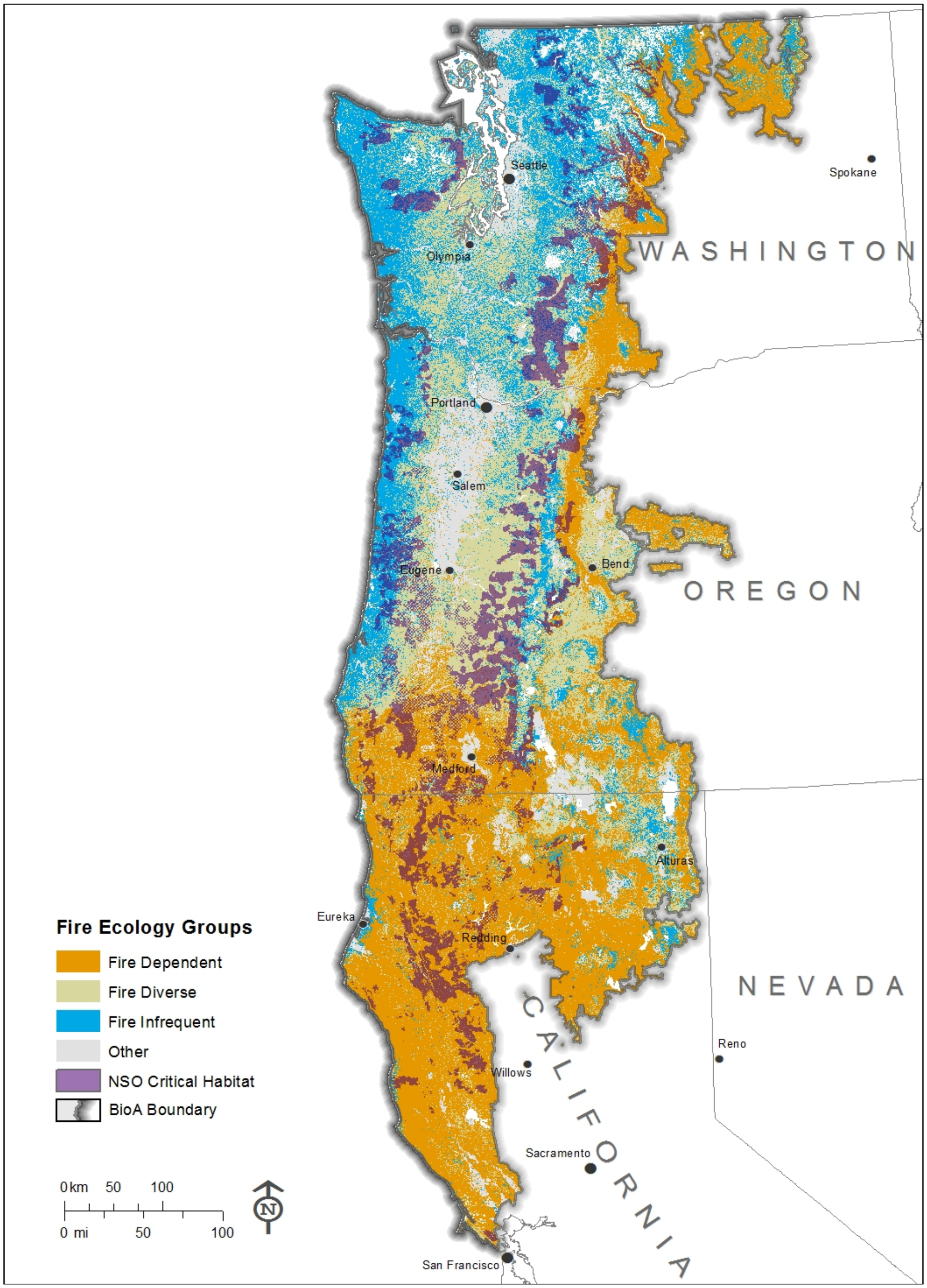
Recommendation 8: Shift from single-species management to maintaining and restoring habitat for multiple species to manage for ecosystem resilience under future uncertainty.

Recommendation 9: Promote active management in plant and animal habitats to restore and promote ecological resilience.

Geographic Considerations

Within the frequent-fire dependent ecosystems common in northern California, southwest Oregon and the eastern Cascade Range, there is a challenge between providing forest structure suitable for nesting and roosting cover and the risk of habitat loss from high-severity fire (map 15). Habitat in fire diverse (mixed severity) ecosystems will increasingly face this challenge under a changing climate. Climate change will influence all areas, including the fire environment in some fire diverse (mixed severity) systems, particularly in south-central and southwestern Oregon, including the Umpqua.

Throughout the BioA area, there is geographic variation in northern spotted owl prey and foraging habitat patterns. In the southern and drier portion of the owl range, woodrats make up a high proportion of northern spotted owl diet. Woodrats are most abundant in shrubby habitats and owls forage from perches in older forest that borders early-seral habitat; in these areas, a mix of early-seral and late-seral forest is more typical. Woodrats require the retention of downed woody debris and other understory shrub species as habitat. In wetter portions of the range to the north, flying squirrels compose a higher portion of northern spotted owl diet and foraging habitat is more uniform, closed canopy older forest. There is also an elevational gradient to this pattern, with woodrats dominating in lower elevations and flying squirrels at higher elevations, especially in the southern extent of the northern spotted owl range. Consideration in this geographic distribution of northern spotted owl prey species is important when choosing active management activities across the range of the northern spotted owl in the BioA area.



Map 15. Broad fire ecology groups with northern spotted owl critical habitat overlaid

Key Change Issue 3—Northern Spotted Owl Habitat Restoration and Barred Owls

Despite the protections afforded by the NWFP, old-growth-dependent species such as the northern spotted owl continue to decline because of factors that were not anticipated. One of these factors is the barred owl, an invasive species in the BioA area. The barred owl has expanded its range in the past 25 years to cover the entire NWFP footprint and has become a significant threat to northern spotted owls. The expansion of the barred owl's range, in combination with disturbances outside of federal lands, has led scientists to conclude that the protections in the NWFP alone are not sufficient to ensure spotted owl recovery (Lesmeister et al. 2018).

In light of the additional impact on northern spotted owls from barred owls, there is an amplified need to continue to promote and conserve northern spotted owl habitat and increase treatment of currently unsuitable habitats to accelerate the attainment of suitable nesting/roosting habitat, while at the same time cooperatively addressing the barred owl threat. Habitat restoration, conservation, and enhancement will continue to provide for the needs of the northern spotted owl as options to mitigate barred owl impacts are evaluated and developed. There is also a need to develop projections of habitat change over time to better understand how northern spotted owl nesting habitat will change as currently unsuitable habitat matures within the reserve system. Managers need better tools to forecast how the total amount of nesting habitat will change, and whether total habitat might increase even if habitat losses continue on the non-federal landscape.

Planning Considerations

In order to retain and enhance northern spotted owl habitat while solutions to the barred owl threat are developed and evaluated, conservation and restoration of habitat should be considered in order to serve as a buffering agent against the compounding threat. Especially in fire-prone forests, there is a need to assess the increased risk that conserving more northern spotted owl habitat poses to fire extent and severity, ecological resilience and integrity, and to other forest management activities. Landscape-level approaches are needed to reconcile the potentially competing goals of forest resilience and northern spotted owl habitat.

Regardless of the status of the owl, it is important that the Forest Service continues efforts to retain and promote diverse and resilient late-successional habitats for the broad and diverse suite of species that rely upon them.

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 4: Reduce the introduction and spread of plant, animal, and other invasive species.

Call-out box 17. Barred owl invasion

A threat to the northern spotted owl that was not anticipated by the Northwest Forest Plan is the invasion and establishment of a non-native competitor. The barred owl, once confined to eastern North America, now co-occupies habitat and outnumbers spotted owls throughout much of their range and continues to increase in population density. Barred owls have higher annual survival, produce more offspring, and inhabit smaller home ranges than spotted owls. They compete for resources that would otherwise be available to spotted owls, including nest sites. They are slightly larger, and are strongly aggressive toward their native counterparts, usually quickly excluding spotted owls from territories and habitat. The competitive relationship between the two owl species has become a key limiting factor to spotted owl recovery (Lesmeister et al. 2018).

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Recommendation 7: Expand the use of timber harvest as a restoration tool to provide economic and social benefits to communities.

Recommendation 8: Shift from single-species management to maintaining and restoring habitat for multiple species to manage for ecosystem resilience under future uncertainty.

Recommendation 9: Promote active management in plant and animal habitats to restore and promote ecological resilience.

Geographic Considerations

A threat to the northern spotted owl that was not fully anticipated by the NWFP is the invasion and establishment of a non-native competitor. The barred owl, once confined to eastern North America, now co-occupies and outnumbers northern spotted owls throughout much of their range and continues to increase in density (map 26). The barred owl's newly extended geographic range now completely overlaps that of the northern spotted owl (Gutiérrez et al. 2007). Barred owls use the full range of forest types used by spotted owls, and a broader range of forest cover types outside of areas historically occupied by spotted owls. Barred owls have higher annual survival, produce more offspring, and inhabit smaller home ranges than spotted owls. They compete for resources that would otherwise be available to spotted owls, including nest sites. They are slightly larger, and are strongly aggressive toward their native counterparts, usually quickly excluding spotted owls from territories and habitat. The competitive relationship between the two owl species has become a key limiting factor to spotted owl recovery (Lesmeister et al. 2018). However, systematic studies have yet to quantify the full range of forest conditions that support barred owls in the Pacific Northwest. Incidental field data show a rapid increase in barred owls as they expanded their populations westward and southward into the range of the spotted owl (Dugger et al. 2016) (figure 45).

Photo 26. Juvenile barred owl

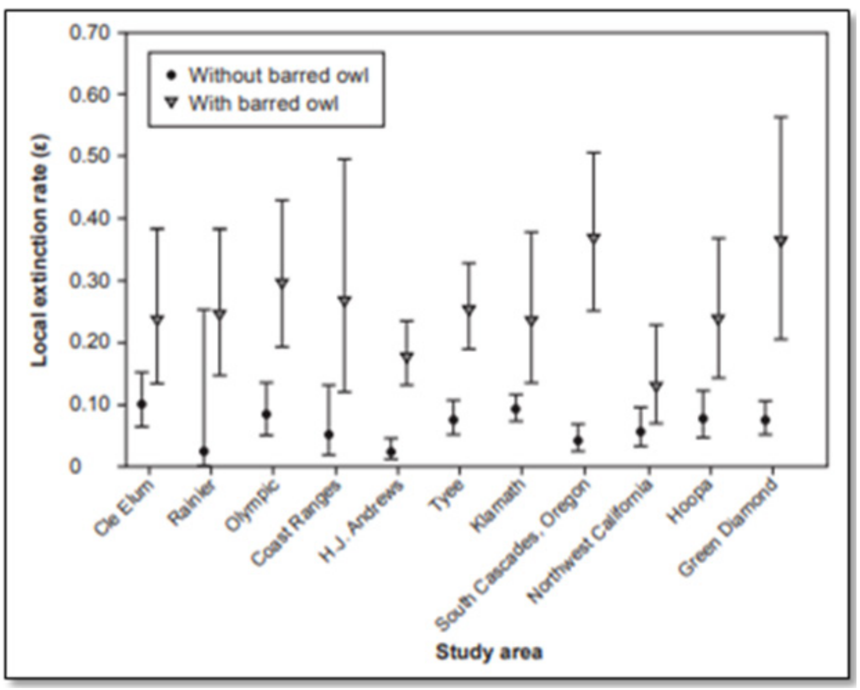


Figure 45. Mean annual local extinction rates (with 95 percent confidence intervals) for northern spotted owls on 11 study areas relative to presence of barred owl (Dugger et al. 2016)

It appears that northern spotted owls are more at risk of extinction with barred owls living in the area.

Key Change Issue 4—Marbled Murrelet Habitat

Call-out box 18. Marbled murrelet

The marbled murrelet is a small seabird that spends the majority of its time on the ocean but depends on old forest for nesting. Ranging from central California to the Aleutian Islands in Alaska, murrelets roost and forage primarily on small fish and krill in the nearshore marine environment. They may nest up to 55 miles inland, typically nesting in large trees with limbs containing moss or piles of needles large enough for laying a single egg and raising a nestling.

Murrelet populations are limited by available suitable marine and old-forest habitats. Nest predators such as crows, ravens, and jays are another management consideration since they are a primary cause of murrelet nest failure and will most likely limit murrelet populations in many areas. These predators are commonly associated with forest edges and open, thinned forests and are attracted to litter and food waste in human recreation areas. Murrelet populations are declining in the state of Washington but appear to be generally stable in Oregon and California.

The marbled murrelet occupies the coastal portions of the BioA area (map 16), and the current large reserve design on the coast has proven effective in maintaining and enhancing marbled murrelet habitat (Raphael et al. 2018). However, marbled murrelet populations have continued to decline, primarily due to rapid loss of habitat on non-federal lands from logging and threats to the marine environment, such as harmful algal blooms, oil spills, gillnet fishing and climate change. While there is much uncertainty about the role of murrelet movement along the coast and the influence this movement has on observed numbers and trends, this is largely outside of agency control. There is also uncertainty in how changes in marbled murrelet populations are related to the relative importance of change in the amount and distribution of nesting habitat versus changes in marine habitat, including predictions of how marine prey will respond to climate change scenarios.

Even with the success of maintaining and enhancing marbled murrelet habitat in the coastal regions of the BioA area, the shrinking habitat on non-federal lands heightens the importance of securing and protecting existing and additional old-growth habitat.

Planning Considerations

There is a need to maintain large, contiguous blocks of marbled murrelet habitat within its range. Enhancements and modifications to the current late-successional reserve network in the marbled murrelet range needs to focus on the maintenance of large, contiguous blocks of densely canopied late-successional habitat with ample nesting platforms. There is also a need to develop projections of habitat changes over time to better understand how marbled murrelet nesting habitat will change as currently unsuitable habitat matures within the reserve system. Managers need better tools to forecast how the total amount of nesting habitat will change in the future and whether total habitat might increase even if habitat losses continue on non-federal land.

Furthermore, minimizing corvid conflicts especially in developed recreation areas and other management activities areas in and adjacent to marbled murrelet nesting habitat will be an important planning consideration.

Refer to BioA Chapter 2 Management Recommendations

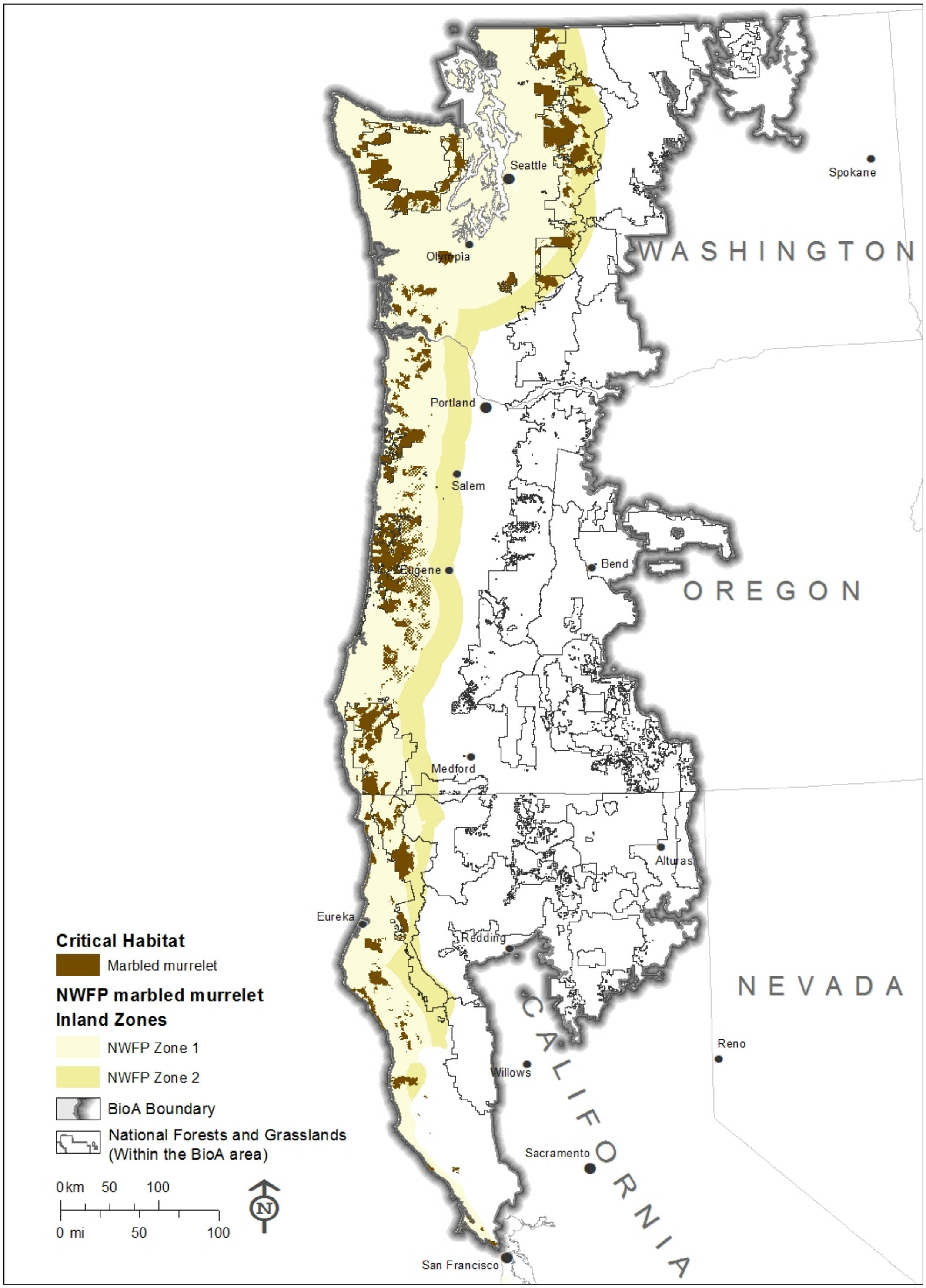
Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 4: Reduce the introduction and spread of plant, animal, and other invasive species.

Geographic Considerations

Marbled murrelet populations have remained steady in Oregon and California but continue to experience steep declines in Washington (Falxa and Raphael 2016). Habitat losses continue on all non-federal lands and climate change is likely to affect future marbled murrelet populations, their nesting habitat, and their food resources.



Map 16. Extent of marbled murrelet critical habitat within the Bioregional Assessment area

NWFP = Northwest Forest Plan.

Key Change Issue 5—Mammalian Carnivores Habitat Connectivity

In the decades since the NWFP was designed, additional conservation focus has been placed on a broader suite of species for which late-successional forest habitats are important (Marcot et al. 2018). These include species such as Pacific marten, fisher, Canada lynx, Sierra Nevada red fox, grizzly bear, and wolverine (photo 27 and photo 28). Potential changes in management should include consideration of the needs of these additional species.

Potential modifications to the reserve network need to account for and provide for habitat linkages and connectivity sufficient for these species' persistence at the range of the species distribution. Planning should emphasize retention of snags, large trees, mistletoe brooms and damaged trees to provide resting and denning structures for fisher and marten; downed wood is also an important habitat feature for resting sites, maternal denning, and prey habitat. These modifications would help align future plans to be consistent with the 2012 planning rule, which requires plans to include components to maintain or restore ecological integrity, including connectivity. Plan direction should emphasize coarse-filter and use fine-filter components where needed to address the connectivity needs of multiple species.

Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Recommendation 8: Shift from single-species management to maintaining and restoring habitat for multiple species to manage for ecosystem resilience under future uncertainty.

Recommendation 9: Promote active management in plant and animal habitats to restore and promote ecological resilience.

Geographic Considerations

Geographic trends for mammalian carnivores are not currently well known in the BioA area; more research on range and distribution would help address the needs of these species.

Photo 27. Wolverine climbing to a feeding platform

Photo 28. Pacific marten perched in a tree

Key Change Issue 6—Habitat Diversity

Beyond old-forest-dependent species, national forests and grasslands provide important habitat for a broad range of species. The NWFP was designed to address the large-scale and rapid decline in late-successional habitats and placed an important emphasis on the conservation and promotion of dense multi-layered older forest conditions, in particular, the closed-canopy, structurally complex forests associated with northern spotted owl nesting and roosting habitat. While this emphasis continues to be critically important, the value of a distribution of forest types that represent resilient landscapes is becoming increasingly apparent. This usually includes multiple successional and seral stages distributed in ecologically significant patterns across the landscape. For example, there is now a greater recognition of the importance of complex early-seral habitats and the key habitat components (snags and downed wood) that they provide through later successional stages (Phalan et al. 2019; Swanson et al. 2011, 2014). These early-seral habitats are vitally important to invertebrate and vertebrate pollinator species and game species, such as deer and elk, which have suffered some population declines due to changes in federal land management that favor older forest conditions.

Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to better respond to future environmental uncertainties.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Recommendation 8: Shift from single-species management to maintaining and restoring habitat for multiple species to manage for ecosystem resilience under future uncertainty.

Recommendation 9: Promote active management in plant and animal habitats to restore and promote ecological resilience.

Geographic Considerations

Fires have created complex early-seral habitat within the historic range of variability in the north central Cascades on the Okanogan-Wenatchee National Forest and southwest Oregon national forests and grasslands (Rogue River-Siskiyou, Umpqua, Fremont-Winema National Forests, and the Middle Fork Ranger District on the Willamette National Forest) and northwest California (particularly, the Klamath, Six Rivers, Shasta-Trinity and Modoc National Forests). Complex early-seral habitat is below historical ranges along the Coast Range (Siuslaw and Olympic National Forests), as well as the central Oregon and Washington Cascades (northern Willamette, Mt. Hood, Gifford Pinchot, and Mt. Baker-Snoqualmie National Forests (Phalan et al. 2019). In those areas in the Coast Range and central Cascades that have not experienced as much wildfire and are therefore lacking in complex early-seral habitat, there are opportunities to create and maintain complex early-seral habitat in previously managed plantations, in particular, plantations planted with off-site conifers.

Call-out box 19. Birds as indicators

Birds can be monitored relatively easily to measure ecological effects of land management actions. A group of bird species can be chosen to represent the key habitat attributes in a given habitat type, such as a mixed-conifer forest, and be monitored to ensure key habitat attributes are present. These bird species are often used as ecological indicators.

The Forest Service is working with several partners to integrate Partners in Flight decision support tools that inform management planning and measure outcomes. We are using birds as indicator species to inform planning and measure forest trajectories based on management outcomes that are expected to be achieved far into the future (for example, old-growth development).

Partners in Flight bird species monitoring, part of a partnership focused on helping species at risk and keeping common birds common, will help inform future plan revision or modernization efforts within the Bioregional Assessment area.

The hermit warbler, along with other indicator species, such as the Hammond's flycatcher, Pacific wren, and brown creeper, are highly associated with mature forests. The habitat attributes these species are associated with represent a range of conditions that are important in these forests (for example, closed canopy, open mid-story, deciduous understory, and forest floor complexity) (Altman and Alexander 2012).

Aquatics, Fish, and Water

Introduction

In the BioA area, 6.7 million acres were designated as riparian management areas through four plan amendments, including (1) the NWFP Aquatic Conservation Strategy (ACS) (USDA FS and USDI BLM 1994); (2) Sierra Nevada Framework Aquatic Management Strategy (USDA FS 2004); (3) PacFish (USDA FS and USDI BLM 1995b); and (4) InFish (USDA FS and USDI BLM 1995a).[16] Seventy-two percent of the BioA area and 85 percent of the aquatic and riparian habitats are managed under the NWFP ACS. Ten percent of the BioA area and 6 percent of the aquatic and riparian ecosystems fall under the Sierra Nevada Framework Aquatic Strategy. The PacFish and InFish aquatic strategies, which are nearly identical, combine to cover 17 percent of the land area and 8 percent of the aquatic ecosystems (map 17).[17] The four amendments will be collectively referred to as the BioA aquatic strategies.

The BioA aquatic strategies include goals, objectives, standards and, guidelines to prevent damage to riparian areas, along with four management components: riparian management areas, key or refuge watersheds, watershed analysis, and aquatic restoration, all of which work in concert to maintain or restore aquatic ecosystems. The NWFP ACS is a good example of a multi-species coarse-filter approach that has improved conditions within aquatic and riparian ecosystems on which anadromous fish and other organisms depend.

---

[16] Links to electronic versions of the four BioA aquatic strategies.

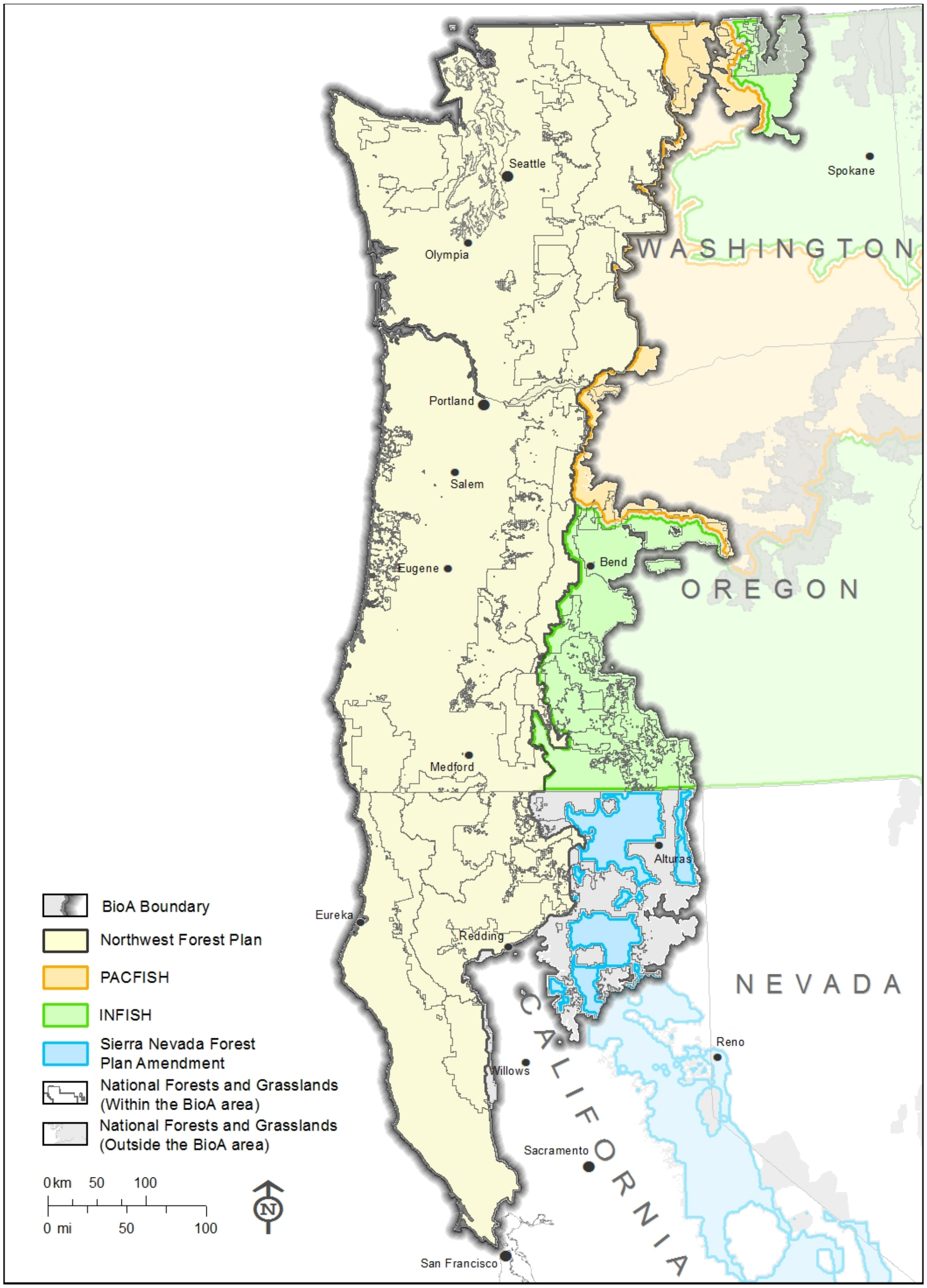
NWFP: https://www.fs.fed.us/r6/reo/acs/

Sierra Nevada Plan:
https://www.fs.usda.gov/detail/r5/landmanagement/planning/?cid=STELPRDB5349922

PacFish: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd591470.pdf

InFish: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_033158.pdf

[17] About one percent of the riparian management acres are not managed by any one of the BioA aquatic strategies.



