Conserving Old-Growth Forest Diversity in Disturbance-Prone Landscapes

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Abstract: *A decade after its creation, the Northwest Forest Plan is contributing to the conservation of old-growth forests on federal land. However, the success and outlook for the plan are questionable in the dry provinces, where losses of old growth to wildfire have been relatively high and risks of further loss remain. We summarize the state of knowledge of old-growth forests in the plan area, identify challenges to conserve them, and suggest some conservation approaches that might better meet the goals of the plan. Historically, old-growth forests in these provinces ranged from open, patchy stands, maintained by frequent low-severity fire, to a mosaic of dense and open stands maintained by mixed-severity fires. Old-growth structure and composition were spatially heterogeneous, varied strongly with topography and elevation, and were shaped by a complex disturbance regime of fire, insects, and disease. With fire suppression and cutting of large pines (*Pinus *spp.) and Douglas-firs (*Pseudotsuga menziesii *[Mirbel] Franco), old-growth diversity has declined and dense understories have developed across large areas. Challenges to conserving these forests include a lack of definitions needed for planning of fire-dependent old-growth stands and landscapes, and conflicts in conservation goals that can be resolved only at the landscape level. Fire suppression has increased the area of the dense, older forest favored by Northern Spotted Owls (*Strix occidentalis caurina*) but increased the probability of high-severity fire. The plan allows for fuel reduction in late-successional reserves; fuel treatments, however, apparently have not happened at a high enough rate or been applied in a landscape-level approach. Landscape-level strategies are needed that prioritize fuel treatments by vegetation zones, develop shaded fuel breaks in strategic positions, and thin and apply prescribed fire to reduce ladder fuels around remaining old