Map 17. Bioregional Assessment (BioA) aquatic strategies and coverage area

What is Working Well

What is Working Well 1—Bioregional Assessment Aquatic Strategies

The BioA aquatic strategies are working; after 20 years of NWFP implementation, the Aquatic and Riparian Effectiveness Monitoring Program detected improving trends for aquatic physical habitat, aquatic macroinvertebrates and 7-day average maximum water temperatures, along with improvements in upslope and riparian conditions (photo 29) (Miller et al. 2017). While complex, the improvements in physical habitat noted by the Aquatic Riparian Effectiveness Monitoring Program across the NWFP national forests show an improving shift in the physical habitat scores. This improvement indicates that changes in land management have been effective at improving aquatic habitat (figure 46).

Outside of the NWFP area, Roper et al. (2019) documented that nine of 10 stream attributes are trending upward or stable on federal lands managed by PacFish and InFish aquatic strategies, supporting the conclusion that 20 years of management under these strategies likely played a role in improving stream conditions. Most apparent was a reduction in fine substrates in the downstream end of pools and an increase in in-stream large wood (Roper et al. 2019). Further, the most current monitoring report for the Sierra Nevada Framework rated the condition of 78 percent of evaluated streams as “good” to “excellent” (Furnish 2013).

The Aquatic Conservation Strategy authors (USDA FS and USDI BLM 1994: B-9) recognized that it may take at least 20 years or even more than a century to restore ecological processes across the NWFP area, a timeframe that can likely be applied to PacFish, InFish, and Sierra Nevada Framework areas as well. Recent monitoring results are promising and help to confirm, along with science reviews (Naiman et al. 2000, Reeves et al. 2018, Spence aet al. 1996), that the four primary components that form the structure of the BioA aquatic strategies are functionally sound and provide a solid foundation to move forward with continued improvements. During the 2015 listening sessions,[18] public participants offered general support for the continuation of existing aquatic programs that protect and improve water quality, habitat for salmon and other aquatic species, and overall watershed health.

[18] https://www.fs.usda.gov/detail/r6/landmanagement/planning/?cid=fseprd523165—page 15–16.

Photo 29. Aquatic and Riparian Effectiveness Monitoring Program field staff collecting data

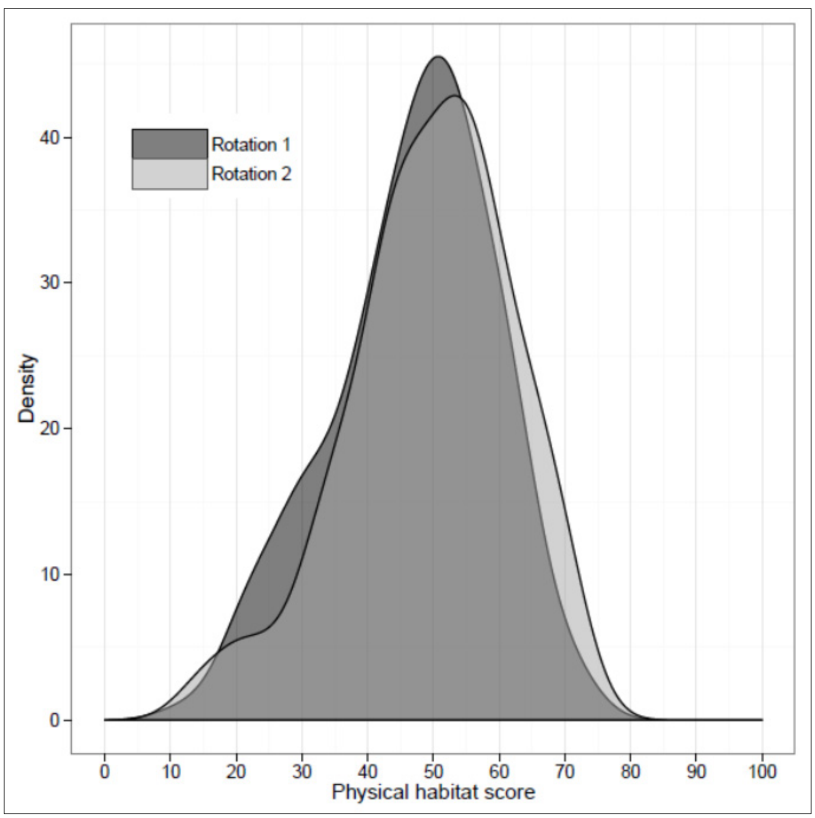


Figure 46. Aquatic habitat improvements in the Northwest Forest Plan (NWFP) area

This graph highlights the improvements in physical habitat noted by the Aquatic Riparian Effectiveness Monitoring Program across the NWFP national forests and grasslands. It shows a rightward (improving) shift in the physical habitat scores from sampling period 1 (2002–2009) to sampling period 2 (2010–2013). (Miller et al. 2017).

What is Working Well 2—Riparian Management Areas

Riparian management areas,[19] a cornerstone to the BioA aquatic strategies,[20] are a primary reason for watershed improvements across the BioA aquatic ecosystems. Composed of approximately 6.7 million acres of land that border 154,000 miles of streams and surround 211,388 acres of lakes, ponds, and wetlands, riparian management areas protect and naturally restore watershed and ecological processes (for example, stream shade, large wood input, floodplain functions). The vast majority of these acres (about 85 percent) occurs on national forests and grasslands managed by the NWFP (table 4). The size of riparian management areas is dependent on several criteria associated with a given waterbody. For example, fish-bearing streams receive greater protection than non-fish-bearing streams.

Table 4. Riparian management acres designated under the four Bioregional Assessment aquatic strategies

Strategy	Acres of Riparian Management Area	Percentage of Acres
Aquatic Conservation Strategy (Northwest Forest Plan)	5,717,362	85
Sierra Nevada Framework	540,716	6
PacFish and InFish	424,623	8
Outside the above aquatic strategies	45,788	1
Total	6,728,489	100

The primary management tool used to attain watershed improvements is passive restoration, meaning that riparian management areas are left to recover naturally without influence from other forest management actions. Trees that might have been targeted for timber harvest before 1994 are now left to grow and provide stream shade and aquatic and terrestrial habitat and help create a network of migration corridors for animal species throughout and between watersheds. Where passive restoration may not be sufficient to restore riparian conditions, silvicultural treatments can be applied within riparian areas; for example, the ACS allows vegetation management to “acquire desired vegetation characteristics needed to attain ACS objectives.”[21]

To facilitate this transformation from timber production to a more balanced management approach, standards and guidelines were developed to ensure that any action in riparian management areas that overlay or intermix with other land use allocations, where active management is permitted, must maintain, protect, or restore watershed and ecological

[19] The term “riparian management areas” is a collective term used to describe NWFP riparian reserves, Sierra Nevada Framework riparian conservation areas, and PacFish and InFish riparian habitat conservation areas.

[20] Citations with page numbers to each of the four BioA aquatic strategies where riparian management area descriptions are located: NWFP aquatic conservation strategy (USDA FS and USDI BLM 1994: C30-31), Sierra Nevada Framework Aquatic Management Strategy (USDA FS 2004: 42), PacFish (USDA FS and USDI BLM 1995b: C6-9), and InFish (USDA FS 1995a: A5-6).

[21] NWFP ACS (USDA FS and USDI BLM 1994: C-32, TM1-c.).

processes.[22] Photos 30 through 36 show the diversity of stream and riparian types that occur throughout the BioA area, from northern Washington's relatively wet Mt. Baker-Snoqualmie and Olympic National Forests south to northern California on the more arid Klamath and Shasta-Trinity National Forests.

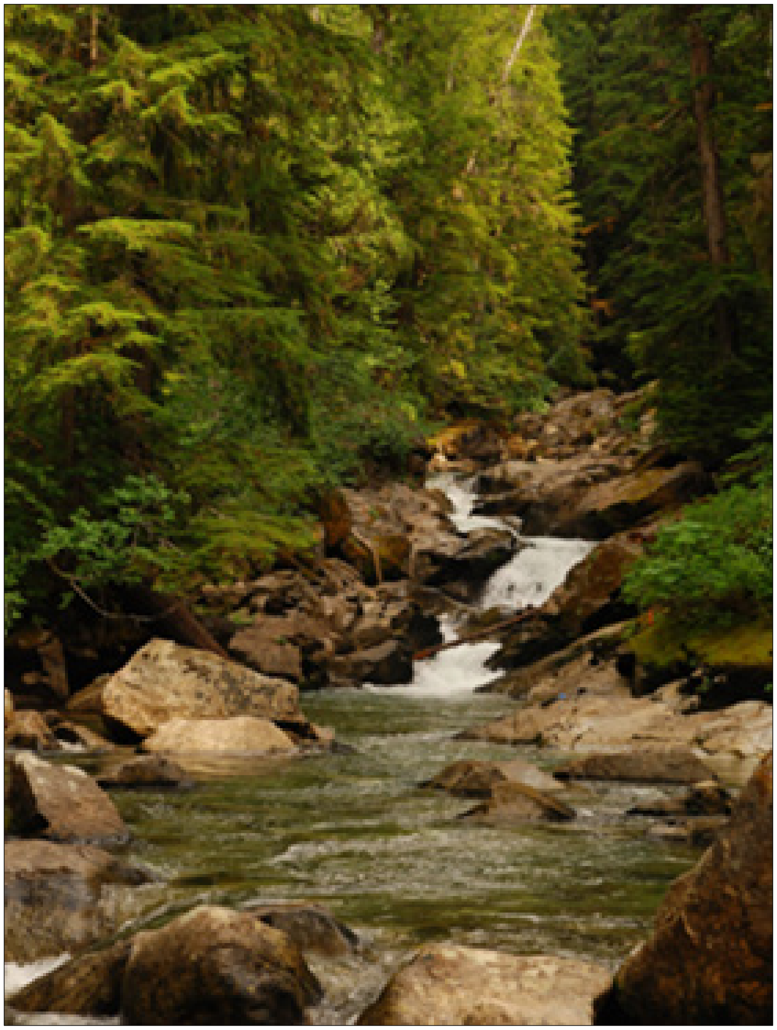


Photo 30. Stream on Mt. Baker-Snoqualmie National Forest

[22] Citations with page numbers where aquatic and riparian standards and guides occur in each of the BioA aquatic strategies: NWFP Aquatic Conservation Strategy (USDA FS and USDI BLM 1994, p. C31-38), Sierra Nevada Framework Aquatic Management Strategy (USDA FS 2004, p. 62-66), PacFish (USDA FS and USDI BLM 1995a, p. C9-18), and InFish (USDA FS 1995b, p. E6-13).

Photo 31. Stream on Olympic National Forest

Photo 32. Stream on Willamette National Forest

Photo 33. Stream on Deschutes National Forest

Photo 34. Stream on Fremont-Winema National Forest

Photo 35. Stream on Klamath National Forest

Photo 36. Stream on Shasta-Trinity National Forest

What is Working Well 3—Watershed Restoration

To complement passive restoration and standards and guidelines provided through riparian management areas, the existing aquatic strategies in the BioA area include a watershed and aquatic restoration component, which targets impaired watershed processes and habitats negatively affected by past management.[23] Under the NWFP, priority projects include treatment or removal of roads prone to landslide and erosion. Photo 37 shows an aquatic restoration project on the Gifford Pinchot National Forest where a road was decommissioned and a culvert removed to reclaim a natural stream channel, restore aquatic organism passage, and reduce road-related sediment in the broader stream network. Photo 38 shows a project in which the Olympic National Forest and partners placed large wood along a river's edge and floodplain to create pools and hiding cover for ESA-listed fish. Large wood placement improves habitat for a variety of other riparian-dependent species, both aquatic and terrestrial, resulting in an abundance of ecosystem benefits.

[23] Citations with page numbers where aquatic restoration sections can be found in each of the four BioA aquatic strategies: NWFP Aquatic Conservation Strategy (USDA FS and USDI BLM 1994, p. B 30-32); Sierra Nevada Framework Aquatic Management Strategy (USDA FS 2004, p. 34 Rod); PacFish (USDA FS and USDI BLM 1995a, p. C 21-22); and InFish (USDA FS 1995b, p. E 15).

Photo 37. Road decommissioning on Gifford Pinchot National Forest

Photo 38. Large wood placement on Olympic National Forest

Prior to 2017, Staley Creek on the Willamette National Forest was intentionally confined by placement of berms to control channel movement and lateral flooding. The berms crowded the stream into a straightened channel, increased stream velocity, and simplified aquatic habitats and the stream's ability to accommodate the broad array of aquatic species native to the area. After restoration in 2017, Staley Creek now flows across a wide floodplain during high-flow events, creating an assortment of habitat types for aquatic and terrestrial species, including ESA-listed bull trout, and recharges groundwater across an expansive area (photo 39 and photo 40).

Photo 39. Staley Creek, before restoration, on Willamette National Forest

Photo 40. Staley Creek, after restoration, on Willamette National Forest

Significant amounts of active riparian management have occurred in the BioA area since the initiation of the aquatic strategies. For example, from 2014 through 2018, restoration projects improved 1,968 miles of stream habitat, restored fish access to 357 miles of stream, and removed 490 miles of roads that affected water quality, local hydrology, and other watershed processes. Projects were, and continue to be, integrated with other actions throughout watersheds, addressing impacts to watershed processes and aquatic habitat.

What is Working Well 4—Watershed Analysis

Watershed and aquatic restoration projects are identified through another aquatic strategy component, watershed analysis, which is an interdisciplinary approach to assess statuses and trends of physical and ecological processes in a watershed.[24] A watershed analysis identifies what is and what is not working for a given area and sets the foundation for remedial actions to treat chronic and systemic problems that alter important watershed

[24] Citations with page numbers where watershed analysis sections can be found in the four BioA aquatic strategies: NWFP Aquatic Conservation Strategy (USDA FS and USDI BLM 1994, B 20-30); Sierra Nevada Framework Aquatic Management Strategy (USDA FS 2004, p. 33); PacFish (USDA FS and USDI BLM 1995a, p. C 19-21); and InFish (USDA FS 1995b, p. E 14-15).

functions. Under the NWFP, the analysis is mandatory for project planning and implementation in riparian reserves and key watersheds.

More than 200 watershed analyses have been conducted on national forests and grasslands in the NWFP area, most of which were completed over a 10-year period from the mid-1990s through the early 2000s. See photo 41 for a watershed view located on the Rogue River-Siskiyou National Forest.

Photo 41. Watershed on Rogue River-Siskiyou National Forest

Watershed analysis, an essential part of the Bioregional Assessment aquatic strategies, considers the entire landscape, from ridge top to valley bottom, to identify where watershed processes are working well and where past management actions negatively affect terrestrial and aquatic habitats, to help determine sites for future restoration.

What is Working Well 5—Key Watersheds

The aquatic strategies in the BioA area include key watersheds,[25][26] which generally are priority areas for aquatic restoration because they are designated as refuge areas for aquatic species and are important sources of water. From 2012 to 2017, nearly 60 percent of watershed and aquatic restoration projects on NWFP national forests in the Forest Service's Pacific Northwest Region were conducted in key watersheds (map 18). In the NWFP area, about 8.5 million acres were designated as key watersheds and currently provide habitat for 23 of the 27 aquatic species listed under the ESA (Reeves et al. 2018). These include 20 species of salmon and steelhead, three distinct populations of bull trout, two sucker species, Pacific eulachon, and the Oregon spotted frog. See photo 42, photo 43, and photo 44 for examples of common fish species in the BioA area.

---

[25] The term "Key Watersheds" are used in the NWFP and PacFish, while Critical Aquatic Refuges are used in the Sierra Nevada Framework, and Priority Watersheds is the term used under InFish.

[26] Citations with page numbers where key watershed sections can be found in each BioA aquatic strategy. NWFP Aquatic Conservation Strategy (USDA FS and USDI BLM 1994, pages B 18-20); Sierra Nevada Framework Aquatic Management Strategy (USDA FS 2004, pages 43-44); PacFish (USDA FS and USDI BLM 1995a, page C 19); and InFish (USDA FS 1995b, pages E 13-14).

Photo 42. Adult bull trout in a stream

In the Bioregional Assessment area, Washington and Oregon national forests offer the primary strongholds for bull trout, a species listed as threatened under the Endangered Species Act. Resident bull trout require clear, cold-water streams, and National Forest System lands often provide the sole source of this essential habitat. (U.S. Fish and Wildlife Service).

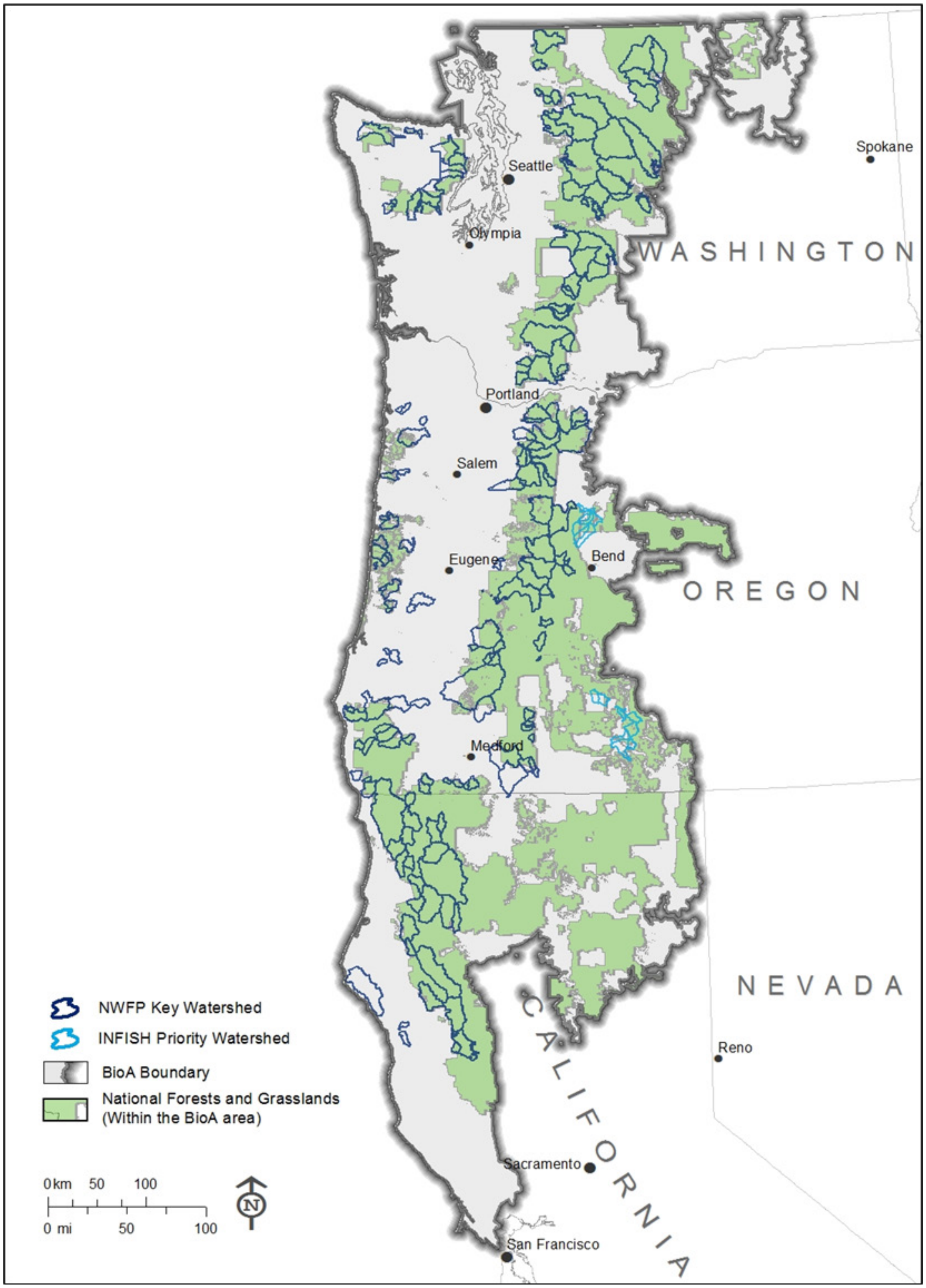
Photo 43. Chinook salmon in a stream

Chinook salmon, the iconic and most recognized Pacific Coast salmon, can be found on 16 of the 19 units in the Bioregional Assessment area. The spring, summer, and fall Chinook, which often exceed 20 pounds, migrate to national forest streams to lay their eggs, and the juveniles seek cool water tributaries to rear and grow before migrating to the ocean. Chinook salmon streams are usually a primary target for national forest aquatic restoration projects. (U.S. Fish and Wildlife Service).

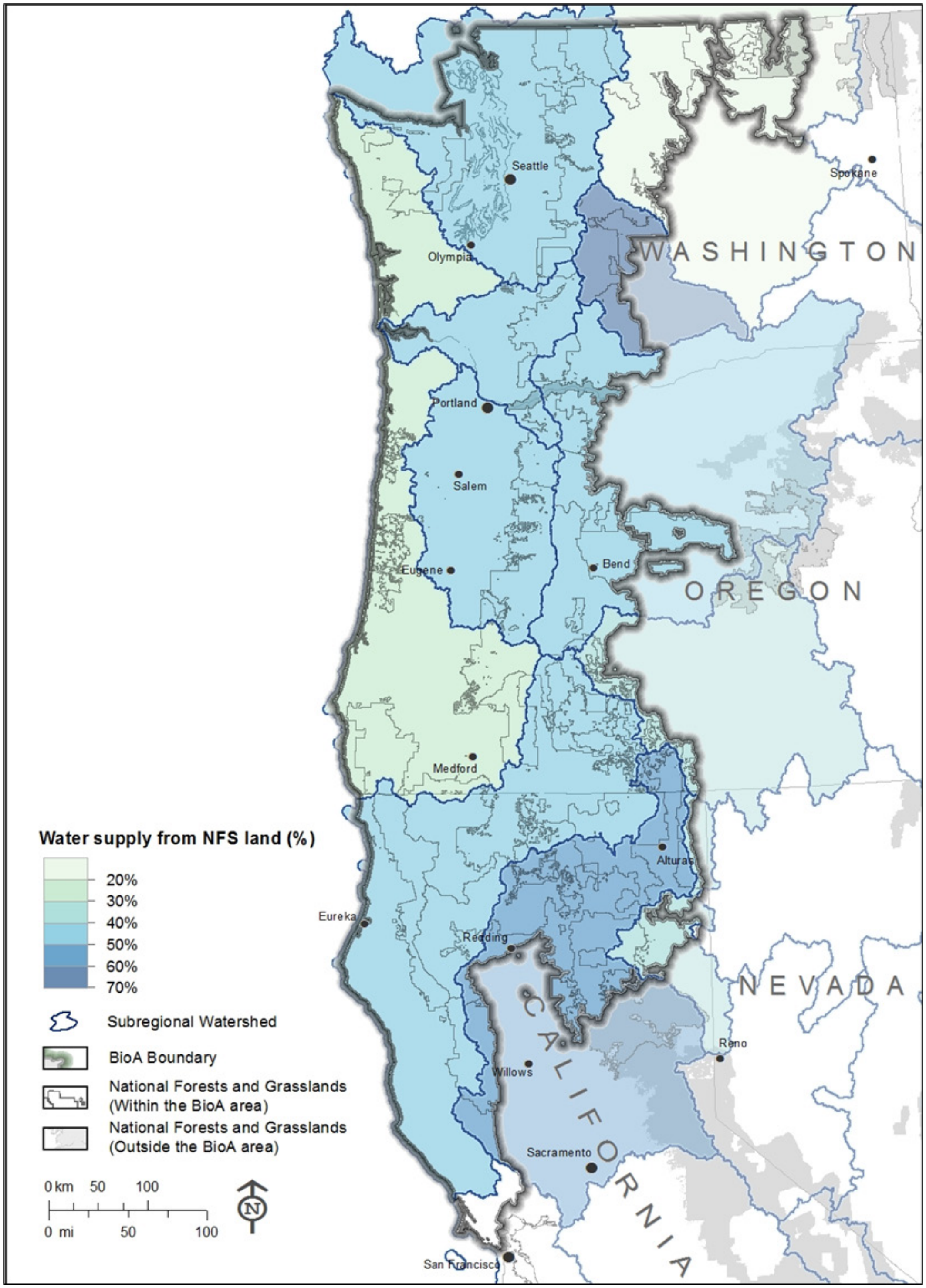
Photo 44. Steelhead trout leaping a barrier

Steelhead, an anadromous trout, moves up the Sacramento River in search of spawning grounds. Steelhead can migrate back and forth from the ocean more than once to spawn, and national forest lands in the Bioregional Assessment area provide much of the headwater spawning and rearing habitat preferred by these fish. (U.S. Fish and Wildlife Service).

Key watersheds and other National Forest System lands provide most of the water supply that sustains the majority of Western U.S. communities with drinking water, and supply irrigation water to nationally important agricultural areas like California's Central Valley, Oregon's Willamette Valley, and the Columbia River valley (map 18 and map 19).



Map 18. Northwest Forest Plan and PacFish key watersheds and InFish priority watersheds in the Bioregional Assessment area



Map 19. Percentage of water supply from National Forest System lands

Percentage of total water supply that originates on National Forest System lands (Luce et al. 2017). National forests and grasslands are an important source of abundant high-quality water for many uses, including aquatic habitat, drinking water, and irrigation. They typically provide much of the water for a given basin. BioA = Bioregional Assessment.

Key Change Issues

Key Change Issue 1—Management Efficiency and Need for Single, Unified Aquatic Conservation Strategy

Aquatic and riparian ecosystems in the BioA area are managed by one of four aquatic strategies: NWFP ACS, Sierra Nevada Framework Aquatic Management Strategy, PacFish, and InFish. All four strategies are similar in their architecture and approach, but the level and types of analysis and compliance requirements vary amongst the strategies, increasing Forest Service planning costs when a project area is covered by more than one strategy. Nine national forests and grasslands in the BioA area, for example, operate under more than one BioA aquatic strategy. On the Okanogan-Wenatchee National Forest, the Chinook salmon, which spawns in the Chewuch River within the forest's borders, can readily swim back and forth across a NWFP-PacFish boundary. When the forest developed the Chewuch Transportation Plan Environmental Assessment, it was required to conduct separate analysis and compliance reviews for the same project, the same fish on the same stream to accommodate two different strategy directives, the NWFP and PacFish.[27] The need to conduct multiple compliance reviews increases direct costs to the affected forest as well as social and ecological costs, which increase when a project area expands to a state, Forest Service region, or larger level, and include an increasing number of aquatic strategies that must be addressed.

Planning Considerations

To eliminate financial, ecological, and social costs required to address multiple aquatic strategies, develop a unified aquatic conservation strategy for the BioA area.

Refer to BioA Chapter 2 Management Recommendation

Recommendation 3: Update and consolidate the existing aquatic direction processes and analysis requirements.

Geographic Considerations

Eight national forests and grasslands and the scenic area, most of which occur on the eastern portion of the BioA, are covered by more than one aquatic strategy and would benefit the most from a unified aquatic strategy: Okanogan-Wenatchee, Gifford Pinchot, Mt. Hood, Deschutes, Ochoco, Fremont-Winema, Modoc, and Lassen National Forests and Columbia River Gorge National Scenic Area.

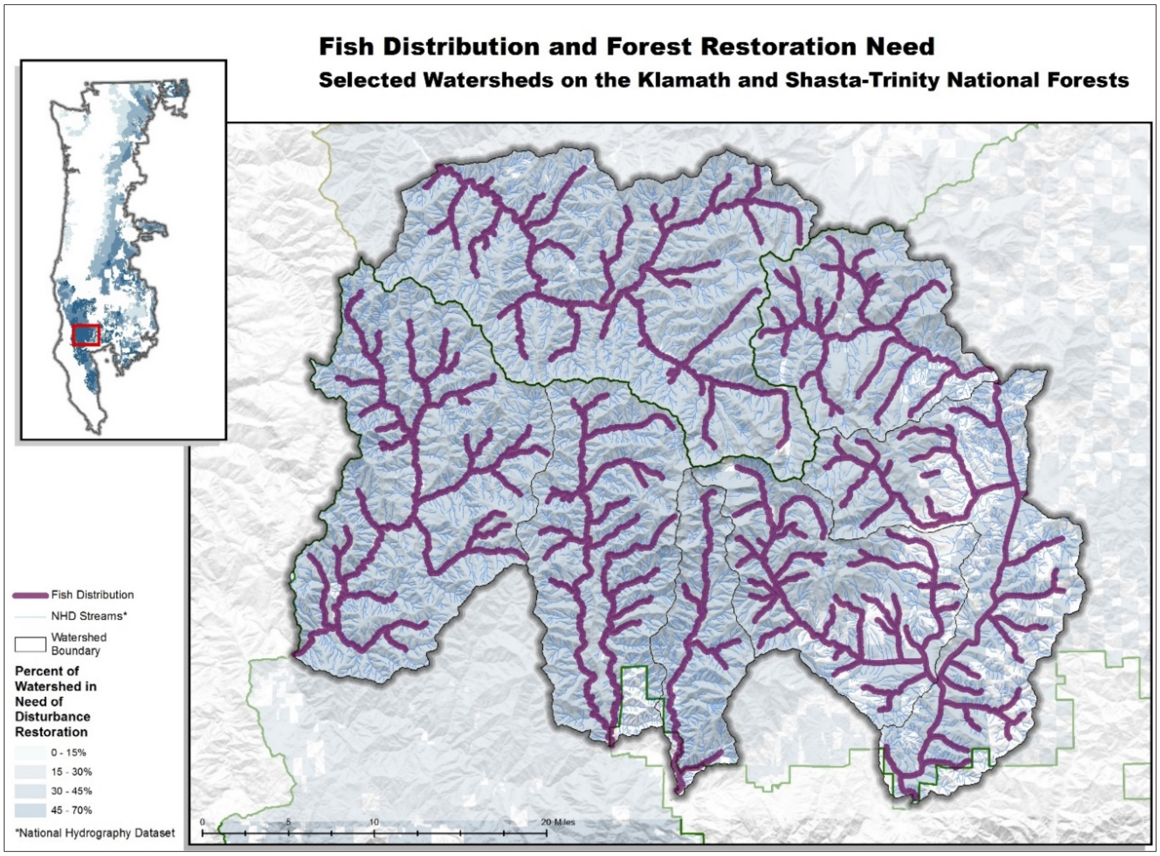
[27] The Endangered Species Act consultation requirements for fish listed as threatened or endangered are complicated when addressing more than one aquatic strategy.

Key Change Issue 2—Fish Species Adaptation and Need for Detailed Descriptions of Desired Future Conditions and Disturbance Regimes

The NWFP ACS objectives, as well as Sierra Nevada Framework, PacFish, and InFish aquatic management goals and objectives, often serve as ecosystem-based desired future conditions that highlight habitats under which aquatic species are uniquely adapted.[28] For example, ACS objective 8 states "Maintain and restore species composition and structural diversity of plant communities in riparian areas…." The general nature of this and other objectives often leads to disputes over the true character of riparian reference conditions and a potential need for active management. There is a need for active management in riparian areas throughout the NWFP area; this includes thinning dense riparian Douglas-fir stands to promote growth of hardwoods and expediting growth of large conifers that could serve as key structural components in stream channels (Reeves et al. 2018). There is a growing concern in frequent-fire dependent forests, where many watersheds that are inhabited by fish contain large areas of densely stocked, mid-seral stands susceptible to stand-replacement fire (map 20). These large stand-replacement fires could negatively affect fish habitat by reducing stream shade, water quality, and aquatic habitat complexity. However, mechanical and fire treatments to reduce stand densities to more sustainable conditions are sometimes avoided in densely stocked riparian areas because of differing views on reference conditions, leaving these areas vulnerable to stand-replacement fires.

Although native fish populations are adapted to natural fire regimes (Flitcroft et al. 2016, Reeves et al. 1995) and demonstrate resiliency even when faced with stand-replacement fires (Dunham et al. 2003), the growing number of uncharacteristically large and intense wildfires could increase adverse impacts and even local extinctions of ESA-listed fish that are already constrained by habitat degradation (Rieman et al. 2003) and fragmentation (Dunham et al. 2003).

[28] This footnote provides page numbers where aquatic and riparian objectives or goals can be found in the BioA aquatic strategies. NWFP Aquatic Conservation Strategy (USDA FS and USDI BLM 1994, p. B-11); Sierra Nevada Framework Aquatic Management Strategy (USDA FS 2004, p. 42-43); PacFish (USDA FS and USDI BLM 1995b, p. C 3-6); and InFish (USDA FS 1995a, p. E 2-4).



Map 20. Fish-bearing watersheds and departed forests

This map displays the convergence of highly departed forests (Ringo et al. 2019), unusually dense timber stands relative to historic conditions, and fish-bearing streams in watersheds on the Klamath and Shasta-Trinity National Forests.

Planning Considerations

To promote a common understanding of riparian reference conditions, revised plan components should detail prevalent disturbance regimes for geographic areas and include descriptions of resulting riparian vegetation (structure, species composition, and landscape patterns), riparian and aquatic habitats, and water quality over space and time.

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 3: Update and consolidate the existing aquatic direction processes and analysis requirements.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Additional planning considerations that were not addressed by the BioA include developing desired future conditions in collaboration with the U.S. Fish and Wildlife Service and National Marine Fisheries Service.

Geographic Considerations

A description of desired future conditions and foundational disturbance regimes would help address forest and non-forest conditions that are departed from more natural conditions across the BioA area. In the BioA area, two groups of fire-dependent forests stand out as having high rates of vegetative departure from the natural range of variation in watersheds inhabited by fish.[29]

Group 1—High Urgency for Action: In 95 percent of fish-bearing watersheds in northwest California's fire-dependent national forests (Klamath, Mendocino, Shasta-Trinity, and Six Rivers), vegetative departure is moderate to high. To compound the urgency for action in northwest California, the Mendocino, Shasta-Trinity, and Six Rivers National Forests have relatively high numbers of ESA-listed fish species[30] and occur in a geographic region that is projected to experience the most extreme climate change impacts, rendering them more susceptible to large, high-severity wildfire, in the NWFP area (refer to "Key Finding 2" in the "Climate Change" section below).

Group 2—Moderate to High Urgency for Action: Approximately 70 to 75 percent of the fish-bearing watersheds in southwestern, south-central, and central Oregon national forests (Rogue River-Siskiyou, Fremont-Winema, and Deschutes) have high departure rates and occur in the geographic region that is projected to experience the most extreme climate change impacts in the BioA area.

Key Change Issue 3—Key Watersheds and Need to Realign with Critical Habitat and Current Science[31]

The NWFP key watersheds and their Sierra Nevada Forest Plan, PacFish, and InFish counterparts were identified as the best places to protect and recover at-risk fish stocks and other riparian-dependent species and to provide high-quality water on and from federal lands. Since that time, new methods to identify valuable habitats for ESA-listed salmon, steelhead, bull trout, and suckers strongly suggest that some key watersheds may not be aligned with important recovery areas for these fish; nearly 40 percent of critical habitat for ESA-listed fish on NWFP national forests and grasslands lie outside key watersheds. This raises uncertainty about the effectiveness of key watersheds in serving as refuge areas for at-risk fish stocks (Reeves et al. 2018). Further uncertainty exists because streams with high intrinsic potential to support fish, based on a methodology developed after the establishment of key watersheds (Burnett et al. 2005), have not been fully mapped across the BioA area, and climate change assessments that provide insights as to where climate impacts will be most adverse to native fish have yet to be incorporated for the entire area.

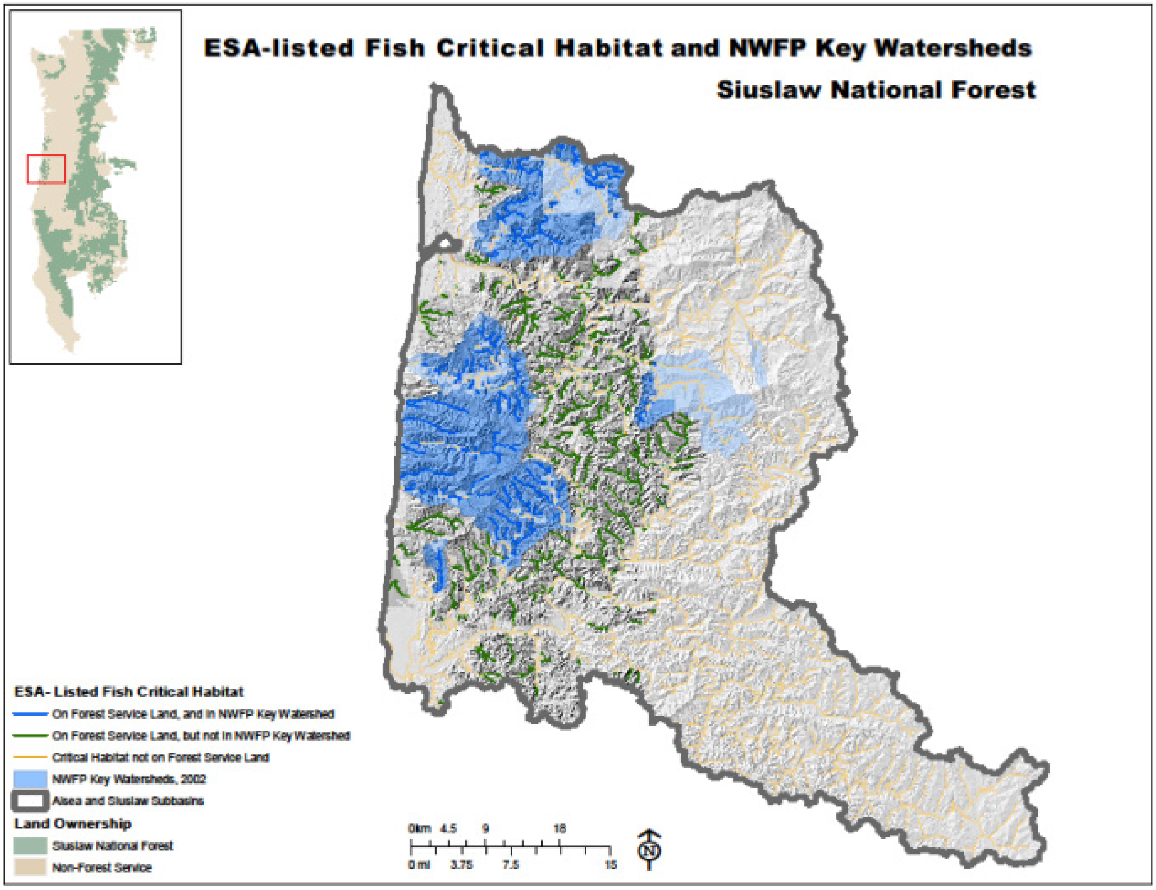
---

[29] At the time of this report, fish distribution data were not readily available for the Modoc and Lassen National Forests outside of the NWFP area. Therefore, these two forests were not included in this analysis.

[30]Number of fish listed under the U.S. Endangered Species Act on high urgency national forests: Mendocino, 5; Shasta-Trinity, 4; Six Rivers, 3. The Mt. Hood and Gifford Pinchot National Forests have higher numbers at 7 and 6, respectively; these forests, however, occur in a geographic region where the urgency for action for this key change issue is low. Fish numbers are taken from Reeves et al. (2018).

[31] The term "key watersheds" is used in the NWFP and PacFish, while "critical aquatic refuges" are used in the Sierra Nevada Framework, and "priority watersheds" is the term used under InFish. The term "key watersheds" is a collective term used to describe these watersheds.

One example of a critical habitat and key watershed disconnect can be found on the Siuslaw National Forest's Siuslaw River basin, where nearly 60 percent of the designated critical habitat for the ESA-listed Oregon Coast coho salmon occur outside of key watersheds that were identified in 1994 (map 21). It is in basins such as this where better alignment between key watersheds and critical habitat may be warranted.



Map 21. Critical habitat alignment with key watersheds

This map displays the amount of critical habitat in and outside of key watersheds in the Siuslaw River basin on the Siuslaw National Forest. Nearly 60 percent of the critical habitat lies outside of key watersheds that were designated in 1994, emphasizing the need to reevaluate whether key watersheds are located in the best areas to address recovery of Endangered Species Act-(ESA)-listed fish. NWFP = Northwest Forest Plan.

Planning Considerations

Where needed, locations of key watersheds could be adjusted to better align with places best suited for recovery of ESA-listed fish and other areas of critical importance to aquatic biodiversity (for example, species of conservation concern). Any adjustment can be based on linkages to critical habitat, high intrinsic potential streams, bull trout core areas, climate change vulnerability assessments, presence of vulnerable aquatic- and riparian-dependent species not listed by the ESA, and priority refuge areas documented in federal ESA-listed fish recovery plans. Assessment actions could be coordinated with the National Marine Fisheries Service and U.S. Fish and Wildlife Service ESA-listed fish recovery programs.

Geographic Considerations

The national forest units with the greatest percentage of critical habitat that occurs outside key watersheds are the Modoc, (100 percent), Siuslaw (61 percent), Willamette (56 percent), Mt. Hood (45 percent), Olympic (38 percent), and Mendocino (32 percent) National Forests and the Columbia River Gorge National Scenic Area (greater than 75 percent). Critical habitat maps were not available for the southern Oregon/northern California coho salmon, which occurs on the Rogue River-Siskiyou, Klamath, Six Rivers, and Shasta-Trinity National Forests. Thus, these national forests could not be included in the key watershed/critical habitat assessment.

Key Change Issue 4—Management Inefficiencies and Need for Revised Watershed Analysis Process

Watershed analysis played a significant role in institutionalizing ecosystem-based management on forest system lands in the BioA area. These analyses provide an interdisciplinary look at a watershed, culminating with a list of resource management actions to help reverse degraded watershed processes, habitats, and undesirable trends. Since the completion of watershed analyses in the mid-1990s and early 2000s, the condition of many watersheds has been altered primarily through extensive wildfires and insect and disease outbreaks. When a watershed analysis is required to plan and implement subsequent projects in these newly disturbed areas, the existing analysis requires revision. The current watershed analysis development and revision process is often unconstrained in scope and level of detail, creating excessive timelines for management activities that demand its use, such as forest plan consistency assessments required to support active management in riparian areas and key watersheds.

Planning Considerations

A plan component could be developed to ensure that new or updated watershed analyses or similar documents address only the most critical current issues and questions and that the type and level of analysis is aligned with current management needs and opportunities, financial resources, and staff capacity. Creation or revision of a watershed analysis may be initiated by project or management requirements.

Geographic Considerations

National forests and grasslands that have and continue to experience large stand replacement fires (northern California, southern Oregon, and eastern Cascade Mountains of Oregon and Washington), which results in altered watershed conditions, have the greatest need to operate under an updated watershed revision process.

Key Change Issue 5—Aquatic Species Connectivity and Need for Stream Passage for all Aquatic Species

The NWFP, PacFish, and InFish aquatic strategies contain a standard and guideline that directs national forests and grasslands to provide fish passage where new culverts are to be installed at road stream crossings (USDA FS and USDI BLM 1994: C-33, 1995b: C-11; USDA FS 1995a: A-8), but does not address the need to provide passage at road stream crossings for all aquatic species to help ensure their long-term viability. For instance, culverts can restrict salamander movement in and along streams

(Anderson et al. 2014, Sagar 2004), and this raises a particular concern in the BioA area because several salamander species are petitioned for listing under the Endangered Species Act (Reeves et al. 2018).

Call-out box 20. A riparian vegetation management case study

Throughout the Bioregional Assessment area, mechanical and fire treatments in riparian areas are often challenging as we seek to better understand local riparian functions and project tradeoffs. In some cases, restoring one part of a riparian area may appear to degrade another. Conifer thinning in riparian areas to increase space for deciduous trees and shrubs, for example, reduces one habitat type and increases another. Therefore, it is important to weigh tradeoffs in the context of natural disturbance regimes and associated plant species, structure and function, and resulting habitats.

In the Dry Hills Forest Restoration Project on the Lassen National Forest, it was critical to understand and clearly describe the natural range of variation of local riparian areas. The Lassen's land and resource management plan and its associated amendment (Sierra Nevada Framework) authorizes active management in riparian areas—similar to the Northwest Forest Plan—as long as it meets or improves riparian conditions. Because the plan's desired future conditions are general in nature, staff time and expertise were spent providing detailed desired future conditions that would identify the need for riparian restoration. In this case, the project team clearly described the natural range of variation for the project's riparian areas, including the fire regime and associated forest plant species and structure. This necessary yet often difficult step helped to develop shared understanding and agreement for the need to do the work in riparian conservation areas.

Planning Considerations

Include direction similar to Sierra Nevada Framework standard and guideline101 (USDA FS 2004: 63): "Ensure that culverts or other stream crossings do not create barriers to upstream or downstream passage for aquatic-dependent species." A similar plan component to provide passage at road stream crossings for all life stages of aquatic organisms where the lack of connectivity is considered to be a limiting factor to species viability could be incorporated.

Geographic Considerations

This issue applies to all BioA national forests and grasslands where stream connectivity has been raised as a limiting factor to species viability, excluding those covered by the Sierra Nevada Framework. Currently, a greater urgency for this type of plan component exists on national forests and grasslands occupied by amphibians that are listed or petitioned for listing under the ESA, species that rely on unencumbered passage to carry out life history stages. These units include the Mt. Hood (5 species), Willamette (5 species), and the Gifford Pinchot (3 species) National Forests and the Columbia River Gorge National Scenic Area (4 species), all of which occur within the Cascade Mountains from southern Washington to central Oregon (Reeves et al. 2018).

Key Change Issue 6—Amphibian Migrations and Need for Riparian Reserve Connectivity Across Watershed Divides

While the NWFP and Sierra Nevada Forest Plan include components that promote unencumbered riparian connectivity within and between watersheds, the PacFish and InFish strategies do not (USDA FS and USDI BLM 1994: B-11, USDA FS 2004: 33). The NWFP ACS objective 2 states the following:

> "Maintain and restore spatial and temporal connectivity within and between watersheds. Lateral, longitudinal, and drainage network connections include floodplains, wetlands, upslope areas, headwater tributaries, and intact refugia. These network connections must provide chemically and physically unobstructed routes to areas critical for fulfilling life history requirements of aquatic and riparian-dependent species."

Aquatic and riparian-dependent species include the Oregon slender salamander (photo 45). However, connectivity corridors typically have been viewed in the context of fish passage requirements, where corridors are synonymous with the stream network and associated riparian designations. Thus, providing fish passage within and between other watershed stream networks was viewed as a primary objective, and because road stream crossings were found to restrict connectivity, culvert replacements or removals were targeted to reunite stream connectivity. This view of corridors addresses connectivity within and between watersheds through the stream network, but it does not provide for connectivity over watershed divides.

Current research has shown that aquatic-dependent species such as salamanders travel over watershed divides and require connectivity corridors with downed trees (Olsen and Kluber 2014) to access riparian areas (Olsen and Burnett 2013). This has broadened the definition of connectivity between watersheds. The aquatic strategies in the BioA area, therefore, require clarification to directly address the migration needs of aquatic species, such as salamanders, or terrestrial species, such as martens and fishers, which require migration corridors over watershed divides that connect riparian reserves in different watersheds (see also "Key Change Issue 5" in the "Terrestrial Wildlife" section above).

Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 2: Address the dynamic nature of ecosystems to better respond to future environmental uncertainties.

Recommendation 3: Update and consolidate the existing aquatic direction processes and analysis requirements.

Recommendation 8: Shift from single-species management to maintaining and restoring habitat for multiple species to manage for ecosystem resilience under future uncertainty.

To better establish migration routes between watersheds, we can create a plan component to establish corridors that connect riparian reserves across watershed divides in priority areas needed for aquatic and terrestrial species migration (figure 47).

Photo 45. Oregon slender salamander

This amphibian is petitioned as threatened under the Endangered Species Act and lives in moist, closed-canopy areas primarily in the western Cascade Mountains on the Gifford Pinchot, Mount Hood, and Willamette National Forests and the Columbia River Gorge National Scenic Area. (Dede Olson, U.S. Forest Service).

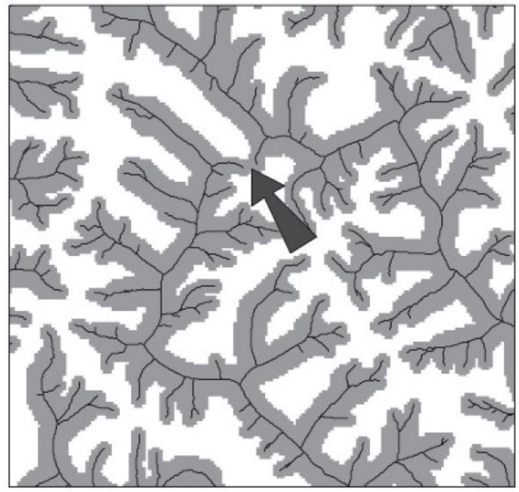


Figure 47. Watershed divide corridors

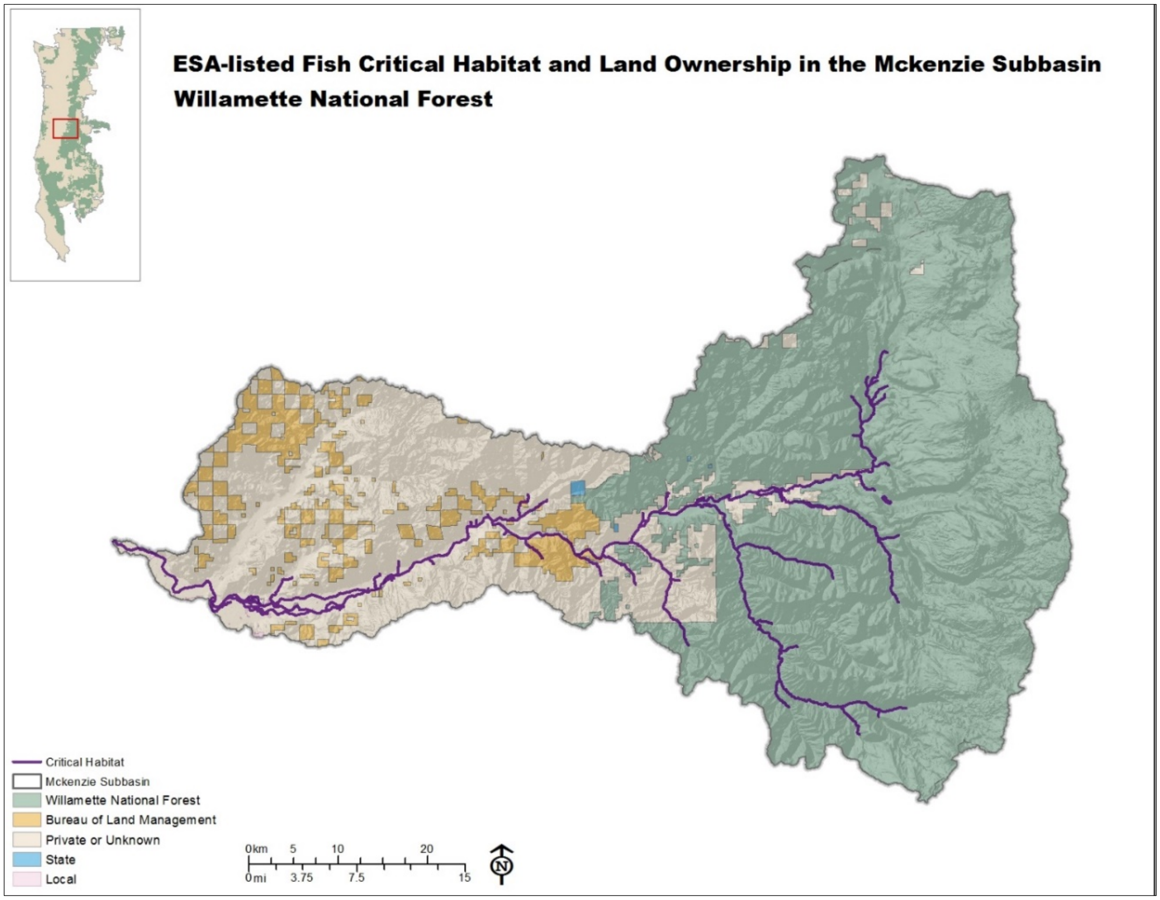
This figure demonstrates the way designated corridors can connect riparian reserves across watershed divides. (Olsen and Burnett 2013). The arrow points to an example over-ridge area where the distance between headwater riparian reserves in different watersheds is small and over-ridge connectivity may be more easily achieved for aquatic species, such as salamanders, and terrestrial species, such as martens and fishers.

Geographic Considerations

This issue applies to the entire BioA area, especially where species viability is a concern and where amphibians are ESA listed or petitioned for listing. All Forest Service Pacific Northwest Region NWFP national forests are occupied by amphibians that are ESA listed or petitioned for listing. National forests that have the highest number of these species are Mt. Hood (5), Willamette (5), and the Gifford Pinchot (3) National Forests and Columbia River Gorge National Scenic Area (4), all of which occur within the Cascade Mountains from southern Washington south to central Oregon (Reeves et al. 2018).

Key Change Issue 7—Species Distribution and Need for All Lands Restoration

The authors of the NWFP recognized the limitations of forest system lands as the sole source of recovery for at-risk fish stocks, noting that fish habitat spans multiple land ownerships and jurisdictional boundaries (Reeves et al. 2018). This is even more apparent 25 years after the completion of the NWFP with the subsequent listing of 24 additional ESA-listed fish and designation of critical habitat. During the 2015 listening sessions, public participants expressed an interest in aquatic restoration across land ownerships. This need can be highlighted by examining the distribution of designated critical habitat of ESA-listed salmonids across multiple land ownerships. For example, of 20,475 miles of designated critical habitat for ESA-listed fish within the NWFP area, the Forest Service manages about 3,147 miles (15 percent), which is more than any other single landowner or manager; however, 17,328 miles (85 percent) of the critical habitat occurs off National Forest System lands and is distributed amongst numerous land owners and jurisdictions.[32] In the McKenzie River sub-basin, 228 miles of salmonid critical habitat span the landscape; 118 miles are on private land, 105 miles are on the Willamette National Forest; 4 miles are on Bureau of Land Management land, and 1 mile is on State and local land (map 22). It is apparent that recovery of fish populations depends on Forest Service participation in an all-lands, stewardship approach to riparian and watershed management.



Map 22. Critical habitat and all lands restoration

This map of the McKenzie Watershed (Willamette National Forest) depicts a typical scenario across the Bioregional Assessment area, where critical habitat for Endangered Species Act-(ESA)-listed fish species is distributed across multiple land ownerships, and highlights the need for landowners to join forces to recover fish species, in this case the ESA-listed upper Willamette Chinook salmon, upper Willamette steelhead, and bull trout.

Planning Considerations

Elevate the need for Forest Service participation in all-lands partnerships that target recovery of ESA-listed fish, water quality, aquatic and riparian restoration, and riparian area connectivity across land boundaries and jurisdictions.

[32] Designated critical habitat miles were not available for southern Oregon/northern California coho, a coho stock that occurs on the Rogue River-Siskiyou, Klamath, Shasta-Trinity, and Six Rivers National Forests.

Geographic Considerations

Focus on national forests with the greatest overlap of key watersheds, ESA-listed fish, water quality issues, and existing partnerships. Additional analysis is required to highlight priority areas.

Call-out box 21. All-lands aquatic conservation

Since the 1994 Northwest Forest Plan, community-based watershed restoration partnerships, which include national forests, have emerged and multiplied. Many have adopted an "all-lands" stewardship approach by which integrated assessments and restoration are applied across federal, state, and private lands to improve fish habitat and water quality. Organizations that regularly serve in this role include conservation districts, water boards, regional fish enhancement groups, and watershed councils.

The McKenzie Watershed Council in Oregon is comprised of many partners, including watershed residents and landowners, Willamette National Forest, Eugene Water and Electric Board, Oregon Department of Fish and Wildlife, Bureau of Land Management, U.S. Army Corps of Engineers, McKenzie River Trust, Upper Willamette Soil and Water Conservation District, Lane Council of Governments, Weyerhaeuser Company, McKenzie Watershed Stewardship Group, and the McKenzie Collaborative. The Forest Service offers unique technical skills and funding for many of the council's projects, including stream restoration, fish passage restoration, and outreach efforts throughout the watershed. This engagement demonstrates an all-lands restoration approach, where partners work through land boundary and jurisdictional issues to improve watershed conditions for fish, water, wildlife, and local communities.

McKenzie Watershed Council members meet during pre-project planning for the Lower South Fork McKenzie River Floodplain Restoration Project, Phase 2. From left: fisheries biologist Paul Powers, Deschutes National Forest; fisheries biologist Mekayla Means-Brous, Willamette National Forest; hydrologist Nick Grant, Willamette National Forest; project coordinator Jennifer Weber, McKenzie Watershed Council; fisheries biologist Kate Meyer, Willamette National Forest; Executive Director Jared Weybright, McKenzie Watershed Council.

Key Change Issue 8—Road Management and Need to Account for Full Suite and Extent of Natural Disturbance Regimes

Currently, about 86,000 miles of roads, the majority of which were constructed before 1994, cross national forests and grasslands in the BioA area and contribute to substantial legacy impacts to terrestrial and aquatic systems. There is a moderate to high probability that road densities in 72 percent of BioA area sub-watersheds have substantially altered local hydrologic regimes (timing, magnitude, duration, and spatial distribution of runoff flows), which increases the likelihood of sediment transport from roads into streams.

Further impacts include creation of passage barriers to aquatic organisms at culverts and restricting watershed process, such as debris flows, downstream large wood movement, and stream channel migration (USDA FS 2011). Even more, increased flood frequency and magnitude, resulting from climate change, is expected to exacerbate hydrology impacts through increased occurrence of landslides and debris flows (Reeves et al. 2018). The NWFP highlighted road impacts to aquatic systems, the need to reverse these impacts, and included standards and guides to direct restoration priorities (USDA FS and USDI BLM 1994: B-31). Existing plans require clarification and revision, given increased understanding of debris-flow dynamics, other ecological processes, and climate change.

Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to better respond to future environmental uncertainties.

Recommendation 3: Update and consolidate the existing aquatic direction processes and analysis requirements.

Furthermore, consider updating existing plans and direction to guide road management in a manner that aids in the restoration of natural disturbance regimes, such as debris flows (photo 46), and other ecological processes, such as channel migration. Updated plans would have heightened influence in areas important to recovery of ESA-listed aquatic species, water quality, and where climate change is expected to result in more and extensive flooding. Prioritization of actions could be coordinated with federal and state fish and water quality recovery programs.

Photo 46. Debris flow in a forested stream

This debris flow, located on the Umpqua National Forest, contains large wood that captures boulders, cobbles, and other sediments as it moves downstream. While often seen as a destructive force, this disturbance event is important for formation of aquatic habitat and other watershed functions.

Geographic Considerations

In the BioA area, three groups of national forests and grasslands stand out as having high percentages of sub-watersheds where road densities pose risks to hydrologic regimes.

- Group 1—High Urgency for Action: Siuslaw (100 percent), Gifford Pinchot (94 percent), Umpqua (94 percent), Willamette (83 percent), Mt. Hood (76 percent), and Olympic (62 percent) National Forests. These national forests occur in debris-flow-prone areas, contain relatively high numbers ESA-listed fish species, and are situated in areas with moderate to high precipitation levels, a trigger to landslides and subsequent debris flows.
- Group 2—High Urgency for Action: Shasta-Trinity (72 percent), Six Rivers (61 percent), Mendocino (60 percent), and Rogue River-Siskiyou (52 percent) National Forests. These national forests occur in debris-flow-prone areas, most contain relatively high numbers ESA-listed fish species and are situated in fire-prone areas that can be more susceptible to landslides and subsequent debris flows.
- Group 3—Moderate Urgency for Action: Fremont-Winema (99 percent), Ochoco (99 percent), Okanogan-Wenatchee (84 percent), and Lassen (74 percent) National Forests. This group of national forests have high percentages of watersheds where road densities can impact hydrologic regimes but are less susceptible to landslides and debris flows.

Key Change Issue 9—Climate Change and Need to Account for Impacts to Hydrologic Regimes

The climate is changing and is projected to continue to change hydrologic regimes in the BioA area. For example, precipitation is projected to increase in the winter and decrease in summer, resulting in lower late summer streamflow (streamflows are also projected to be affected by reduced snowpack and water storage), and increased stream temperatures; these effects are expected to particularly apply to stream systems with little groundwater input and shade (Isaak et al. 2017, Luce et al. 2014, Wenger et al. 2010).

Warmer temperatures will result in less snowpack and water storage, more frequent and larger winter floods (also affected by shift in timing of precipitation), and rain-on-snow events in some high-elevation streams where ecosystems are not adapted to these types of floods. Given this, landslides and debris flows are expected to increase (Reeves et al. 2018). Further, lower mean annual streamflows—lower overall water supply—is also projected (Wenger et al. 2010) and will be most prominent in the south and east parts of the BioA area. Conversely, projected increases in water supply are expected in the western Washington Cascades. There is also a predicted increase in channel forming flows known as bankfull flows, which could influence future stream geomorphology (shape and physical function of stream systems) (Wenger et al. 2010). Notable ecological consequences include a reduction in cold-water habitats required to support native trout, steelhead, and salmon, coupled with an expansion of warm-water habitats that accommodate expansion of aquatic invasive species (plants and animals) (Reeves et al. 2018).

Planning Considerations

Create desired conditions and other land management plan components based on projected rather than current hydrologic conditions. Focus on identification of refuge areas for aquatic species, especially in stream types for which groundwater flow can be restored and maintained as well as areas most susceptible to spread of aquatic invasive species. This climate-informed land management plan direction could assist with the selection of key watersheds, development of restoration action plans, and standards and guidelines for road stream crossings and stream restoration projects.

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to better respond to future environmental uncertainties.

Recommendation 3: Update and consolidate the existing aquatic direction processes and analysis requirements.

Geographic Considerations

Climate change impacts in general are projected to be greatest in southern Oregon, northern California, and the east Cascades (see the “Climate Change” section for specifics). It is expected the impacts to hydrology will be most prominent in the same areas. Climate change impacts are associated with several key change issues described in this section, primarily the following: Lack of detailed desired future conditions and disturbance regimes; key watershed alignment with new science; and road management and natural disturbance regimes.

Call-out box 22. Aquatic invasive species

Aquatic invasive species can significantly alter lake, river, stream, and wetland ecosystems. An example of the impacts of an aquatic invasive species is the tui chub infestation and subsequent removal effort at Diamond Lake on the Umpqua National Forest. The tui chub, inadvertently introduced into the lake in the 1950s, interrupted the lake’s food web, resulting in persistent toxic algae blooms, negatively affecting the lakes renowned trout fishery. To address the issue, the lake was partially drained, treated with rotenone, which killed all the fish, and then restocked with trout. The tui chub has continued to plague the fishery throughout the years, and the lake was treated with rotenone again in the mid-2000s.

Kids at a Diamond Lake fishing derby on the Umpqua National Forest

The key to controlling aquatic invasives is to avoid introduction in the first place. The Forest Service, Oregon Department of Fish and Wildlife, and Washington State Department of Natural Resources have coordinated policy and enforcement efforts to protect National Forest System lands from aquatic invasive species, including plants and animals.

The Northwest Forest Plan Aquatic Conservation Strategy does not explicitly consider invasive species, and a narrow interpretation of this strategy can be an obstacle to efficient treatment of invasive species in riparian and aquatic habitats. Recent plan revision efforts outside of the BioA area have incorporated plan components to address aquatic and riparian invasive species.

Call-out box 23. Potential climate change effects on bull trout

Northwest Forest Plan (NWFP) monitoring has detected decreased summer stream temperatures throughout the NWFP area (Miller et al. 2017) because of increased stream shading and improved stream geomorphology, yet with a changing climate, most streams are projected to increase in temperature over the next 60 years (Isaak et al. 2017). In the Yakima River Basin, for example, this could result in more than a 50-percent loss of available habitat for threatened bull trout because of summer warming above the level at which the species can survive. Depending on the extent of climate change in the area, cases such as this would isolate local bull trout populations, placing them at risk of extirpation. See the figure 48 below.

One area of apparent relief from increasing stream temperatures will be in complex terrain where there is prolonged stream shading combined with subsurface streamflow and cooler groundwater inputs. Maintaining stream buffers for shade and complex channel and floodplain dynamics appear to be important for minimizing the impacts of a changing climate on stream temperatures and fish habitat (Spies et al. 2018). These are examples of climate refugia.

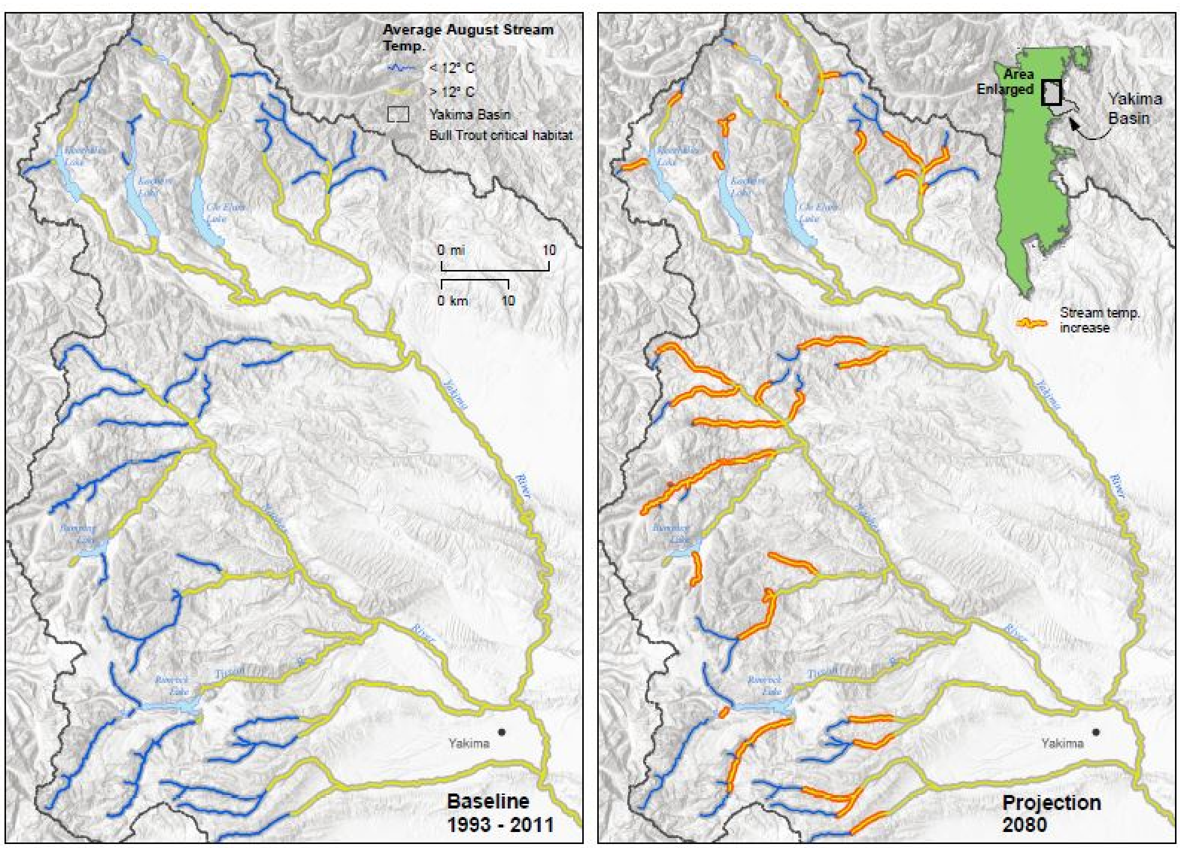


Figure 48. Yakima River Basin critical habitat for threatened bull trout

Projected change in average August stream temperatures in the Yakima River Basin. Comparing baseline (1993–2011) temperature to projected increased stream temperatures in 2080. Highlighted is the threshold of 12 °C.

Wildfire Ecology and Management

Introduction

Fire is an essential and natural part of the BioA area. In appropriate proportion, accounting for frequency, severity and extent, fire is a critical ecosystem driver that helps sustain ecological integrity. When fire is excluded it can lead to uncharacteristic fires that threaten communities and valued resources.

Before Euro-American settlement of the Northwest, fire played a critical role in many of the ecological systems that make up the BioA area. Active fire was promoted by many different American Indian tribes as part of their land stewardship to sustain foods and materials. Because the BioA area encompasses a diverse suite of ecological systems that span vast moisture, temperature, and elevational gradients, fire's role (both positive and negative) is different for different systems. In designing appropriate management strategies for the BioA area, it is essential to consider the natural role of fire to promote ecological resilience and integrity.

In this report, ecological systems have been differentiated into three primary groups, based on characteristics of fire ecology.

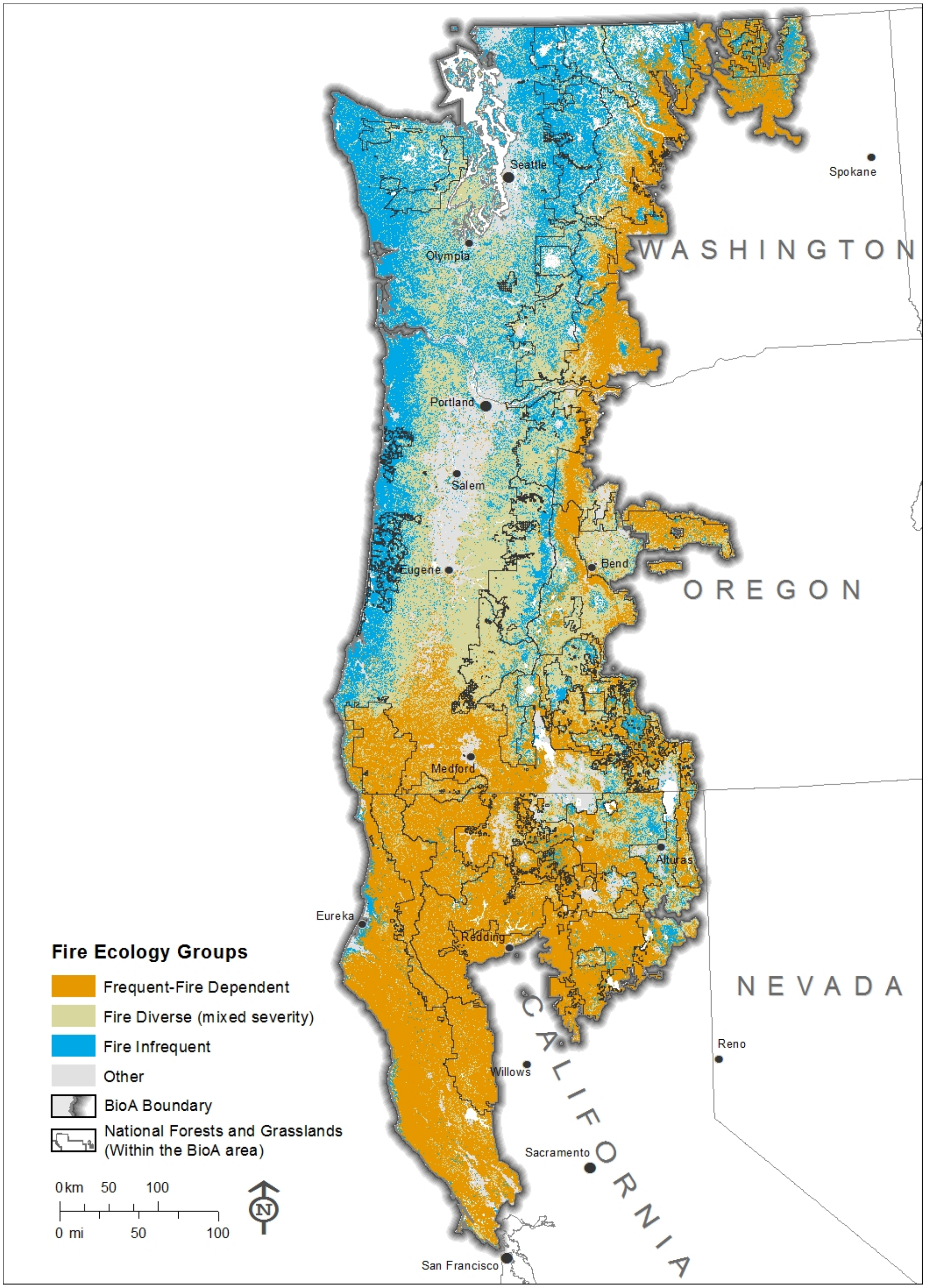
Frequent-Fire Dependent—These are systems in which fire is essential to overall ecosystem functions. Fires were historically (before Euro-American settlement) quite frequent, of low or mixed severity, and served as the primary cornerstone disturbance within these systems. Fire in these systems drove structural and successional dynamics, favoring fire-dependent and fire-adapted species.

Within the BioA analysis area, a total of nine national forests and grasslands have nearly 50 percent or more of their acreage in frequent-fire dependent systems, including the Six Rivers, Klamath, Shasta-Trinity, Rogue River-Siskiyou, Lassen, Mendocino, Ochoco, Modoc, and Fremont-Winema National Forests. The Okanogan-Wenatchee and Deschutes National Forests each have more than a third of their acreage in frequent-fire dependent ecosystems, although both forests contain a broad mix across fire ecology groups.

Fire Diverse (mixed severity)—These are systems in which fire can be important to ecosystem function, but is not the primary driver of successional dynamics, including structure and composition. Historically, fires were moderately frequent, ranging between mixed and high severity in a variety of patch sizes. These highly diverse systems represent a middle gradient between the frequent-fire dependent and fire infrequent ecosystems and are typified by a combination of mixed-severity and stand-replacing fires at medium to long return intervals (approximately 35 to 200 years). The systems generally are associated with forested stands consisting of both fire-tolerant and fire-intolerant species and are most common on the Umpqua, Willamette, Gifford Pinchot, and Mt. Hood National Forests.

Fire Infrequent—These are systems in which fire is not necessarily a part of most ecosystem functions, and when fires do occur, they can be highly impactful. Fires historically were rare or infrequent, of mixed to high severity in large patches, and a rare disturbance within these systems. The infrequent events are an important element associated with the natural range of variation of the long-term successional characteristics of the systems. Historically, lightning was uncommon throughout fire infrequent systems, and fuel moistures in these densely canopied forests prevented fire spread. As a result, these areas developed very large, highly complex old-forest structures consisting of species that have little fire tolerance. Fire serves as a stressor in the systems, due to the infrequency and length of time between disturbance events (200+ years), rather than a driver of successional dynamics. These systems are the dominant type on the Siuslaw, Mt. Baker-Snoqualmie, and Olympic National Forests. Also included in this category are systems that have a moderately long fire return interval range (35 to 200 years); these are characterized by stand replacement type events and have a wide, but scattered range throughout the BioA area.

Map 23 shows the three primary fire ecology groups as they occur across the BioA area. No single national forest is represented by just one type or another; however, it is apparent that many forests contain a significant amount of one type or another. While these three primary groups in no way capture the full complexity and pyro-diversity of the assessment area, they represent a useful construct from which to better understand management successes and potential needs for change across the broad landscape.



Map 23. Fire ecology groups and national forests and grasslands in the Bioregional Assessment area

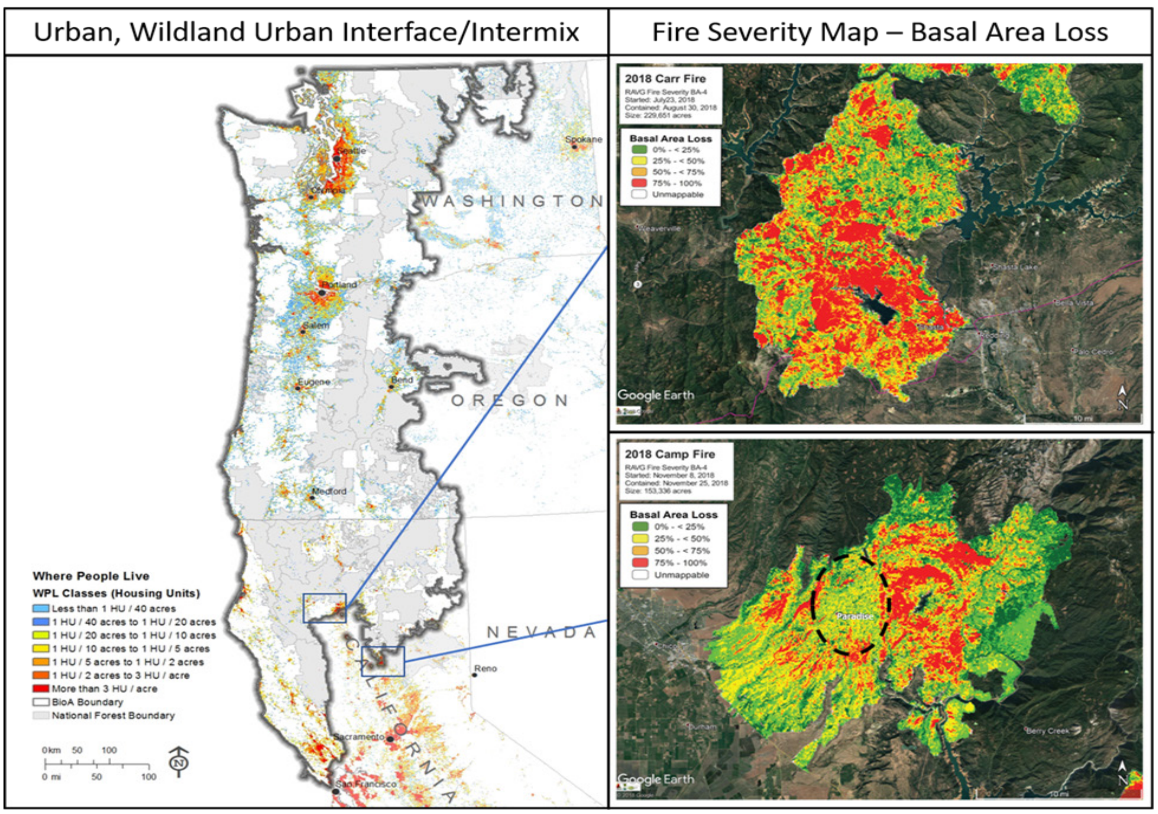
Note that no individual national forest is completely one fire ecology group, but some can be primarily one fire ecology group.

Key Change Issues

Key Change Issue 1—Reduced Wildfire Risk in the Wildland-Urban Interface

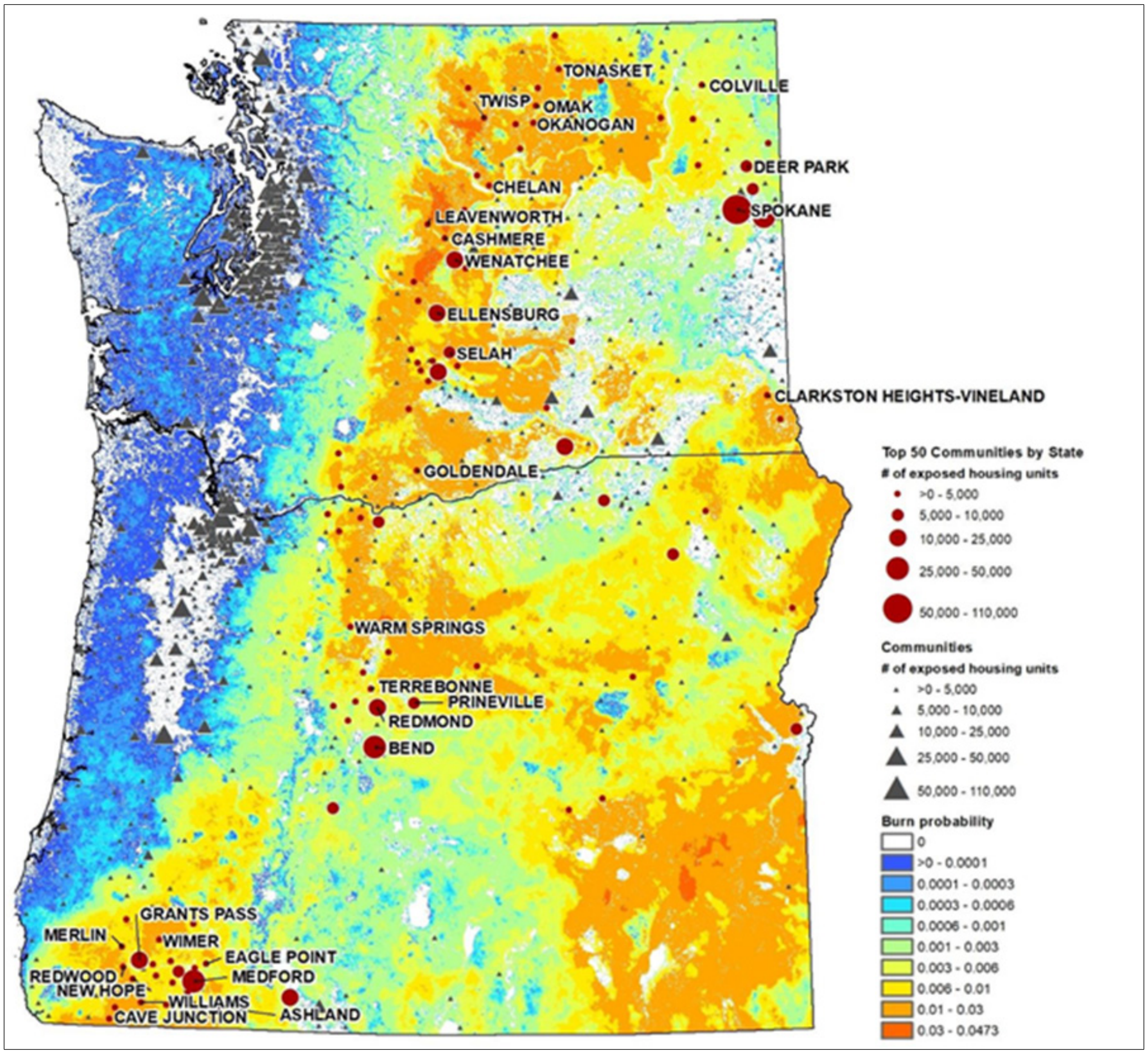
Within the BioA area, existing land use allocations complicate risk management in the wildland-urban interface; where a mismatch occurs, management direction should be revised to be current with direction that prioritizes protection of populated areas. Existing planning guidance does not adequately address the need for strategic risk mitigation in and around communities and the wildland-urban interface.

Fire impacts to the wildland-urban interface/intermix has continued to increase because of two primary factors: (1) increased urbanization of previously remote locations has increased the proportion of National Forest System lands in the interface and (2) climate change continues to extend and intensify fire seasons. Both complicating factors are expected to continue to increase into the foreseeable future (map 24).



Map 24. Housing density in the Bioregional Assessment area

The housing density in and near national forests and grasslands in the BioA area. Where people live (WPL) is measured by housing units (HU) per acre. The graphic on the right highlights the proximity of two communities to forests that are frequent-fire dependent ecosystems with high fire suitability that in 2018 experienced wildfires under conditions that enable extreme fire growth and had severe impacts to these communities and many structures were lost. Basal area loss is an indicator of vegetation fire severity and tree mortality. Dashed line oval in lower right graphic is where about 11,000+ structures were lost in Paradise, California.



Map 25. The 50 most-exposed communities to wildfire risk in Oregon and Washington

Example of post-processing of quantitative wildfire risk assessment (Scott et al. 2018). This depicts the 50 most-exposed communities in Oregon and Washington based on annual burn probability, mapped in dark red. Derived from the Pacific Northwest Quantitative Wildfire Risk Assessment (Gilbertson-Day et al. 2018), to identify community fire threats. Though not currently available for California (in progress), similar data could be displayed to highlight risks to communities and conduct large scale risk assessments.

Planning Considerations

Land use allocations and the associated direction can be adjusted to allow for community protection as a management objective. The 2012 planning rule highlights the need to develop integrated plan components for management areas associated with the wildland-urban interface providing for both ecological objectives and community protection objectives.

Refer to BioA Chapter 2 Management Recommendation

Recommendation 5: Prioritize community and firefighter safety in forested areas near communities at risk from wildfires.

Geographic Considerations

For this key change issue, emphasis should be placed on all forests; forests in primarily frequent-fire dependent ecosystems should be regarded as the highest priority, followed by forests with predominantly fire diverse (mixed severity) ecosystems, and then predominately fire infrequent ecosystem forests.

Key Change Issue 2—Need for Increased Fire and Vegetation Management in Frequent-Fire Dependent Ecosystems

In the frequent-fire dependent ecosystems found in the southern, eastern, and northeastern portions of the BioA area, there is an immediate need to increase the pace and scale of work aimed at reducing the risk of undesirable fire effects. This management should be informed by the natural disturbance processes inherent in the development of frequent-fire dependent ecosystems and may involve mechanical treatments paired with extensive prescribed fire and managed wildfire to achieve resource benefits. This management should be targeted where it is strategically and operationally effective both ecologically and from a risk-based framework.

Recent trends in wildfire activity throughout the drier, frequent-fire dependent ecosystems of the plan area demonstrate that current treatments are insufficient in pace and scale to mitigate and restore fire resiliency in this ecosystem (table 5; map 26; figure 49, figure 50). These are systems that evolved with fire and are now highly departed from their historic frequency. Current conditions in these systems are the result of more than a century of fire exclusion combined with grazing and historic timber harvest that often removed the largest, oldest, and most fire-resistant stands of trees. This has resulted in forest conditions that are very different from their natural range of variation, with an overabundance of dense stands of young and immature trees. These highly departed conditions have facilitated a shift in fire effects, resulting in an increase in high-severity fire where historically it was uncommon, which then results in an increased risk of uncharacteristically severe fire types and size of high-severity patches during conditions that are favorable to high-intensity fire and explosive growth.

Despite the highly altered conditions present in many of the frequent-fire dependent ecosystems, there are opportunities to increase the use of managed fire to achieve desired ecological effects. Managing fire for multiple objectives affords opportunities, where and when appropriate, to use fire as a tool to aid in the restoration of departed ecosystems. While some landscape settings currently lend themselves to managing natural ignitions to achieve resource benefits, additional strategic investments in mechanical treatments or prescribed fire applications can make this important and cost-effective tool more widely applicable.

The costs associated with managing and mitigating the direct and indirect impacts from wildfires have increased. This is especially true for large-scale and long-duration high-severity fires that are becoming more common. Opportunities exist to reduce overall suppression costs by using a strategic risk-based decision support process to inform wildfire management response and manage fire as a natural ecological process when and where it can be done safely, taking into account values at risk (Thompson et al. 2015). Managing wildfire based on time and conditions (right place, right time, and right conditions) is an important tool to assist in the reduction of undesirable losses resulting from uncharacteristic wildfires. In the current and projected climate and environment, using all tools, including managed wildfire to strengthen ecosystem resiliency, will be necessary.

Challenges exist in managing wildfire across agency and multi-ownership lands (Charnley et al. 2018, Zald and Dunn 2018). Upfront recognition and acknowledgment of the conflicts and tradeoffs of managing wildfire can be evaluated through risk-based planning and analysis process (for example, quantitative wildfire risk assessments) (Finney 2005; Calkin et al. 2010, 2011; Scott et al. 2013). Reducing wildfire risk to maintain and protect community and socioeconomic health, alongside other resource values, such as wildlife habitat, watershed integrity, and timber producing markets will have tradeoffs. This may include leveraging risk-based analyses and planning to direct limited funding to wildfire risk reduction and restoration activities near communities, major infrastructure, and other values that are at high risk of being affected by wildfire with great loss and negative consequences. By focusing wildfire risk reduction and restoration activities on and around areas that are highly valued, such as communities at risk, we reduce capability to prioritize and implement funded restoration activities in areas that are away from highly valued areas at risk. This is where a strategic wildland fire management plan approach (including quantitative wildfire risk assessment) helps in identifying areas on the landscape where the potential for managing wildfire for multiple objectives to support for restoration needs may be achieved. This type of pre-decisional assessment and planning primes time-sensitive decision processes by identifying areas where decision-makers can opt to manage a wildfire for multiple objectives or not. Of course, the decision whether to manage a wildfire for multiple resource objectives will continue to be based on a current risk-based decision process for each wildfire incident, where the results could have greater variability of fire effects ranging from undesired to desired.

Planned and identified tradeoffs in managing wildfires through risk-based decision planning, plan components, and agreements would enable and facilitate a timely and appropriate response to implementing a plan to manage wildfire for multiple objectives.

Planning Considerations

Develop plan direction and desired conditions that are informed by ecology and promote natural fire adaptations to improve resilience through the use of prescribed and managed wildfire.

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to better respond to future environmental uncertainties.

Recommendation 5: Prioritize community and firefighter safety in forested areas near communities at risk from wildfires.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Recommendation 7: Expand the use of timber harvest as a restoration tool to provide economic and social benefits to communities.

Recommendation 8: Shift from single-species management to maintaining and restoring habitat for multiple species to manage for ecosystem resilience under future uncertainty.

Recommendation 9: Promote active management in plant and animal habitats to restore and encourage ecological resilience.

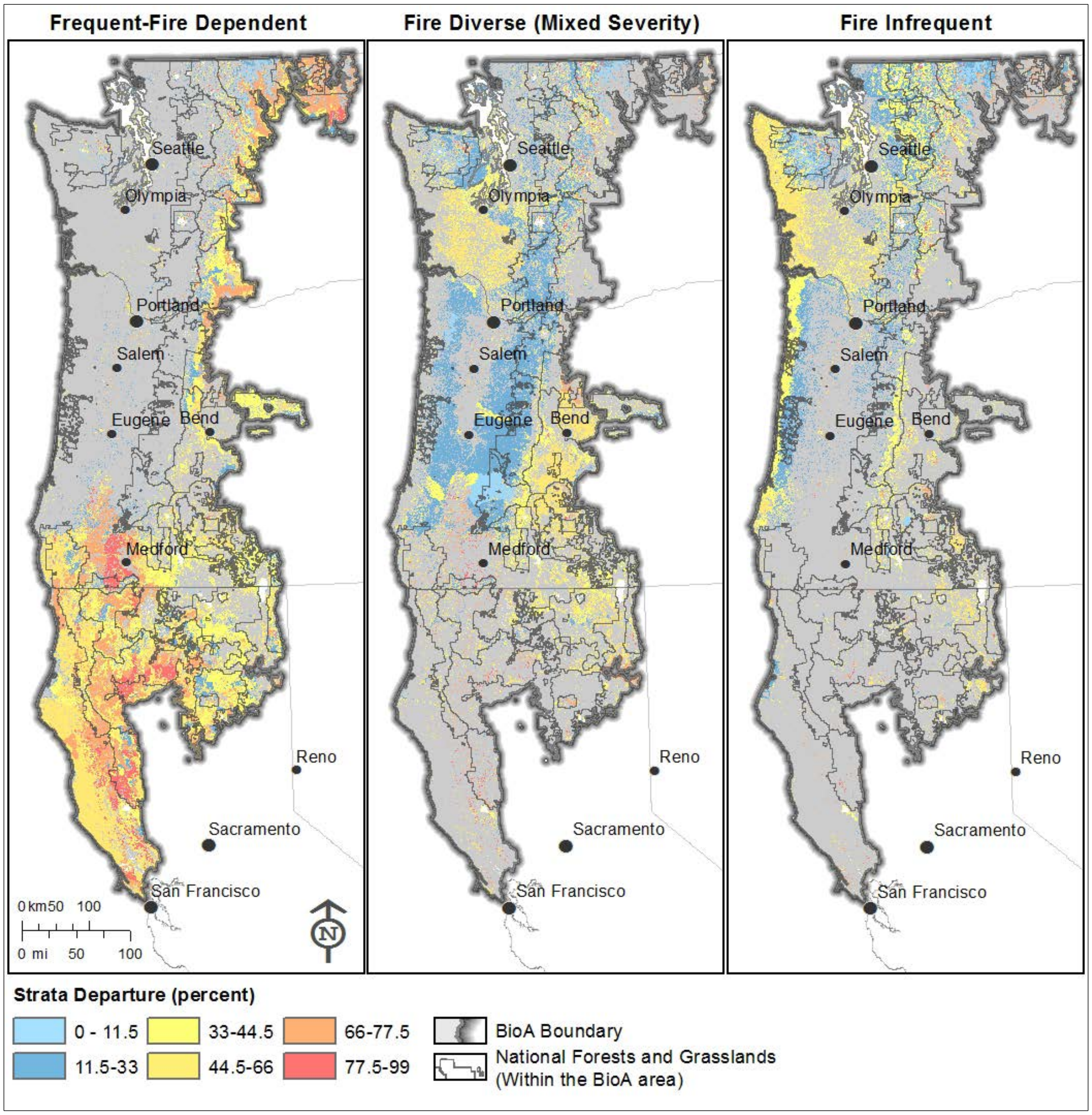
Geographic Considerations

Within the BioA area, a total of nine national forests and grasslands have nearly half or more of their acreage in frequent-fire dependent systems, including the Six Rivers, Klamath, Shasta-Trinity, Rogue River-Siskiyou, Lassen, Mendocino, Ochoco, Modoc, and Fremont-Winema National Forests. The Okanogan-Wenatchee and Deschutes National Forests each have more than a third of their acreage in frequent-fire dependent ecosystems, though both of these forests contain a broad mix across fire ecology groups.

Table 5. Ecological departure from reference condition for National Forest System lands within the Bioregional Assessment area by fire ecology group

Note the greater proportional acreage in high and moderate ecological departure in frequent-fire dependent ecosystems. Values are presented by forest at the end of the “Background Information to Support Key Change Issues” section.

Fire Ecology Group	Ecological Departure “ Low (acres)	Ecological Departure Moderate (acres)	Ecological Departure High (acres)	Ecological Departure Total (acres)
Frequent-fire dependent	1,125,388	7,896,770	2,986,012	12,008,170
Fire diverse (mixed severity)	4,840,502	3,296,774	180,791	8,318,066
Fire infrequent	1.844,456	3,090,506	141,397	5,076,359
Total	7,810,346	14,284,050	3,308,199	25,402,595



Map 26. Ecological departure of fire ecology groups panel map

A geographical representation of the current ecological departure (from reference condition) within the Bioregional Assessment area. Each panel represents a different fire ecology group. Note the concentration of moderate and high ecological departure in frequent-fire dependent ecosystems.

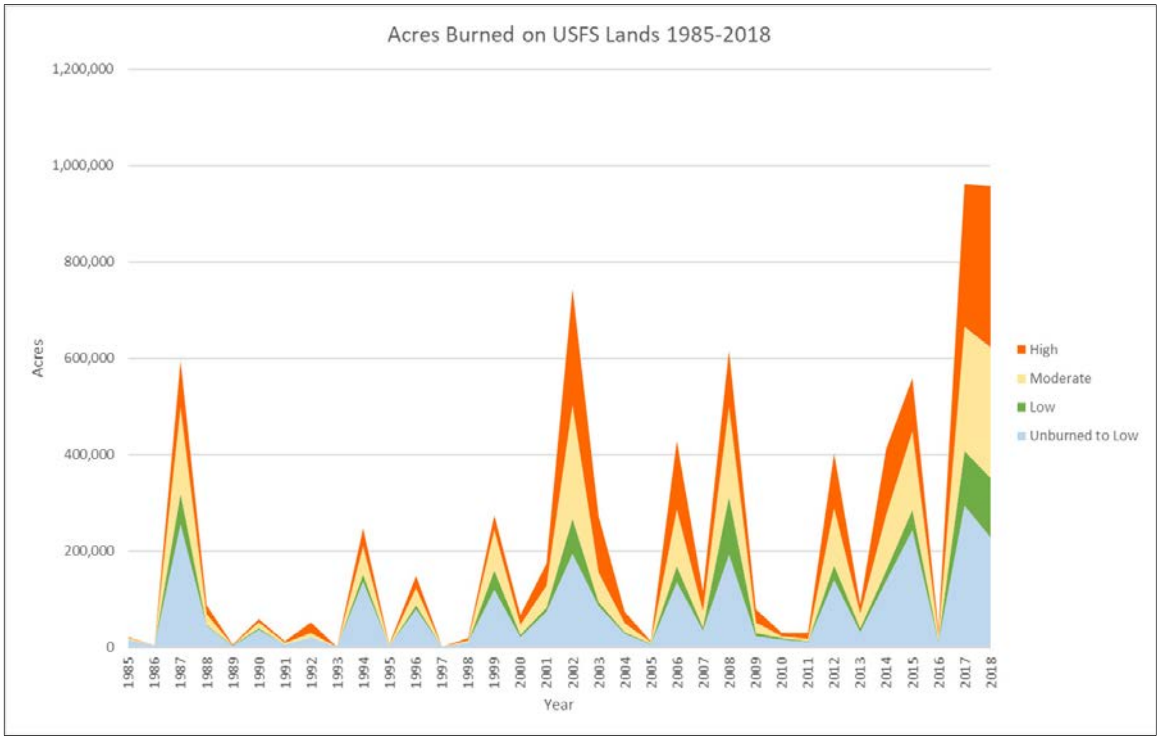


Figure 49. Total annual acres burned by severity class on U.S. Forest Service lands in the Bioregional Assessment area, 1985–2018

Note the widely variable nature of area burned and the apparent increased burn area and regularity of fire on an annual basis.

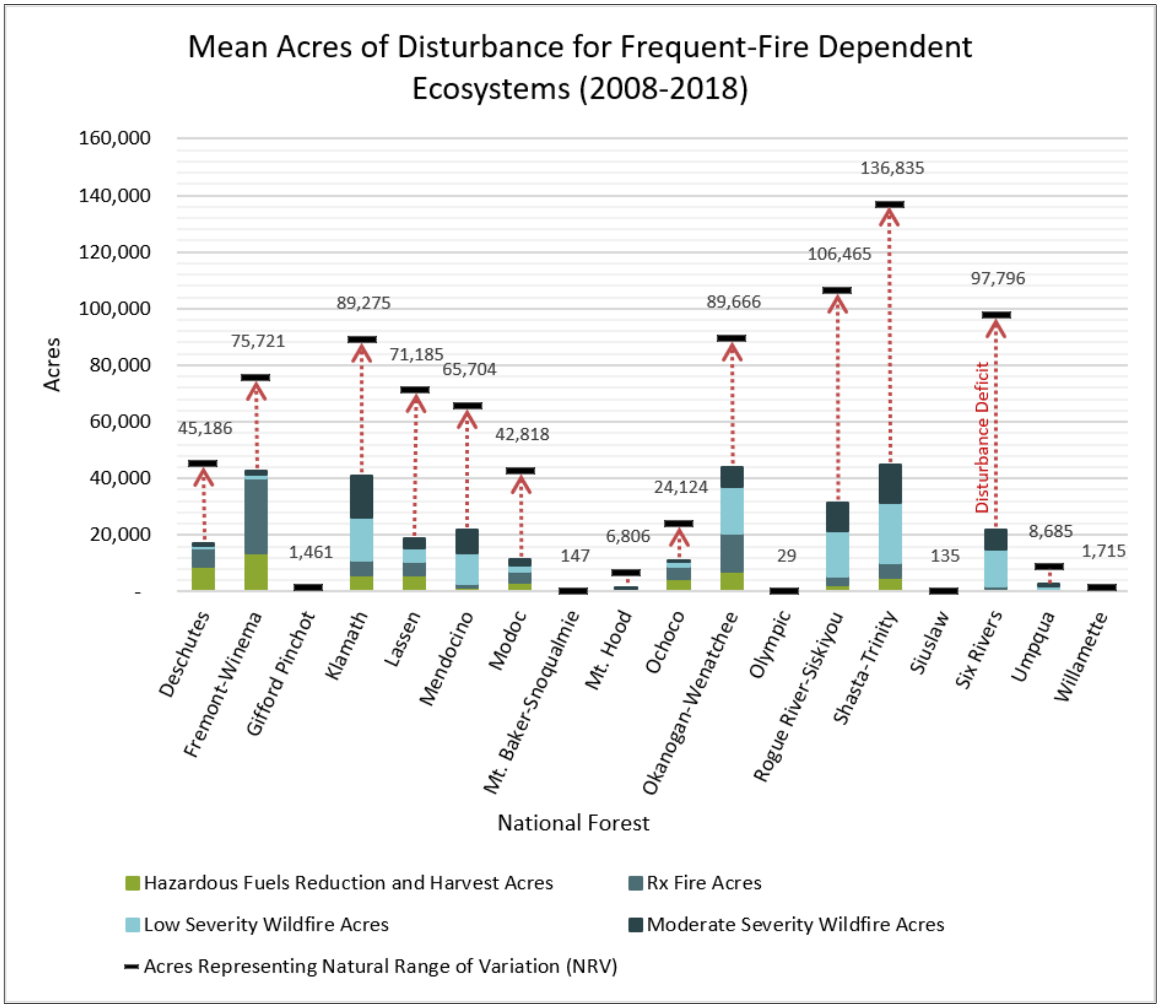


Figure 50. Mean acres of disturbance for frequent-fire dependent ecosystems by national forest, relative to natural range of variation

Totals are based on 2008–2018 data. The gap between the black bar and the colored bar is the gap between the amount of fire that historically, or naturally, was on the landscape and the amount of fire, wildfire or prescribed, and hazardous fuels treatment that is currently on the landscape. This illustrates the gap that needs to be accomplished to restore ecosystems, and fire's role in those ecosystems.

Key change issue 3—Develop and Articulate Appropriate Desired Future Conditions

Management direction should be developed based on a comprehensive understanding of ecological dynamics and fire adaptation. Desired conditions that are developed to promote ecological integrity and resilience should be paired with site potential and underlying ecosystem dynamics. These desired conditions and associated management direction should be applied specifically to where these systems occur on the landscapes.

Fire plays a variable role in different biophysical settings of the BioA area both historically and contemporarily. Land management plan direction should better differentiate between these systems and better align management with the goal of improving sustainable or resilient conditions across the variable landscape.

Additionally, fire-diverse systems are highly variable across the BioA area, and management should be tailored to local conditions to best address this variability, accounting for site potential and natural disturbance regime. This is especially true for desired conditions relating to patch size and patch distribution, where local topography and spatial juxtaposition of vegetative systems have a large influence on natural conditions.

Planning Considerations

Move away from the dry versus moist dichotomy that is prevalent in the NWFP. Replace it with a more comprehensive classification of ecosystems based on their natural disturbance regimes.

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Geographic Considerations

Frequent-fire dependent ecosystems are found primarily in northern California, southwestern Oregon, and along the east side of the Cascade Range in both Oregon and Washington (map 23).

Key Change Issue 4—Reduced Risk of Uncharacteristic Wildfire Events

Current vegetation conditions in the BioA include forest structures that are outside of natural ranges of variability primarily in the frequent-fire dependent ecosystems. This has resulted in contemporary fires that are often uncharacteristic and can negatively affect ecological integrity. Climate change is projected to exacerbate the conditions that contribute to uncharacteristic fire effects.

Increased mechanical treatment may, in some settings, mitigate against the negative effects of uncharacteristic stand-replacing fire, especially in drier systems. Investments in reducing and modifying fuel configurations associated with contemporary conditions will require periodic maintenance using a combination of prescribed fire, managed natural fire or repeated fuels reduction treatments at levels higher than those occurring under current management. Without this maintenance, resiliency will be lost and the risk of uncharacteristic stand-replacing fire in the frequent-fire dependent ecosystems will again increase.

Planning Considerations

Management strategies should be developed and applied to reduce the risk of extreme wildfire events across the BioA area.

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 5: Prioritize community and firefighter safety in forested areas near communities at risk from wildfires.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Recommendation 7: Expand the use of timber harvest as a restoration tool to provide economic and social benefits to communities.

Recommendation 8: Shift from single-species management to maintaining and restoring habitat for multiple species to manage for ecosystem resilience under future uncertainty.

Recommendation 9: Promote active management in plant and animal habitats to restore and encourage ecological resilience.

Geographic Considerations

Frequent-fire dependent ecosystems are located primarily in northern California, southwestern Oregon, and along the east side of the Cascade Range in both Oregon and Washington (map 23).

Key Change Issue 5—Opportunity for Integrated Vegetation Restoration

Land management allocations should promote the potential synergy between noncommercial mechanical treatment, timber harvest, and fire (see also "Sustainable Timber"). The original NWFP land use allocations were broadly designed to separate the land into conservation- versus production-focused areas. The majority of the timber volume produced on National Forest System lands today comes as byproduct of vegetation management that focuses on fuel reduction, restoration, and resiliency. An opportunity exists to better align these activities across land use allocations. Doing so will require aligning objectives with science-based, ecologically appropriate treatments and obtaining the public trust and approval to manage in such a fashion. This will require shifting some timber harvest away from a volume-production focus and toward an ecologically sound, outcome-driven approach.

Prescribed fire and managed wildfire to promote resource benefits are important tools for achieving desired conditions and can be paired with timber harvest where practicable to obtain optimal results. The ability of mechanical treatments alone to mimic fire on the landscape is varied across the BioA area and falls short of producing the full effect of fire as a natural and important disturbance in these landscapes. These treatments are an important tool to use in concert with fire, where appropriate, to reintroduce healthy disturbance in many northwestern systems.

This synergy is strongest in the dry, frequent-fire dependent systems, where mechanical thinning is often essential before first entry with fire to mitigate the potential for high-severity fire and unwanted effects associated with fire occurrence in the current, dense fuel configurations.

Outside the dry, frequent-fire dependent regime systems, mechanical treatments can be used to create settings where fire can play a more natural role on the landscape.

In places where managing fire is difficult due to the occurrence of communities, homes, and highly valued resources and assets in settings where they are prone to fire degradation, mechanical treatment should be used to mitigate risk and exposure. In some places, this has the potential to produce timber volume as hazardous fuels are removed. This synergy can be used to help defray and support the cost of initial fuel reduction treatments where it applies. It should be recognized that long-term maintenance of these strategic fuel treatments likely will not produce significant volume. Future maintenance of these critical fuel reductions will need to be supported without this cost defrayment.

With regards to complex early-seral conditions, mechanical treatments tend to do a poor job of mimicking the effects of fire for creating this important habitat type. The need for complex early-seral conditions is a larger and more relevant topic in fire diverse (mixed severity) and fire infrequent systems, though contemporary fire rates in these systems are currently adding complex early-seral conditions naturally. Large patches of complex early-seral were not typical of the frequent-fire dependent regimes. Early-seral conditions in these regimes occurred as small patches (less than 1 to 2 acres) imbedded in a mosaic dominated by relatively open older patches of trees.

Planning Considerations

Increase the use of prescribed and managed wildfire as a tool to achieve ecological objectives by pairing it with mechanical treatments and timber production objectives where possible.

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to be better positioned to respond to future environmental uncertainties.

Recommendation 5: Prioritize community and firefighter safety in forested areas near communities at risk from wildfires.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Recommendation 7: Expand the use of timber harvest as a restoration tool to provide economic and social benefits to communities.

Recommendation 8: Shift from single-species management to maintaining and restoring habitat for multiple species to manage for ecosystem resilience under future uncertainty.

Recommendation 9: Promote active management in plant and animal habitats to restore and encourage ecological resilience.

Geographic Considerations

This potential synergy of activity types is predominantly applicable in the frequent-fire dependent ecosystems that are located primarily in northern California, southwestern Oregon, and along the east side of the Cascade Range in both Oregon and Washington (map 23).

Background Information to Support Key Change Issues

The fire regime classification background, crosswalk, and methods section identifies how the existing data were used to simplify and define new terms to address wildfire across a very diverse landscape to help clarify urgency and need for change issues in current plan components. Defining the wildfire ecology groups was paramount to this process, and this section defines what they are, and in what context they relate to the key points.

In the fire suppression and risk management section, fire management and technological advances that contribute to increased suppression capability provide a recent example of extreme fire events and identified wildfire risk assessment processes are described. Reducing adverse effects from wildfire and smoke provides socio-economic context to the impacts that wildfire smoke have on communities and how growing urbanization of wildlands and climate change are contributing.

The fire policy section provides historical context to how wildfire policy has contributed to the legacy of suppression and the contemporary effects of wildfire on communities, ecosystems, and current policies and direction. This section also identifies and provides context for how wildfire suppression has contributed to and changed forest health and ecosystem resilience to insects, disease, and drought affecting a majority of the BioA area.

Fire Regime Classification

The BioA area spans an enormous geographic area that is home to a diverse suite of ecological systems (see map 12 “vegetation zones” in chapter 3). These ecological systems exist along climatic gradients, including moisture and temperature. Fire is an essential and natural part of the BioA area, and before the contemporary period, fire played a critical role in many of these ecological systems. Understanding the role of natural fire along the climatic gradients as a driver of ecological trajectories and as a moderating, maintaining force is critical to designing appropriate management strategies and supporting ecological integrity and resiliency.

Due to the inherent complexity in ecological systems, fire ecology groups were created for the BioA; these classify fire regimes and their connection to ecosystem function and forest management. The fire ecology groups represent elements of current and reference conditions and the ecology of how fire interacts with vegetation, topography, climate, and fire variables (Agee 1996, Barrett et al. 2010, Schmidt et al. 2002). The fire ecology groups helped characterize the fire departure for the fire regime type, characterize where on the landscape the need for management for restoration and resiliency is most urgent, and use terminology that clearly integrates these concepts for planning purposes.

These groups include:

- Frequent-fire dependent
- Fire diverse (mixed severity)
- Fire infrequent

Figure 51 illustrates how the different classification methods used in the *Synthesis of Science to Inform Land Management Within the Northwest Forest Plan Area (*NWFP Science Synthesis) and NWFP BioA crosswalk to the LANDFIRE fire regime groups were established after approval of the National Fire Plan (2000), which led to a charter to provide a consistent and comprehensive classification for the nation (Rollins 2009).

LANDFIRE Regime Groups

Fire Regime	Frequency (years)	Severity
I	0-35	low/mixed
II	0-35	replacement
III	35-200	mixed/low
IV	35-200	replacement
V	200+	replacement/any severity

NWFP SS 2018

Terminology Used for Fire Regime	Frequency (ref data years)	Severity
Very frequent, Low Severity	5-25 (3-36)	low severity
Frequent, mixed severity	15-50 (12-27)	mixed severity
Moderately frequent to somewhat frequent, mixed severity	50-200 (40-246)	mixed severity
Infrequent, high severity	200-1000 (No data)	stand replacing

LANDFIRE Regime Groups

Fire Regime	Frequency (years)	Severity
I	0-35	low/mixed
II	0-35	replacement
III	35-200	mixed/low
IV	35-200	replacement
V	200+	replacement/any severity

NWFP BioA

Terminology Used for Fire Ecology Group	Frequency (ref data years)	Severity
Frequent-Fire Dependent	0-35 (6-35)	low/mixed & replacement
Fire Diverse (mixed severity)	35-200 (27-185)	mixed/low
Fire Infrequent	35-200 & 200+ (36-unknown years)	replacement & any severity

Figure 51. Fire regime classification crosswalk for LANDFIRE (Barrett et al. 2010), volume 1 synthesis of science to inform land management within the Northwest Forest Plan area (Spies et al. 2018), and the NWFP Bioregional Assessment fire ecological groupings.

This information is provided for readers who are familiar with LANDFIRE regime groups or the fire regime terminology used in the NWFP Science Synthesis, to facilitate understanding of how those terminologies relate to the simplified fire ecology groups described in the BioA.

Table 6 provides a crosswalk for the terminology between fire ecology groups and fire regimes (Barrett et al. 2010, Hann et al. 2004), and table 7 includes a brief description of each system type and their subtypes. It also shows how each fire ecology group relates to traditional fire regime groups and terminology used in LANDFIRE (based on Hardy et al. 1998, 2001).

Map 23 shows the spatial extent and configuration of these broad fire regime types across the BioA area. Figure 52 depicts the proportional representation of these fire systems, and figure 53 illustrates subgroups on each forest within the BioA area.

Table 6. Relationship between fire regime groups and the fire ecology groupings

This table is another crosswalk to relate some terminology you may be familiar with to the fire ecology terminology used in the Bioregional Assessment.

Terminology	Fire Ecology Group	Fire Regime Group	Frequency (data range)	Severity
Frequent-fire dependent	Frequent-fire dependent	Fire regime groups I and II	0–35 years (6–35 years)	Low/mixed and replacement
Fire diverse (mixed severity)	Fire diverse (mixed severity)[1]	Fire regime group III	35–200 years (27–185 years)	Mixed/low
Fire infrequent	Fire infrequent[2]	Fire regime groups IV and V	35–200 and 200+ years (36–unknown years)	Replacement and any severity

1. System in fire regime group III but with long mean fire return intervals and limited fuels to carry fire were classified into fire infrequent (for example, biophysical settings [BpS] 10190).

2. Represents primarily stand replacement fire for fire regime group IV, and long mean fire return intervals for any BpS.

Methods

To depict the fire ecology groups for the BioA footprint, the use of existing datasets were tiered from the datasets used in the ecological vegetation zones and subzones and crosswalks to the biophysical settings (BpS). Percentage of seral stage, reference percentage of fire severity type, and reference mean fire return interval are spatially depicted on the landscape at 30m pixel level. The results were used to depict levels of departure, based on mean fire departure and type of fire/frequency for fire regime type and adaptation, using the three-categories (frequent-fire dependent; fire diverse (mixed severity); fire infrequent).

This process follows the same linkage of vegetation subzone mapping and BpS as was conducted in support of the developed ecological departure scoring and associated restoration/succession needs analysis (Haugo et al. 2015, Ringo et al. 2019). Using the same base underpinning for the two products is essential in linking the necessary evaluation of ecological departure to the underlying disturbance regimes and balance/imbalance that contribute to the departure (table 5).

Table 7. Fire ecology groupings for the Bioregional Assessment area

This table provides a more thorough description of the fire ecology groups as split by subgroups for those new to fire regimes and similar terminology.

Fire Ecology Group	Fire Ecology Subgroup	Description
Frequent-fire dependent	Driven by fire	These systems naturally develop with frequent, low-intensity fire, and that repeated disturbance is important in modifying vegetative structure and composition through time. This natural disturbance favors fire tolerant species, with structures conducive to low-intensity fire.
Frequent-fire dependent	Regenerated by fire	These systems are generally fire dependent, but fire naturally regenerates vegetation conditions. Dominant vegetation tends to be fire intolerant.
Frequent-fire dependent	Tolerant of fire	Systems where frequent, predominantly low-intensity fire was naturally common, but is not critical to maintain and promote natural stand development. Dominant species in these systems tend to be highly tolerant of fire and are long lived.
Fire diverse (mixed severity)	not applicable	These systems naturally supported predominantly mixed-severity fires. They historically burned relatively infrequently and are comprised of a combination of fire tolerant and fire-intolerant species.
Fire infrequent	Fire prone – Regeneration	These systems naturally had infrequent, but high-severity fire. These fires were often episodic and correlated with extreme climate and weather events.
Fire infrequent	Limited fire	These systems naturally had very little fire of any type in them because of fuel configurations and/or climate.
Fire infrequent	not applicable	No subclass identified.

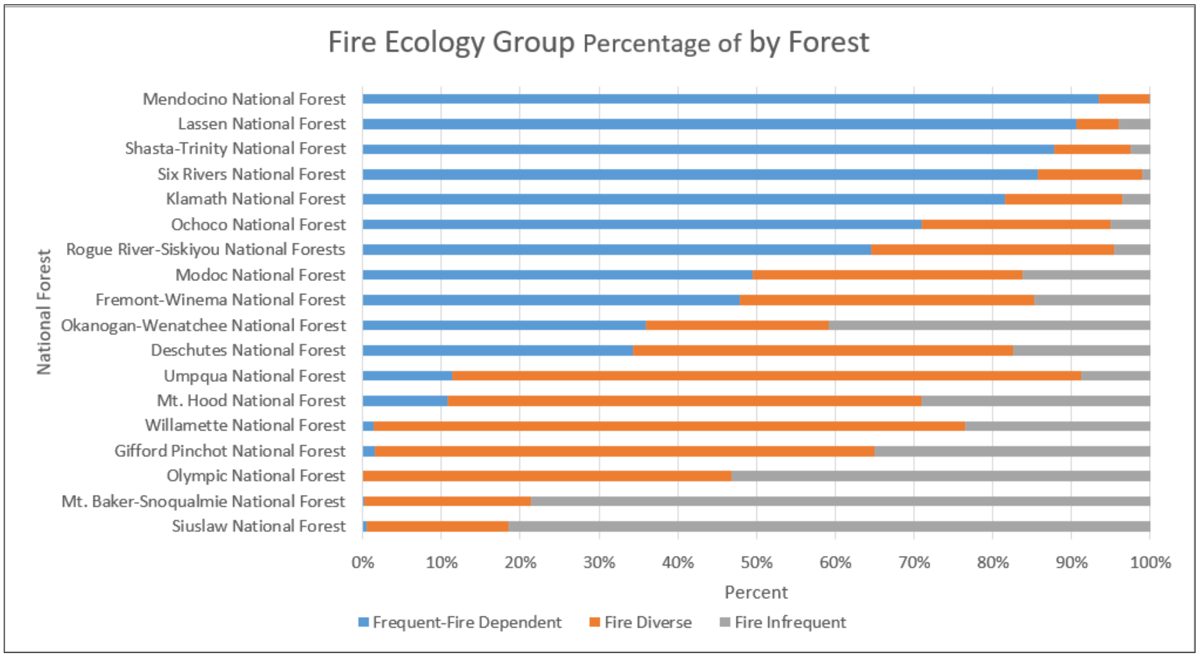


Figure 52. Percentage of fire ecological group based on historical fire regime by national forest. Note that no forest is all one fire ecology group.

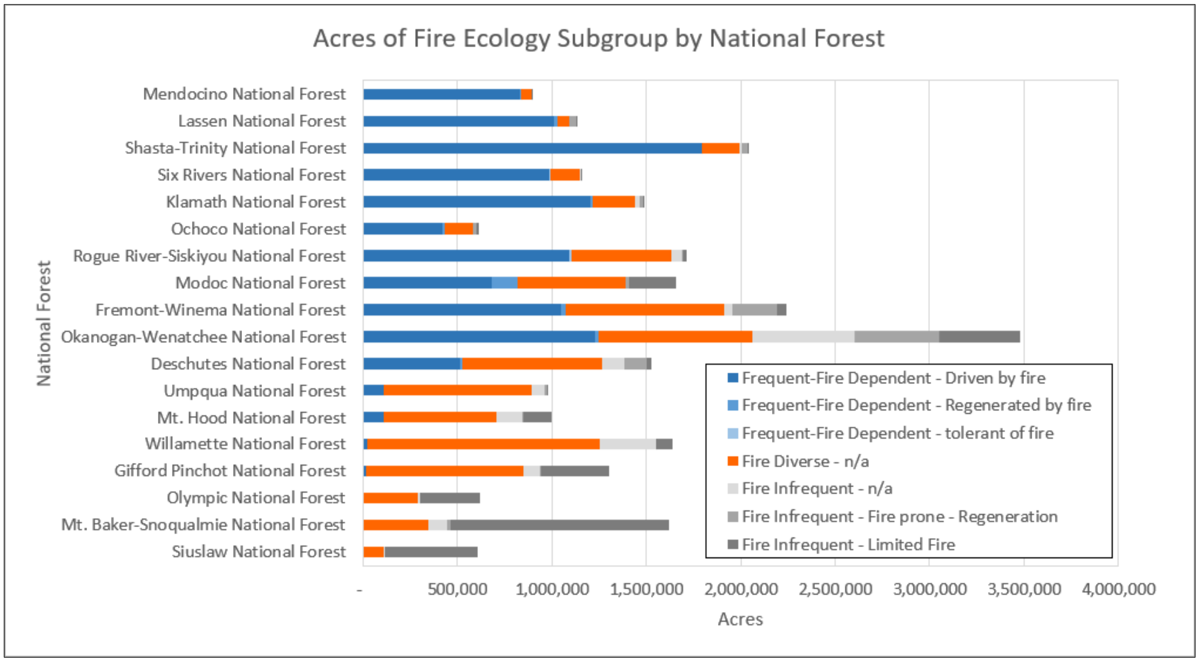


Figure 53. Acres of fire ecology subgroup by national forest within the Bioregional Assessment area

This chart includes the overall acreage of fire ecology subgroup by forest so that the size of some of these areas plays a role in overall impact across the BioA area.

Frequent-Fire Dependent Ecosystems

Frequent-fire dependent ecosystems consist of landscapes where wildfire is essential to overall ecosystem functions. Before Euro-American settlement, fires were more frequent, of low or mixed severity, and served as the primary cornerstone disturbance within these systems. Wildfire in these systems drove structural and successional dynamics, favoring frequent-fire dependent and fire-adapted species, which typically were the most fire resistant.

Current conditions are the result of more than a century of fire suppression combined with historic timber harvest that often removed the largest, and oldest stands of trees. This resulted in forest conditions that are very different from their natural range of variation with an overabundance of young and immature, dense stands. These highly departed conditions have facilitated a shift in fire effects, resulting in an increase in high-severity fire where historically it was uncommon.

Within the BioA area, nine national forests and grasslands have nearly half or more of their acreage in frequent-fire dependent systems: Six Rivers, Klamath, Shasta-Trinity, Rogue River-Siskiyou, Lassen, Mendocino, Ochoco, Modoc, and Fremont-Winema National Forests. The Okanogan-Wenatchee and Deschutes National Forests each have more than a third of their acreage in frequent-fire dependent ecosystems, with both of these forests containing a broad mix across fire ecology groups. Table 8 illustrates the relative proportions of each of these forests based on predominant fire regime characteristics.

Table 8. National forests dominated by frequent-fire dependent ecosystems within the Bioregional Assessment area

National Forest	Frequent-Fire Dependent	Fire Diverse (mixed severity)	Fire Infrequent
Fremont-Winema National Forest	48%	37%	15%
Klamath National Forest	82%	15%	4%
Lassen National Forest	91%	5%	4%
Mendocino National Forest	93%	6%	0%
Modoc National Forest	49%	34%	16%
Ochoco National Forest	71%	24%	5%
Rogue River-Siskiyou National Forest	65%	31%	5%
Shasta-Trinity National Forest	88%	10%	3%
Six Rivers National Forest	86%	13%	1%
Okanogan-Wenatchee National Forest	36%	23%	41%
Deschutes National Forest	34%	48%	17%

While the overall amount of wildfire in these systems is significantly less than the amounts that historically drove these systems (table 9), there has been a pronounced shift from low-severity fire to high-severity fire. Figure 54 shows the contemporary percentage of all burned acres by severity class. It also illustrates the relatively high percentage of mixed-severity and stand-replacing fire that has occurred in the frequent-fire dependent ecosystems which historically would have burned predominantly with low-severity fire.

Table 9. Calculated contemporary mean fire return interval in years for frequent-fire dependent ecosystems (all fire severity classes 1993 to 2018)

For those forests with a high proportion of frequent-fire dependent ecosystems, fires are currently burning less frequently than they would have.

	Frequent-Fire Dependent				
	Driven by Fire	Regenerated by Fire	Tolerant of Fire	**Frequent-Fire Dependent Total**	Percent of forest in Frequent-Fire Dependent:
Forest	*Mean Fire Return Interval (MFRI) in Years*				
Deschutes National Forest	*123*	*190*		**124**	34%
Fremont-Winema National Forest	*267*	*866*		**270**	48%
Gifford Pinchot National Forest	*213*	*29,263*		**218**	2%
Klamath National Forest	*57*	*513*		**58**	82%
Lassen National Forest	*116*	*409*	*312*	**118**	91%
Mendocino National Forest	*44*	*55*	*46*	**44**	93%
Modoc National Forest	*157*	*82*		**135**	49%
Mt. Baker-Snoqualmie National Forest	*2,310*	*15,500*		**2,964**	0%
Mt. Hood National Forest	*1,124*	*5,980*		**1,125**	11%
Ochoco National Forest	*182*	*170*		**181**	71%
Okanogan-Wenatchee National Forest	*53*	*35*		**53**	36%
Olympic National Forest	*588*			**624**	0%
Rogue River-Siskiyou National Forest	*37*	*123*	*96*	**37**	65%
Shasta-Trinity National Forest	*68*	*136*		**69**	88%
Siuslaw National Forest					0%
Six Rivers National Forest	*67*	*184*	*513*	**67**	86%
Umpqua National Forest	*67*	*106*		**67**	11%
Willamette National Forest	*317*	*169*		**316**	1%
MFRI (1993-2018) and Percent of BioA Forests	***70***	***96***		***70***	***44%***

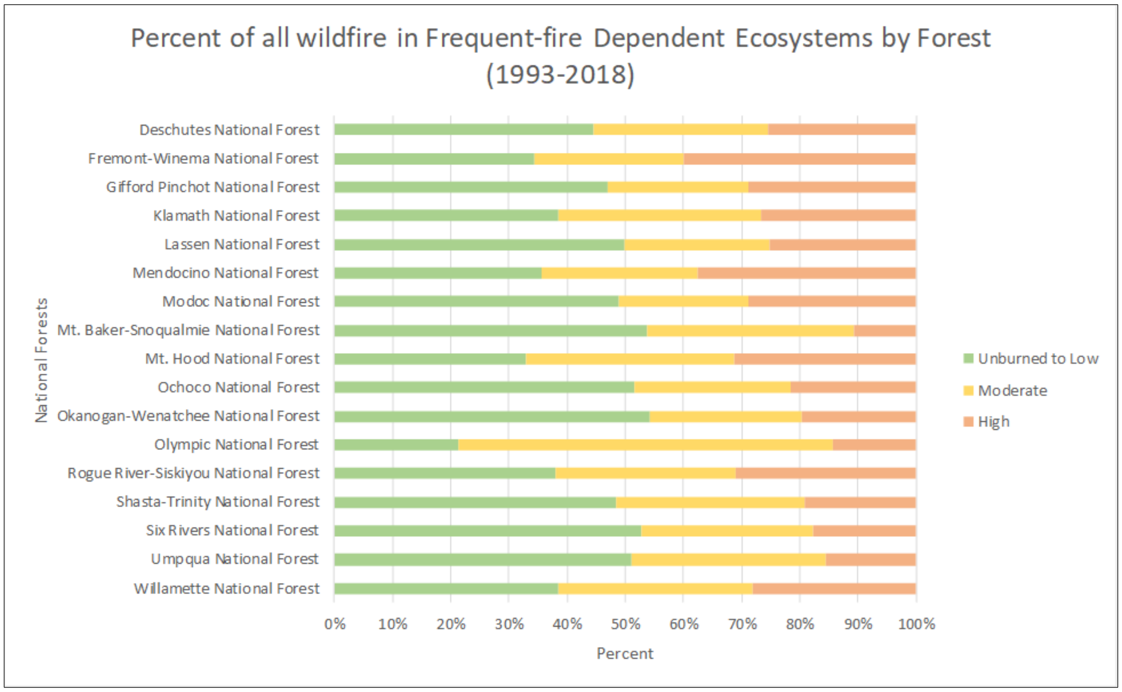


Figure 54. Percentage of severity class for all wildfire in frequent-fire dependent ecosystems by national forest

The Siuslaw National Forest did not have a wildfire of minimum threshold size to be evaluated by Monitoring Trends in Burn Severity database from 1993 to 2018.

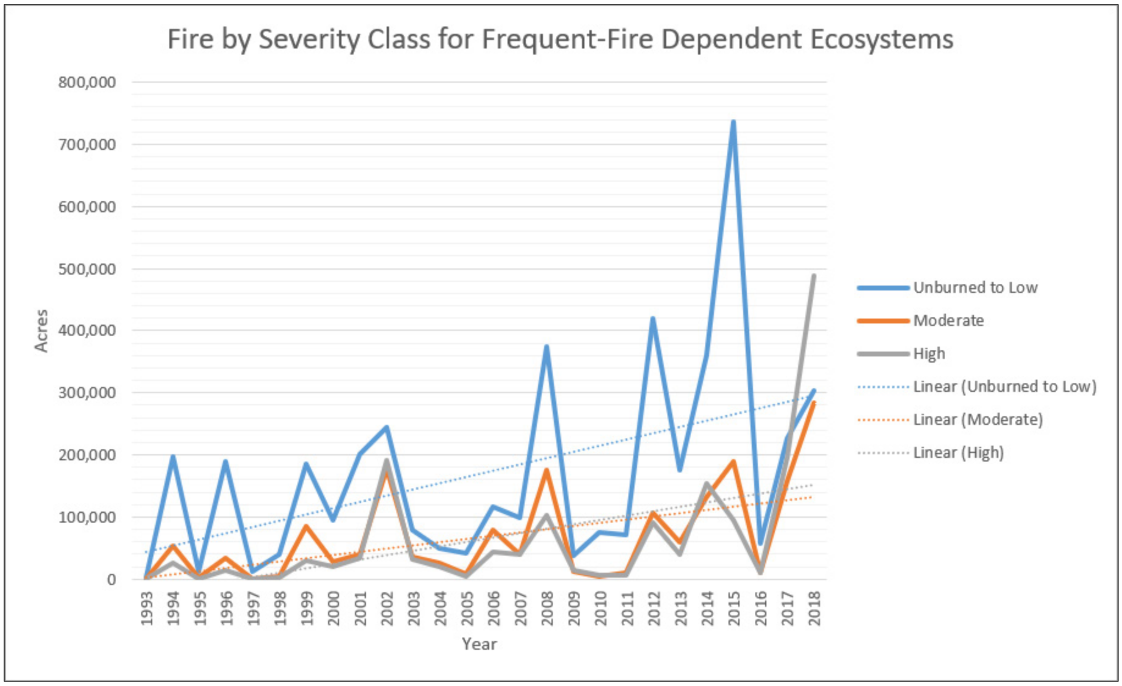


Figure 55. Fire severity class trend for frequent-fire dependent ecosystems of the Bioregional Assessment area, 1993–2018

Burn area is increasing and low-severity fire is increasing faster than both high- and moderate-severity fire.

The frequent-fire dependent ecosystems also generally align with the highest overall burn probabilities. This is a result of increased ignition sources as well as flammability of the systems. Figure 55 illustrates the trend in fire occurrence by severity type for the fire-driven subcategory of the frequent-fire dependent ecosystems. There is an overall increase in acres burned across all severity classes, though the steepest increase has been observed in the unburned-low-severity class. While the low-severity fire is generally beneficial to this ecosystem type, the overall percentage as well as the increase in mixed and stand-replacing fire in these systems illustrates the imbalance in these systems. The environmental condition to host large wildfires is expected to increase with projected climate change (Davis et al. 2017). The effects of these large fires as they move north and upslope are likely to change from historic effects, especially because forest conditions are outside of the natural range of variation (Ringo et al. 2019). Larger fires in more dense, multi-strata forests would reasonably have more severe effects than expected based on historical fire effects. This is especially important to consider, given climate change and the associated changes in periods of critical fire weather.

Fire Diverse Systems (Mixed Severity)

Fire diverse (mixed severity) ecosystems occur on landscapes where fire can be important to ecosystem function, but is not the primary driver of successional dynamics, including structure and composition. Fires historically were moderately frequent, primarily ranging between mixed and high severity in a variety of patch sizes. These systems represent a middle gradient between the frequent-fire dependent and fire infrequent ecosystems and are typified by a combination of mixed-severity and stand-replacing fires at medium to long return intervals (about 35 to 200 years). These systems are highly diverse and are typified by stands consisting of both fire-tolerant and fire-intolerant species. Fire diverse (mixed severity) ecosystems are most common on the Umpqua, Willamette, Gifford Pinchot and Mt. Hood National Forests (table 10).

Table 10. National forests dominated by fire diverse (mixed severity) ecosystems within the Bioregional Assessment area

National Forest	Frequent-Fire Dependent	Fire Diverse (mixed severity	Fire Infrequent
Umpqua National Forest	11%	80%	9%
Willamette National Forest	1%	75%	23%
Gifford Pinchot National Forest	2%	64%	35%
Mt. Hood National Forest	11%	60%	29%

Unlike the frequent-fire dependent systems, these systems show less pronounced impacts from fire suppression (Reilly et al. 2017). Historically, these areas supported closed-canopied and multi-storied systems, and naturally burned with mixed to high severity. This pattern remains, though overall fire in these systems remains below historical averages (table 11). The fire diverse (mixed severity) ecosystems exhibit departure from reference conditions, and the mechanisms for departure are less driven by fire exclusion than past management and harvest. While some loss of system heterogeneity may be a result of fire suppression in these types, legacy timber harvest is a much bigger driver of these ecological departures.

Table 11. Calculated contemporary mean fire return interval in years for fire diverse ecosystems (all fire severity classes, 1993–2018)

Forest	Fire Diverse	
	Fire Diverse Total *Mean Fire Return Interval (MFRI) in Years*	Percent of forest in Fire Diverse:
Deschutes National Forest	**333**	48%
Fremont-Winema National Forest	**368**	37%
Gifford Pinchot National Forest	**1,463**	64%
Klamath National Forest	**92**	15%
Lassen National Forest	**128**	5%
Mendocino National Forest	**45**	6%
Modoc National Forest	**154**	34%
Mt. Baker-Snoqualmie National Forest	**820**	21%
Mt. Hood National Forest	**1,834**	60%
Ochoco National Forest	**163**	24%
Okanogan-Wenatchee National Forest	**74**	23%
Olympic National Forest	**7,871**	47%
Rogue River-Siskiyou National Forest	**104**	31%
Shasta-Trinity National Forest	**72**	10%
Siuslaw National Forest		18%
Six Rivers National Forest	**69**	13%
Umpqua National Forest	**365**	80%
Willamette National Forest	**912**	75%
MFRI (1993-2018) and Percent of BioA Forests	***217***	***33%***

Fire exclusion, and to a much larger degree past timber harvests, have changed patch size and continuity as well as reduced the prevalence of complex early-seral conditions on these landscapes. Current landscapes have high proportions in early-seral conditions, especially on private timber lands, but conditions on these post regeneration harvest sites lack many of the important ecological functions of complex early-seral forests created by fire (Reilly and Spies 2015).

Fire as a disturbance agent enhances nutrient cycling and provides fire defects in trees and snags, which provides important ecological benefits and habitats for wildlife species. Mixed and stand-replacing fire can aid in the creation of complex early-seral conditions in these ecosystems since fire, in the right proportions, is the primary driver in this important habitat type.

Impacts of fire exclusion may be more limited in these systems, and the increased risk of large-scale, stand-replacing fire presents unique problems. Because these systems produce significant biomass and support multistoried stand structures, fuel arrangements are favorable for large and intense fires. Compounding this is the contemporary and predicted shift in climatic conditions to favor more extreme fire weather days and longer fire seasons. This combination of factors makes this system at risk for loss due to wildfire. Trends in fire occurrence show an increase in area burned across all severity types for the fire diverse (mixed severity) ecosystems, as shown in figure 56.

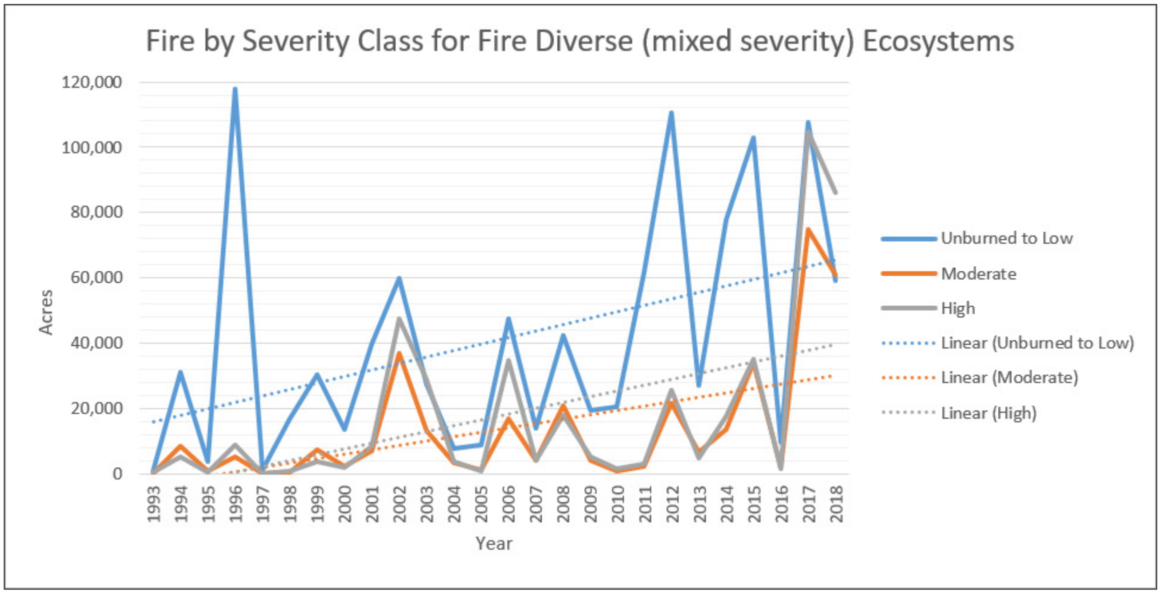
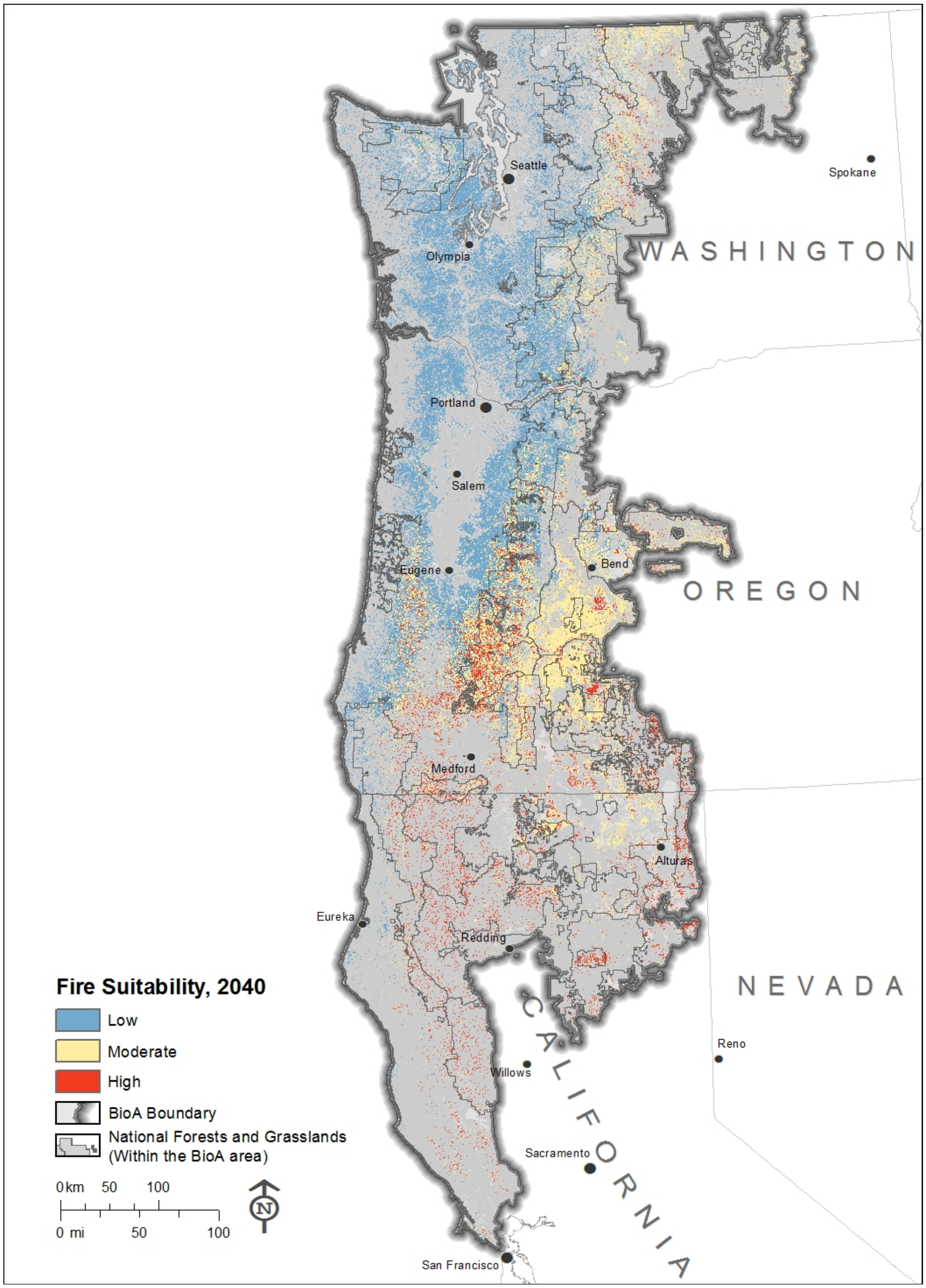


Figure 56. Fire severity class trends for fire diverse (mixed severity) ecosystems of the Bioregional Assessment area,1993–2018

Burn area is increasing in fire diverse (mixed severity) ecosystems, but in this case high severity is increasing at a faster rate than low- and moderate-severity burn area.

By examining projected changes in climate as it relates to the fire environment, it is evident that some portions of the BioA area, including portions of the fire diverse (mixed severity) landscapes, will be subjected to increased fire likelihood (Davis et al. 2017). Portions of the broader landscape where fire diverse (mixed severity) ecosystems are projected to become more suitable to large fire likelihood in the future, are more susceptible to uncharacteristic loss. These areas of convergence are candidates for more intensive management to reduce the potential effects of large-scale fire events (map 27).



Map 27. Projected future large-fire suitability within the fire diverse (mixed severity) areas in 2040

Large-fire suitability model results for mid-century climate projections based on methods by Davis et al. (2017).

Fire Infrequent Systems (Infrequent, Stand Replacing, and Limited Fire)

Fire infrequent ecosystems represent systems where fire is not necessarily a frequent component of most ecosystem functions; these include historically wetter ecosystems, high elevation, rocky areas, and environments with sparse fuels. When fires do occur, they can be highly influential and important for system dynamics. Historically, fires were rare or infrequent, of mixed to high severity, and occurred in large patches. These infrequent events are an important element in the natural range of variation in the long-term successional characteristics of these systems. Fire also serves as a stressor in these systems and can be uncharacteristic due to the infrequency and length of time between disturbance events (typically 200 plus years) for their natural range of variation, rather than a driver of successional dynamics.

These areas have not missed natural fire cycles and there is not a widespread need to reintroduce natural fire into these systems, especially because these fires can be hard to control and threaten human values. These systems are highly departed from reference conditions in some places, primarily due to historic and contemporary regeneration harvest and large-patch clear-cuts. As contemporary and projected climate adds system stressors to these forests and given the predicted increase in extreme fire weather events, there is a risk of large-scale stand-replacing fire in these systems.

Concentrated primarily in Oregon's north-central coastal mountains, the Olympic Peninsula and on the western slope of the north Cascades, are a suite of systems that historically developed without much natural fire. These systems are the dominant types on the Siuslaw, Mt. Baker-Snoqualmie, and Olympic National Forests (table 12).

Table 12. National forests dominated by fire infrequent ecosystems within the Bioregional Assessment area

National Forest	Frequent-Fire Dependent	Fire Diverse (mixed severity	Fire Infrequent
Olympic National Forest	0%	47%	53%
Mt. Baker-Snoqualmie National Forest	0%	21%	79%
Siuslaw National Forest	0%	18%	81%

Lightning was uncommon throughout this area, and fuel moistures in these densely canopied forests prevented fire spread. As a result, these areas developed very large, highly complex old-forest structures consisting of species that have little fire tolerance.

Pre-settlement fires, which did occur in these systems, would have been extremely infrequent, occurring only in periods of highly uncharacteristic fire weather conditions and coinciding with infrequent ignition sources. Such fires burned large areas with high severity due to these conditions. Despite the lack of historic fire as a primary driver in these systems, there remains some risk of stand-replacing fire. The conditions under which these systems are most likely to burn (extreme fire weather) are the same conditions that hinder suppression effectiveness.

Areas in productive forests had naturally high fuel loads, and widespread fuel reduction treatments are not an effective way to reduce fire risk in these infrequent-fire forest systems. Some strategic landscape-scale fuel breaks can help with fire management activities, ranging from suppression to resource benefit (or for multiple objectives) in the regimes where fire was less frequent. Additionally, managed natural fires that occur in wilderness areas and that do not threaten other values can maintain patch/stand dynamic mosaics, such as complex early seral-conditions and meadows.

As contemporary and projected climate adds system stressors to these forests and given the predicted increase in extreme fire weather events, one challenge for management will be protecting these areas from large-scale, stand-replacing fire long enough for them to age.

Because these systems represent less fire-prone areas, there is less urgency to resolve the potential management needs for change in these fire infrequent areas.

Table 13. Calculated contemporary mean fire return interval in years (all fire severity classes, 1993–2018) for fire infrequent ecosystems

	Fire Infrequent				
	N/A	Fire Prone - Regeneration	Limited Fire	Fire Infrequent Total	Percent of forest in Fire Infrequent:
Forest	*Mean Fire Return Interval (MFRI) in Years*				
Deschutes National Forest	*80*	*297*	*187*	**131**	17%
Fremont-Winema National Forest	*274*	*160*	*440*	**189**	15%
Gifford Pinchot National Forest	*267*	*465*	*1,674*	**816**	35%
Klamath National Forest	*64*	*930*	*180*	**114**	4%
Lassen National Forest	*476*	*395*	*197*	**377**	4%
Mendocino National Forest	*113*	*60*	*46*	**73**	0%
Modoc National Forest	*8,956*	*424*	*205*	**213**	16%
Mt. Baker-Snoqualmie National Forest	*699*	*1,585*	*2,506*	**2,069**	79%
Mt. Hood National Forest	*324*	*1,439*	*846*	**476**	29%
Ochoco National Forest	*28*	*177*	*272*	**200**	5%
Okanogan-Wenatchee National Forest	*94*	*47*	*181*	**80**	41%
Olympic National Forest	*5,066*	*3,007*	*12,531*	**11,609**	53%
Rogue River-Siskiyou National Forest	*80*	*222*	*90*	**88**	5%
Shasta-Trinity National Forest	*304*	*4,715*	*690*	**954**	3%
Siuslaw National Forest					81%
Six Rivers National Forest	*76*	*259*	*186*	**99**	1%
Umpqua National Forest	*189*	*9,974*	*740*	**237**	9%
Willamette National Forest	*135*	*237*	*418*	**159**	23%
MFRI (1993-2018) and Percent of BioA Forests	***126***	***83***	***636***	***202***	***23%***

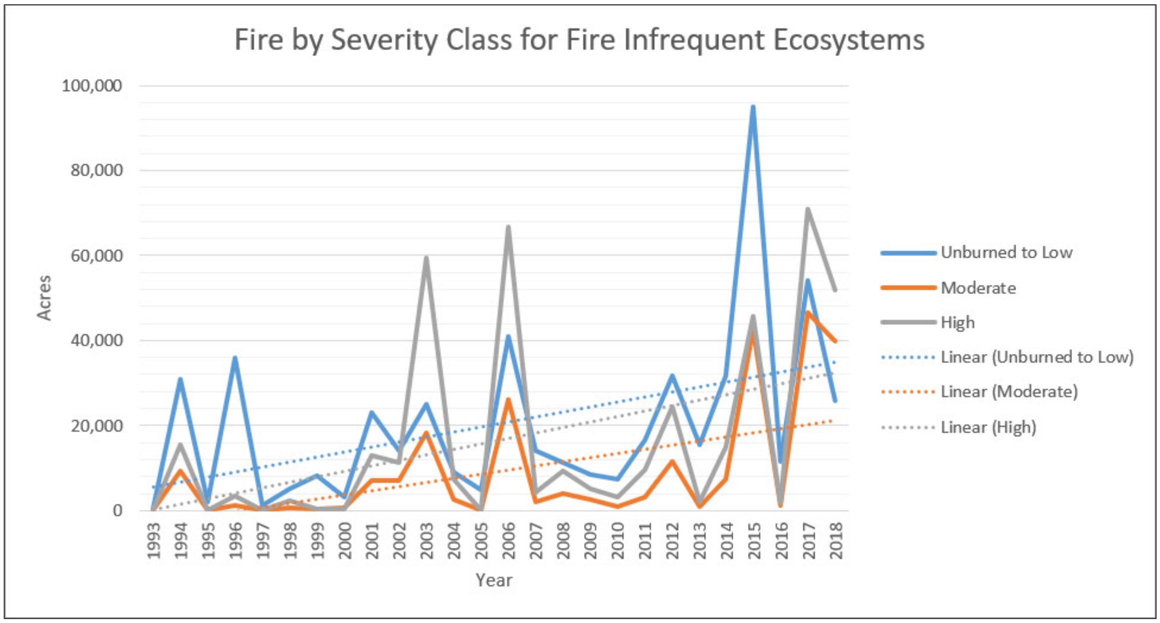


Figure 57. Fire severity class trends for fire infrequent ecosystems within the Bioregional Assessment area, 1993–2018

Fire Suppression and Risk Management, Effects on Communities and Timber

Increasingly, wildfires have directly or indirectly affected communities in and around the Pacific Northwest and northern California, from single homesteads to major cities. Communities that are in or near fire-adapted ecosystems will always have risks from wildfires. Such risks can range from short to long term and from low to high cost, and may be related to smoke, resource changes, economic losses and gains, changes in recreation opportunities, and personal health and well-being. It is well established that since fire suppression efforts began in the early part of the 20th century in the Western United States, suppression efficiency and effectiveness have improved tremendously. This is associated with an increase in the number of suppression forces being staffed, access to improved training and equipment, and continuing advances in technology (Nelson 1979). There has been improvement in the ability to effectively respond to and manage wildfire, which has helped to reduce impacts in some communities and has enabled land managers to be able to look at a range of alternatives when managing fires.

Relatively recent events—such as the 2018 Carr Fire near Redding, California, (229,651 acres burned; 1,604 structures destroyed; 3 lives lost) and the 2018 Camp Fire in Paradise, California, (153,336 acres burned; 18,793 structures destroyed; 86 lives lost)—have illustrated that even with advances in our suppression ability, wildfires can still impact communities directly, albeit under rare or uncharacteristic circumstances. Figure 58 illustrates the fire severity, represented by basal area loss, for these two fires, where initial wind-driven fire growth caused great losses to structures and life. There are many elements that have contributed to the recent change in wildfire size and severity in fire-adapted ecosystems. Some of these elements are climate change, drought, reduction of fire in fire-adapted ecosystems (Haugo et al. 2019), forest densification, differing land management agency (local, state, federal) fire management plans and policies, and continued encroachment and growth of communities into areas susceptible to wildfires.

Over time, the effects of fire as a natural and human-caused disturbance process in frequent-fire dependent and fire diverse (mixed severity) ecosystems have shifted from beneficial to having increasing impacts to communities and natural resources.

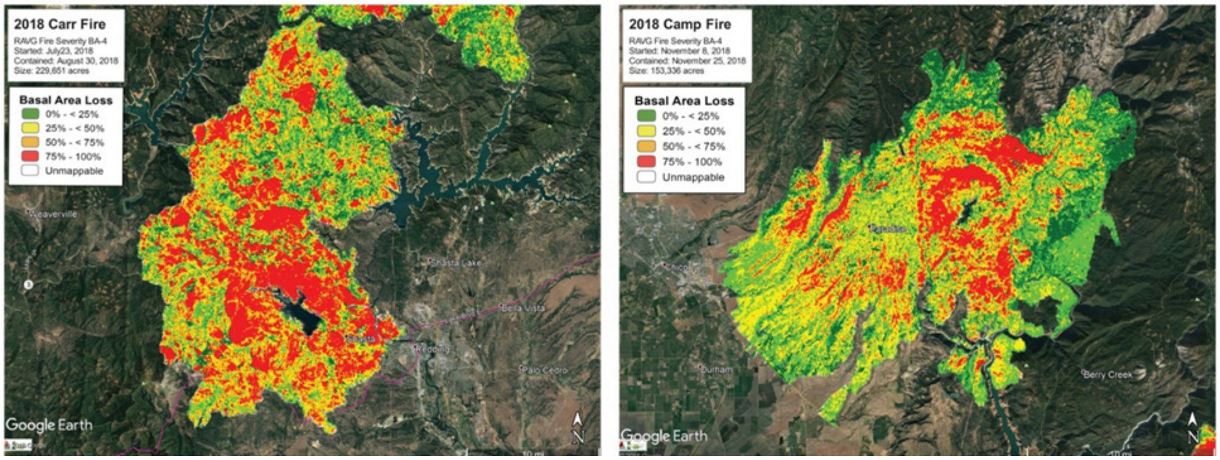


Figure 58. Basal area lost in the 2018 Carr and Camp Fires

Fire severity in percent basal area loss from postfire Rapid Assessment of Vegetation Condition after Wildfire (RAVG) program.

Wildfire risk assessments and analyses have become much more sophisticated and comprehensive, from preplanning quantitative wildfire risk assessments to near real-time wildfire incident decision support (for example, Wildland Fire Decision Support System), because of technological and research advancements and development. Working together with cooperators and neighbors to review and use the results in risk assessments provides a way to collaborate, prioritize, and address the risk from wildfires. There is an increasing number of quantitative wildfire risk assessments completed or in progress, varying in complexity and extent. In the BioA footprint, for example, there is the recently completed Pacific Northwest Quantitative Wildfire Risk Assessment (Gilbertson-Day et al. 2018), which covers all lands for the states of Washington and Oregon. Quantitative Wildfire Risk Assessments serve many purposes and can be used to identify relative exposure to communities. An example application of Quantitative Wildfire Risk Assessment to identify community exposure across Oregon and Washington is presented in map 25.

Reducing Adverse Effects from Wildfire and Smoke

Adverse fire impacts to communities in the wildland-urban interface/intermix areas have continued to increase because of two primary factors: increased urbanization of previously remote locations has increased the proportion of forest lands located within this area, and climate change effects continue to extend and intensify fire seasons. Both of these complicating factors are expected to continue to increase into the foreseeable future, causing concern for communities.

Smoke from wildfires also adversely affects forest communities, resulting in social and economic impacts, including impacts on the health and quality of life of local residents and economic effects to communities that are dependent on recreation visitation when visitors choose to avoid smoke-filled areas**.**

Prescribed fire can also negatively impact the health and quality of life of local residents. However, these fires are burned under specific “prescriptions” designed to limit smoke impacts on communities, while achieving desired conditions on the ground. The prescriptions include season of burning, wind direction, and the ability to loft smoke high into the atmosphere. Additionally, prescribed burns can result in less smoke during subsequent wildfires in the same area.

Call-out box 24. Economic and health impacts of smoke

There seems to be no good time for smoke. Prescribed fire in the spring and fall can reduce future increases of more intense, longer duration smoke from wildfires during the summer fire season. The effects of smoke during wildfires can be wide reaching. In 2018, many communities in the Bioregional Assessment area experienced long periods of heavy smoke from wildfires. Ashland in southwest Oregon is home to the Oregon Shakespeare Festival, which canceled or moved more than 26 outdoor performances, resulting in estimated losses of $2 million to the local community. This does not include any additional trickle-down impacts on ancillary businesses. Visits to nearby Crater Lake National Park dropped by 22 percent; and uses of other area outdoor recreation businesses declined as much as 45 percent. Ashland Chamber of Commerce noted some member’s sales were 20 to 60 percent lower during this smoke of the summer of 2018.

Fire Policy and Management Changes

The federal wildland fire management policy provides guidance for fire response and management on federal lands and has evolved substantially over the past few decades since around the time the NWFP went into effect. After the establishment of the Forest Service in 1905, fire suppression/exclusion became a primary agency goal for the better part of the 20th century. In 1926, Forest Service objectives were to restrict wildfires to 10 acres, and in 1935 the agency added a temporal element known as the 10 am policy, under which all fires were to be suppressed by 10 a.m. the next day (Husari and McKelvey 1996). After World War II, with a surplus of personnel and a unified nation, advances in suppression continued and firefighting capability improved with the addition of smokejumpers, chainsaws, and bulldozers; fire science and technology and an understanding of fire ecology also advanced (Nelson 1979).

The passing of the Wilderness Act of 1964 (Husari and McKelvey 1996) began to bring about change on how the agency manages fire by recommending fire be allowed to play a more natural role in designated wilderness areas. However, it was not until the early 1970s, that a decisive split in fire management objectives and policy began between suppression and reintroduction of fire (Husari and McKelvey 1996). In 1972, the Chief of the Forest Service signed an exemption letter for the Selway-Bitterroot Wilderness from the 10 a.m. fire policy (Smith 2014), representing the first deviation from the agency’s full suppression emphasis that had been in effect for three quarters of a century.

The National Forest Management Act of 1976 provided additional measures that have assisted in mitigating the fire control paradox[33] (Arno and Brown 1991, Boisrame et al. 2017, Calkin et al. 2015, Thompson et al. 2018). When land and resource management plans were first being developed as a result of the 1976 National Forest Management Act, the Forest Service outlined specific management goals and objectives where the role of fire could be described for both natural and human-caused fires. These initial first forest plans underemphasized the important role natural fire ignitions play and failed to adequately address what type of prescribed fire activity would be appropriate.

A clear path forward for managing fire for resource benefits began to materialize, and a national program was initiated for the use of what was then described as “prescribed natural fire” (later “wildfire use”). However, the Yellowstone fires if 1988 paused this program until a review could be completed. In 1989, the Final Report on Fire Management Policy was completed with recommendations to strengthen interagency cooperation in applying fire management programs, review fire management plans, and reaffirm that agency policy describe fire as either a prescribed fire or wildfire, and that natural fires should not be allowed to burn free of prescriptions or appropriate suppression actions.

Modern wildfire management policy began with recognition of wildland fire as a natural ecosystem process. The 1995 Federal Wildland Fire Management Policy and Program Review is the first fire management direction that integrates the broad spectrum of fire responses that are possible, based on sound risk management and land management plan direction. The 1995 policy looks at a range of fire responses, from reintroducing wildland fire to full suppression, as appropriate. Even under this new policy, not much progress was made for several reasons: for example, most forest plans were completed before the 1995 national fire policy and did not include managed wildfire or associated decision space. Also, it takes time to change the culture of fire suppression and management that emphasized fire exclusion or restricted use of fire in the Western United States.

Increases in fire frequency and losses from wildfires during the late 1990s and early 2000s prompted policy milestones, including the National Fire Plan in 2000, identification of wildland-urban interface communities at high risk from wildfire (USDA FS and USDI BLM 2001), and the Healthy Forests Restoration Act of 2003 (PL 108-148). Together, these policies provided land managers planning direction and funding opportunities that helped improve acres treated and protect communities. This is also when the National Cohesive Wildland Fire Management Strategy[34] was developed in response to a report by the General Accounting Office regarding catastrophic fires (US GAO 1999).

The 1995 national fire management policy was updated in 2001 with minor changes, to provide greater emphasis on fire program management and implementation. Implementation strategy for the fire plan update came out in 2003, describing three types of fire (suppression, appropriate management response, prescribed fire). Then in 2009, further

[33] Wildfire paradox: when fires are suppressed quickly and at a small size to protect ecosystem resources in a fire-adapted ecosystem, the result is greater vegetation fuel loads and connectivity, increasing difficulty in controlling future fires, and the creation of conditions that may be outside the range of historical variation for fire departure for ecosystem fire regime.

[34] https://www.forestsandrangelands.gov/strategy/thestrategy.shtml.

clarification is provided in the Updated Guidance for Implementation of Federal Wildland Fire Management Policy, where types of fire were revised from three to two, wildland fire: wildfire and prescribed fire. Also, wildland fire may be concurrently managed for more than one objective.

The Federal Land Assistance, Management and Enhancement Act of 2009 (FLAME Act) required the secretaries of the U.S. Departments of the Interior and Agriculture to submit a cohesive wildland fire management strategy to Congress. The National Cohesive Wildland Fire Management Strategy identified three primary factors that would provide the best opportunity to respond to the increasing size and severity of wildfires: restoring and maintaining resilient landscapes, creating fire-adapted communities, and responding to wildfires. It also required the development of a national wildfire risk assessment process to be able to evaluate wildfire risk at multiple scales, from national to local. The risk assessment process provides a way to be able to prioritize risk reduction to communities, national resources, and fire management, in order to improve decisions in ecosystem resilience, fire management response and risk management, and create fire adapted communities as we learn to live with fire.

The 1994 NWFP is a result of conflicts that occurred between highly contrasting social, economic and environmental values, and represents a long-term cohesive strategy that has successfully moved the Forest Service forward. A more recent example of a cohesive strategy is the Rogue Basin Cohesive Forest Restoration Strategy, developed by The Nature Conservancy and the Southern Oregon Forest Restoration Collaborative (Metlen et al. 2017). This strategy uses a wildfire risk assessment process to quantify the wildfire risk to highly valued resources and assets. It illustrates conflicts that exist spatially between managing fire, reducing community wildfire risk, producing timber, while conserving wildlife habitat, and provides a way to prioritize activities based on high-risk areas. It also incorporates planning scenarios for fires that have the potential to occur before mitigation actions can be accomplished.

Synopsis of Current Management

Although wildfire was considered during development of the NWFP, the effort focused primarily on sustaining economic viability of communities, retaining old-growth forest systems, and protecting the northern spotted owl and other old-growth-associated species. The degree to which wildfire planning and management was incorporated in the associated land management direction was somewhat limited. Fire was generally characterized at that time as a stressor on otherwise functioning ecosystems. The role of fire as a critical ecosystem driver from an ecological process perspective, especially in historically fire-prone ecosystems, was not well addressed.

Contemporary land management recognizes the importance of fire as a system driver, as well as a system stressor with associated resource loss. Existing plan direction makes interweaving these two concepts difficult, and the result is a continued emphasis on fire suppression and risk mitigation. While fire suppression and risk mitigation remain agency priorities, an added emphasis on ecological restoration requires better incorporation of managed fire (both naturally and management ignited) to support functional and resilient ecosystems.

In project-level planning, the role of fire is normally incorporated. For example, a recent objective in a project record of decision included “Protect forest ecosystems from high-intensity, stand-destroying wildfires and provide safe locations for fire-suppression personnel.” Few projects are currently including restoring fire as a management objective to improve resiliency and reduce departure. More often, the associated objectives are to mitigate fire impacts, such as reduction of wildfire risk, improve forest resiliency to disturbance, and reduce surface and ladder fuels. These are desirable objectives, but inclusion of fire restoration would be more comprehensive in recognizing the role of fire.

During the project development phase, when alternatives are being developed for management activities, these two concepts often intersect: wildfire as a risk to highly valued resources and assets, and prescribed fire as a natural disturbance process and fuels management tool. Consequently, during the project development stage different layers of land management direction from the forest’s standards and guidelines are identified, and then used in identifying risks and barriers to implementation and where opportunities exist. This is more often a process of paring down areas to treat that removes many areas that should be a high priority due to risk from unplanned wildfire and the need to reduce fire departure but are dropped due to real and perceived constraints in implementing the project. Risk, both of unintended impacts and litigation, is also considered during project planning.

An additional compounding factor for wildfire management has been the multiple, and at times conflicting, management direction resulting from decades of overlapping policy and plans.

Fire Management and Forest Resilience

It is important to note that fire exclusion impacts forest resilience in many ways, not just in changes to fire behavior. Wildfire exclusion, grazing, and historic logging activities have created overly dense stands, a loss of species and age diversity, and an altered mix of vegetation across many areas; this results in effects to ecosystem integrity, including increases in susceptibility to insects, pathogens, and weather-induced stresses such as drought (Cochrane 1998, Egan et al. 2010). When tree stress and mortality occur, there can be effects to fire behavior through altered fuel patterns that are different from the fuel patterns left by mortality from fire. Fire exclusion and its legacy have led to negative effects for ecological resilience and integrity throughout the BioA area.

> *Fire and the Land are Inextricably Linked—So Too Should Be Our Understanding and Response:*
> Fire is an essential ecological process that to differing degrees shapes the ecology and land management responses for many of our ecosystems. Fire also is responsive to other ecological processes and land-use practices. In practice, wildland fire cannot be separated from other aspects of land management. Fire inevitably, and on its own terms if need be, will occur on the landscape. Our ability to prevent it will be temporally and spatially limited; however, by acknowledging its role in a broader ecological and social context, we may be able to shape its occurrence and effects and thereby better live with fire on the landscape. Given the history of fire suppression, we will be challenged to determine how to use all the tools of vegetation management,

> including prescribed fire, to not only reduce the risk of catastrophic wildfire but also to maintain, and increase if needed, an ecosystem's resiliency under changing environmental conditions and its capacity to provide the variety of ecosystem services that society demands (Hall et al. 2018: 16–17).

Climate Change

Introduction

Since enactment of the NWFP in 1994, climate change has emerged as an overarching theme in natural resource science and management. Climate change has the potential to affect all ecological and socioeconomic components of the BioA area as well as other objectives for federal forest and grassland managers in this region.

Current land management plans do not directly address climate refugia and mitigation strategies, but there is the opportunity to include these as the Forest Service updates the plans. Incorporating the role of natural processes into our ecological desired conditions will also be important.

For the past few decades, unanticipated conditions associated with invasive species, wildfire, and climate change have begun affecting the sustainability of our forests and grasslands and their ability to provide numerous benefits. This includes benefits to rural and urban communities, as well as to American Indian tribes who rely on national forests and grasslands for maintaining their culture and way of life. It is a challenge under existing land management plans to maintain and restore natural processes, such as fire, which promote ecological resilience. Altered conditions due to a changing climate will impact ecosystems, biodiversity, and the delivery of benefits to people.

Within the BioA area, anticipated effects of climate change will be the greatest in northern California, southern Oregon, and the eastern Cascades. Increases in greenhouse gases and temperature, as well as altered precipitation and disturbance regimes (for example, fire, insects, pathogens, and windstorms), may profoundly affect biodiversity, socioeconomics, and the delivery of ecosystem services within the BioA area over the next century (Dale et al. 2001, Franklin et al. 1991).

The BioA area is projected to enter a novel climate regime during the next century, and conditions are projected to exceed the 20th century range of variability by the 2040s for some portions of the area. Significant warming may occur across the BioA area, although the magnitude of the warming may differ. Increased frequency and intensity of extreme temperature and precipitation events may occur (Davis et al. 2019, Gutzler and Robbins 2011, Williams et al. 2012), and climate extremes, such as acute drought, may have disproportionate effects on vegetation and result in rapid vegetation change.

Water balance deficits are also projected throughout the BioA area. A water-balance deficit is the difference between the atmospheric demand for water from vegetation and the amount of water that is actually available for use. Changes in the magnitude and seasonality of temperature and precipitation patterns will most likely affect vegetation by altering the availability of water in the soil. Water balance deficit indicates there will be drought impacts on trees and is an early sign of potential future mortality.

What is Working Well

What is Working Well 1—Carbon Sequestration

Forests and grasslands in the BioA area have great potential to mitigate the effects of climate change through the storage of large amounts of carbon in both live and dead biomass (Smithwick et al. 2002). At current rates, harvest and disturbance have little overall impact on carbon sequestration on federal lands in Oregon and Washington as a whole (Gray and Whittier 2014).

Adaptation and mitigation are essential to strategic planning for the effects of climate change (Millar et al. 2007).

Adaptive management actions at both the stand and landscape scales can reduce vulnerabilities to climate change. Mitigation includes efforts to increase carbon sequestration in forest ecosystems and provide new energy-efficient products and technologies for society (see ”Key Change Issues 3—Carbon Sequestration and Need for Increased Emphasis” below).

What is Working Well 2—Aquatic Refugia

Restoring watersheds has resulted in improved water quality and streamflow conditions (USDA FS 2017), as well as improved stream temperature and macroinvertebrate diversity (Miller et al. 2017).

What is Working Well 3—Water Supply from National Forests and Grasslands

Most of the water supply for drinking water, irrigation, habitat, recreation, and more comes from National Forest System land, and that has been largely maintained or improved through better streamflow and water quality conditions.

Key Change Issues

Key Change Issue 1—Changing Landscapes and Determining Suitability of Use

Climate change will continue to alter the composition, structure, and function of forested and non-forested ecosystems in the BioA area (Vose et al. 2012). Climate change is expected to alter vegetation through both direct and indirect effects. Direct effects may lead to changes in mortality, growth, and reproduction, all of which may be sensitive to altered phenology and biotic interactions within and among species (Peterson et al. 2014). Indirect effects are expected to be expressed through increases in the frequency, severity, and extent of disturbances, including drought, fire, insects, and pathogens.

Planning Considerations

Consider the impacts of climate change when determining suitability of uses, such as timber, range, and recreation. Develop standards and guidelines or other plan components that would encourage suitable uses based on best available science and projections. Include plan components that encourage the use of best available tools, processes, and science, including adaptive management.

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to better respond to future environmental uncertainties.

Geographic Considerations

The effects of climate change will likely be most pronounced in the southern portion of the BioA area (northern California and southern Oregon) and in the drier forested and non-forested types (eastern Cascades).

Key Change Issue 2—Longer and Warmer Fire Seasons and Need for More Active Management

Fire is an important factor in disturbance regimes in the BioA area. Increases in the frequency and extent of fire are related to longer fire seasons, which are associated with earlier snowmelt, warmer spring and summer temperatures and drought. Since the mid-1980s, there has been an increase in annual area, however, there is growing consensus that fire suppression has led to dry vegetation zones experiencing less fire during this period than they would have historically (Steel et al. 2015).

Planning Considerations

Desired conditions should be developed for these systems based on their natural disturbance regimes and disturbance-succession dynamics that promote and encourage the use of prescribed and managed fire to achieve desired outcomes where appropriate.

Refer to BioA Chapter 2 Management Recommendation

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Additional planning considerations include increasing stand and landscape resilience, which may be accomplished by reducing stand densities, shifting toward fire-adapted species' compositions through mechanical treatment, using wildfire and prescribed fire, increasing heterogeneity and diversity of patch sizes, using topography to guide treatments, and favoring fire-tolerant species in natural regeneration and planting (table 14).

Table 14. Summary of adaptation and mitigation options for climate change vulnerabilities in the Bioregional Assessment area (adapted from Halofsky and Peterson 2016)

Vulnerability	Strategy	Tactics
Increased drought stress	Increase resilience	Reduce forest/stand densities
		Favor drought-resistant species/genotypes
	Foster genetic and phenotypic diversity	Protect trees adapted to water stress
		Collect seed for future
		Maintain connectivity for natural species migration

Vulnerability	Strategy	Tactics
Increasing area affected by fire, insects, and pathogens	Increase stand resilience	Reduce stand densities, shift toward adapted species compositions through mechanical treatment, wildfire use, and prescribed fire
		Increase stand heterogeneity
		Favor fire-tolerant species
	Increase landscape resilience	Increase landscape heterogeneity
		Increase diversity of patch sizes
		Use topography to guide treatments
Loss of forest cover	Monitoring of change	Use existing data and add more where needed
		Planting/assisted migration
		Maintain connectivity for natural species migration
Exotic species	Increase control efforts	Early detection/rapid response/frequent inventory
		Interagency coordination

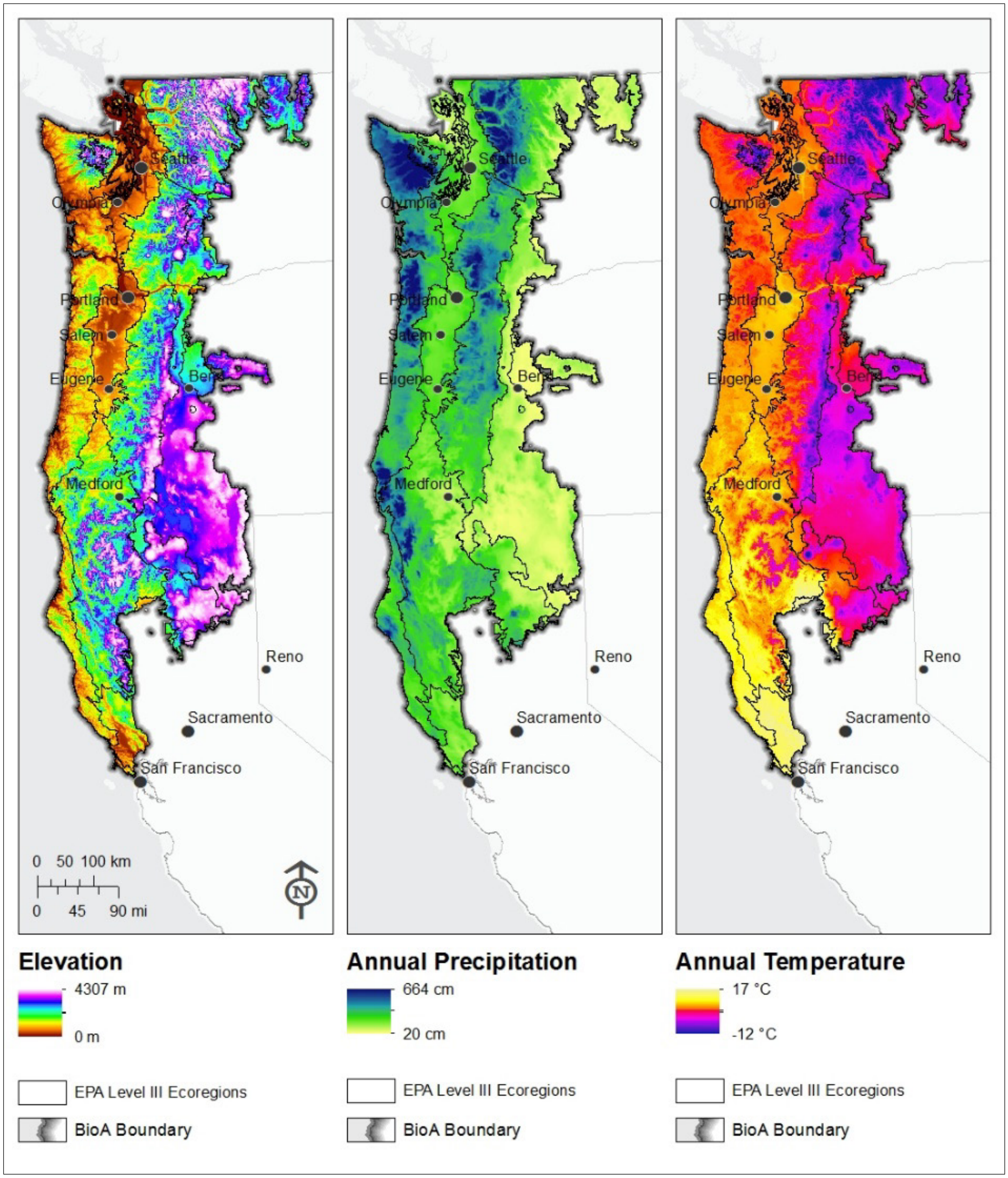
Geographic Considerations

The greatest fire increases are expected in drier forest types of northern California, southern Oregon, and the eastern Cascades (frequent-fire dependent). Most studies project little increase in fire activity in the moist maritime forests, for example Sitka spruce, redwood, and western hemlock forests (fire infrequent).

Key Change Issue 3—Carbon Sequestration and Need for Increased Emphasis

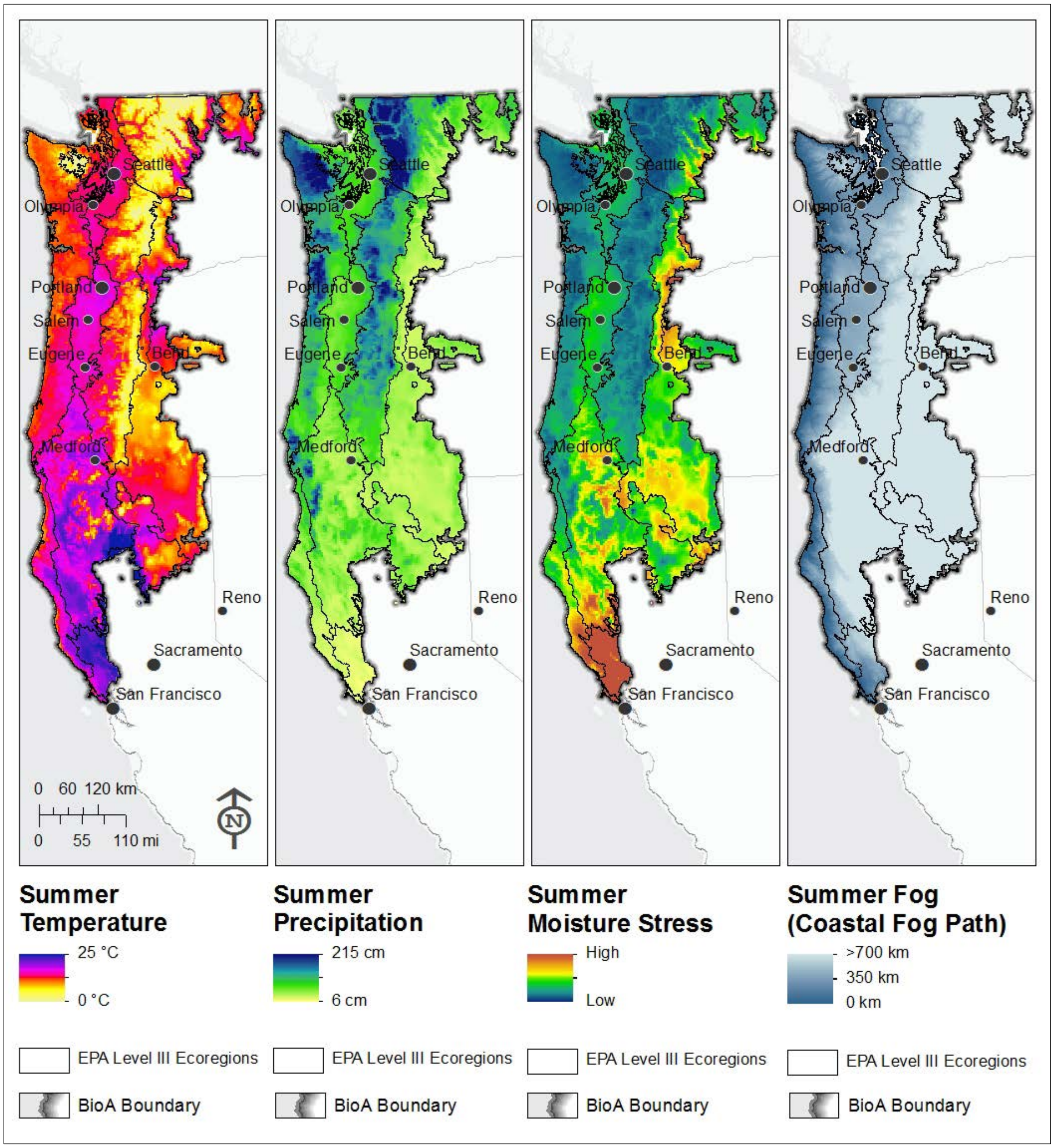
Although they are not actively managed for carbon storage, the forests within the BioA area store carbon at some of the highest rates and levels in the United States. Annual temperatures are generally highest in areas with the least amount of annual precipitation in the eastern and southern portions of the BioA area and are linked to both increased drought and wildfire risk (map 28 and map 29), which reduce carbon storage stability over the long term. Summer environmental variables such as these illustrate the difference between the hot and dry Mediterranean climate of the southern BioA area and the cooler and wetter summer conditions in the Pacific Northwest. These cooler and wetter forests are better suited for long-term carbon storage. Warming is projected to occur across all seasons, with the greatest temperature increases occurring during summer months. Along the coast, decreases in summer fog may substantially reduce suitable climate for redwood and other coastal species.

Changes in the magnitude and seasonality of temperature and precipitation patterns will most likely affect vegetation by altering the availability of water in the soil. These effects will be most dramatic in the southern and eastern portions of the BioA area, and most of the region is projected to experience increased summer (June through September) water balance deficits by the middle of this century (map 30). Carbon fluxes, or changes from one form to another, can be complex but it is important to note that management actions, including wildfire, shift where carbon is located but rarely result in near 100-percent emissions or loss to the atmosphere (figure 59).



Map 28. Range of environmental and climatic variables across the Bioregional Assessment area from 1981 to 2010 (PRISM)

EPA = Environmental Protection Agency. Adopted from Reilly et al. (2018) with updated date range.



Map 29. Mean summer temperature, total summer precipitation, summer moisture stress, and summer fog in the Bioregional Assessment area from 1981 to 2010 (PRISM)

EPA = Environmental Protection Agency. Adopted from Reilly et al. (2018) with updated date range.

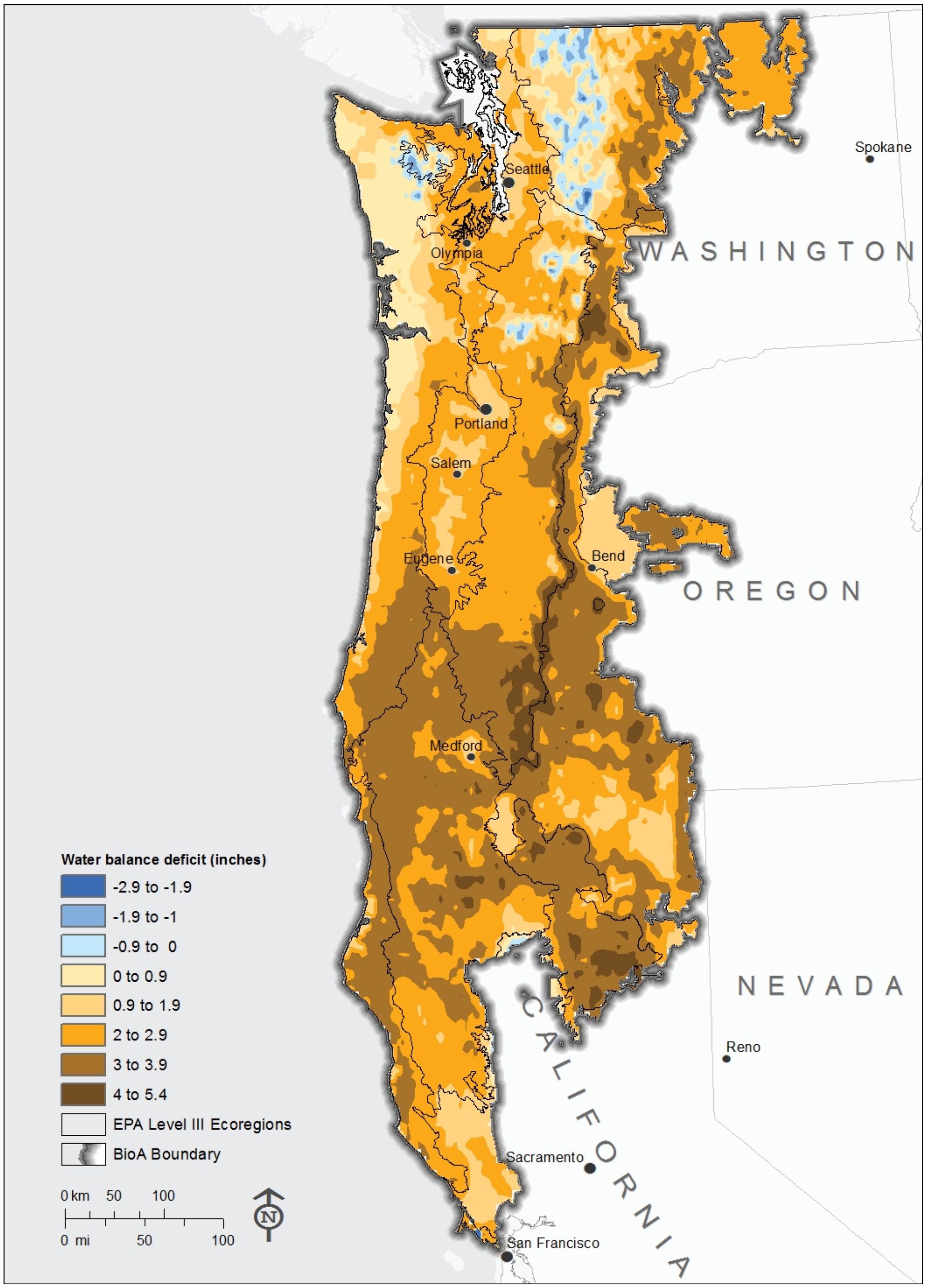
Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to better respond to future environmental uncertainties.

Planning components that focus on carbon sequestration should be developed for the wetter, west-side forests of Oregon and Washington; these should include guidelines for wood retention and minimizing soil disturbance, along with an objective of creating stable carbon.



Map 30. Water balance deficits in the Bioregional Assessment area

The water deficit in inches indicate changes in the magnitude and seasonality of temperature, and precipitation patterns will most likely affect vegetation by altering the availability of water in the soil. EPA = Environmental Protection Agency.

Figure 59. Forest carbon sequestration

This figure illustrates the importance of carbon sequestration by showing carbon stored in forests as live trees, dead wood, and soil and how these pools change after fire. Carbon amounts and the time since fire are relative and only shown for illustration. (Adapted from Ryan et al. 2010).

Geographic Considerations

Carbon is still being stored in forests throughout the BioA area but at a slower rate in forests to the east and south. This is due to slower plant growth rates. but more importantly, due also to higher carbon emissions from wildfires. As the historic fire regimes are restored and continue to shift with climate change it is likely these forests will store less carbon overall, and they will have fewer episodes of high carbon emissions.

Key Change Issue 4—Soil Productivity and Need for Increased Attention on Soil Carbon Sequestration

Soils can provide long-term carbon storage. Soil organic carbon is linked with soil productivity, yet little attention has been paid to soil organic carbon in land management planning.

Planning Considerations

For long-term soil productivity and carbon storage, objectives for down wood and slash retention in areas with infrequent fire and rapid decomposition can be considered in planning. In areas with more frequent fire, direction to use tools such as broadcast burning or creation of biochar, a form of charcoal, at landings and redistributing biomass across the stand should focus on the outcomes of higher carbon storage/retention on site after treatments. Focusing on outcomes and objectives in land management plans, rather than specific methodology, allows for management flexibility as additional research into carbon storage informs development of tools and techniques.

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to better respond to future environmental uncertainties.

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Geographic Considerations

Managing for carbon retention is best focused on areas with infrequent wildfire. Retention of stable carbon through mitigation techniques such as the creation of biochar is possible throughout the BioA area, but most urgent in frequent-fire dependent and fire diverse (mixed severity) areas.

Key Change Issue 5—Species Viability and Need to Identify Refugia to Buffer Climate Change Impacts

Linking isolated habitats to nearby climate refugia, increasing colonization capacity of sustainable reserve networks, and optimizing reserve networks can all help to mitigate projected changes in climate. Climate refugia may enable species persistence during unfavorable climatic conditions and serve as sources for future recolonization, provided that suitable conditions return in the future. Identifying these areas can be challenging, and climate refugia will most likely be found in topographically complex landscapes where microclimates differ because of differences in aspect, shading, insolation, and cold-air drainages (Dobrowski et al. 2011). Therefore, identifying areas that may serve as climate refugia on forests is important (figure 60).

Planning Considerations

Refer to BioA Chapter 2 Management Recommendations

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Recommendation 2: Address the dynamic nature of ecosystems to better respond to future environmental uncertainties.

Recommendation 3: Update and consolidate the existing aquatic direction processes and analysis requirements.

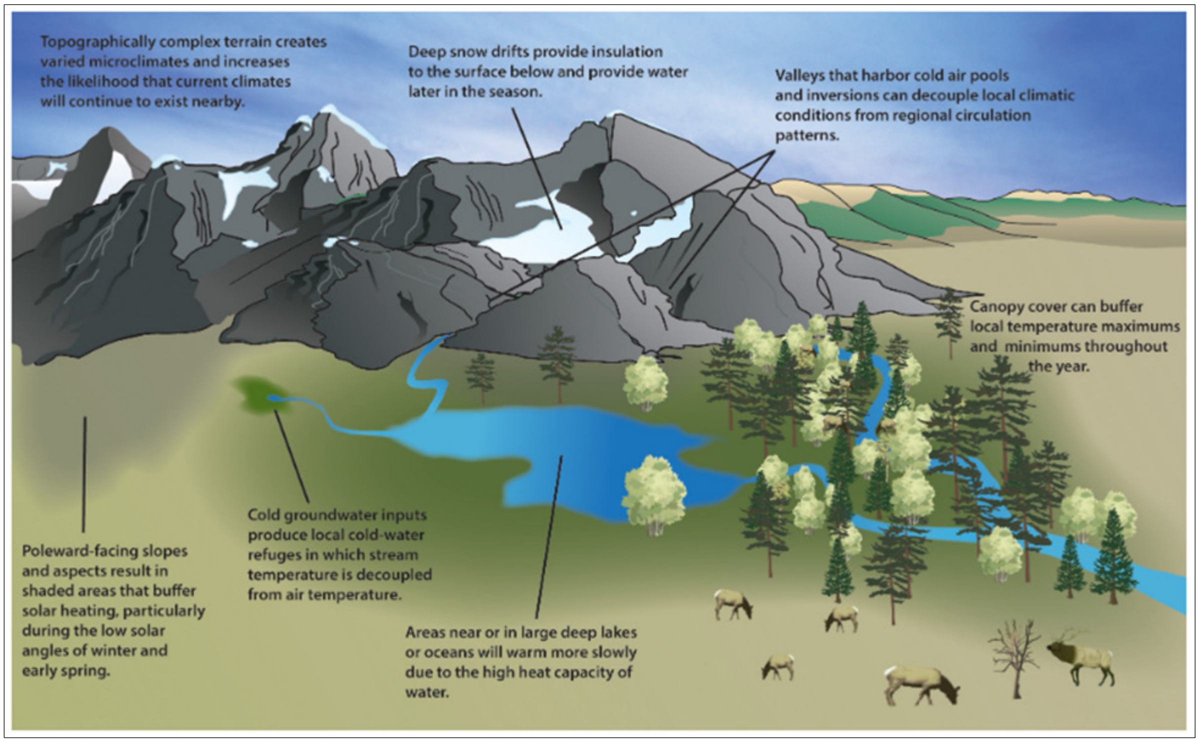


Figure 60. Landscapes and climate change refugia

Illustrated graphic of climate refugia principles and examples of the physiographic and vegetation-based refugia that may experience reduced rates of climate change. Source: Morell et al. (2016). After Spies et al. 2018.

Geographic Considerations

During the past century, average annual temperatures in western Oregon and Washington increased more than in northern California and in the Cascade Range. Overall, the entire BioA area has experienced warming on some level. In Oregon and Washington, precipitation increased the most during spring. Trends in precipitation in northern California are more variable with some areas experiencing decreases in precipitation. The recent drought in northern California (2012-2016) was the hottest and driest period on record, followed by extreme precipitation events and severe flooding.

Future climate projections for Washington and Oregon include warming across all seasons and the possibility of wetter winters and drier summers. Projections for northern California and the eastern Cascades depict drier futures and greater wet and dry extremes during the wet season (October to March). The entire BioA area may see reduced snowpack with more precipitation falling as rain at higher elevations. Heavy precipitation events from warming and shifts in seasonal precipitation patterns may also increase flooding in most of Oregon and Washington (Tohver et al. 2014) and the northern California Coast Range (Kim 2005). The projected future climate in the Klamath Mountains represents conditions of temperature and precipitation not experienced in the recent past (Saxon et al. 2005). Fragmented populations at their range margins, narrowly distributed species, and species with poor dispersal are all vulnerable to declines from losses of climate-suitable habitat.

Water-balance deficits are projected throughout the NWFP area, with the greatest deficits in the eastern Cascades, Klamath Mountains, southeastern portion of the Oregon Coast Range, northern portion of the California Coast Range, and southern portion of the western Cascades in Oregon (Littell et al. 2016). The least amount of change is projected in the northern portions of the Coast Range along the Pacific Ocean, and at higher elevations of the Olympic Peninsula and the northern portion of the western Cascades.

Fog frequency in coastal northern California declined by 33 percent during the 20th century (Johnstone and Dawson 2010), and the area experienced lower summertime cloudiness (Schwartz et al. 2014).

Decreases in summer fog along the coast may substantially reduce suitable climate for redwood and other coastal species that depend on it to mitigate summer drought.

Key Change Issue 6—Drought Stress and Ecosystem Resiliency

Tree mortality from higher temperatures and drought stress is already occurring over much of the Western United States and is expected to increase (Allen et al. 2010; 2015). Warmer temperatures and increased frequency and length of droughts are likely to increase climate-induced physiological stress on plants (Adams et al. 2009). Old-growth forests may be vulnerable to periods of elevated mortality rates associated with increases in insects and pathogens during drought (Reilly and Spies 2016, van Mantgem et al. 2009). Tree growth and viability will also be affected by warmer winters, earlier snowmelt, and changing water availability.

Native insects and pathogen activity are likely to increase as trees experience more growing season drought, and the magnitude of their effects will likely vary geographically as well as among species (Chmura et al. 2011, Kolb et al. 2016, Sturrock et al. 2011).

The timing of seasons may also change, interacting with both biological and social processes tied to phenology.

Planning Considerations

Include adaptive measures to increase stand and landscape resilience in the face of increasing drought stress, insects, and pathogens.

Refer to BioA Chapter 2 Management Recommendation

Recommendation 1: Maintain and restore ecosystem characteristics and processes by working toward desired conditions that are compatible with the diverse landscapes across the BioA area.

Geographic Considerations

Climate change will likely lead to the loss of some high-elevation species (especially subalpine forests) where warmer winters and earlier snowmelt may increase the potential for drought and water stress, especially toward the southern portion of the BioA area. Wetter forests in coastal Washington in particular may be vulnerable to a continued northward shift of high-wind events and windthrow.

Key Change Issue 7—Invasive Species and Need to Increase Control Efforts

The effect of invasive species is one of the primary concerns associated with maintaining ecological integrity across the BioA area. Agency understanding of the ecological and economic impacts of invasive species has greatly increased over the last few decades. Invasive species can have widespread social, economic, and ecological impacts, including negative impacts to native species, reductions in water quality, altered fire regimes, degraded forage quality, adverse effects on human health and well-being, and economic losses. Increasing temperatures may favor spread and introduction of some invasive species, especially grasses in California (Sandel and Dangremond 2012).

Planning Considerations

Existing land management plans are quite limited in addressing potential impacts of invasive species and focus primarily on invasive plants. However, the term “invasive species” also includes native terrestrial and aquatic insects, animals, and pathogens that have moved into habitats or areas where they previously did not exist. Land management plans can address the need to manage habitats to reduce and prevent introduction of invasive species. Land management plans can also address proactive invasive species management.

Refer to BioA Chapter 2 Management Recommendation

Recommendation 4: Reduce the introduction and spread of plant, animal, and other invasive species.

Geographic Considerations

Invasive species, and insect and pathogen activity will occur throughout the BioA area but may be most pronounced in the southern and drier portions.

Key Change Issue 8—Changing Hydrologic Regimes and Need to Reevaluate and Adjust Riparian Management

Increases in winter temperatures are linked with decreases in snowpack (Mote 2006), and earlier snowmelt has altered streamflow timing (Hamlet et al. 2005; Jung and Chang 2011; Stewart et al. 2004, 2005). There are also decreases in the proportion of annual precipitation falling as snow (Klos et al. 2014) and decreases in the amount of water contained in spring snowpack (Hamlet et al. 2005). Lower late summer streamflow, affected by reduced snowpack and water storage, creates a potential for warmer stream temperatures in streams with little groundwater input. In the future there may be more frequent and larger winter floods and rain-on-snow events higher in elevation in streams that do not have the capacity to handle intense floods. Lower mean annual streamflows are also projected and may be most prominent in south and east parts of the BioA with projected increases in water supply in the western Washington Cascades. There is also a predicted increase in channel-forming flows, known as bankfull flows, which could influence future stream geomorphology (Wenger et al. 2010).

Planning Considerations

Future land management plan direction can focus on adapting to new and projected future hydrologic conditions. Future land management plans could include monitoring to assess changed hydrologic and riparian habitat conditions. Riparian management area vegetation management to address departed vegetation conditions would mirror departed forest conditions across the BioA area. These are most prevalent in the southern and eastern forests of the BioA area.

Refer to BioA Chapter 2 Management Recommendation

Recommendation 6: Recognize that fire is a natural process and plays an important role in reducing the risk of uncharacteristic fire and in promoting ecosystem health.

Geographic Considerations

The greatest climate change impacts are projected in northwestern California and east Cascades, and, the impacts to hydrology are expected to be most prominent in the same areas. Groundwater drawdown (using more than is replenished every year) is most evident in drier areas of the BioA (south and east); potential impacts to groundwater-fed ecosystems like fens are mostly of concern on the high desert plateau (Modoc and Lassen National Forests). Mean annual streamflow is projected to decrease in the south and east portions of the BioA area and somewhat increase in the western Washington Cascades. Trends in eastern and southern portion of the BioA area indicate at least some drawdown of groundwater levels.

These trends may impact sustainable and available drinking and irrigation water supplies coming from national forests and grasslands in western communities and nationally important agricultural areas like California’s Central Valley, Oregon’s Willamette Valley and the Columbia River valley.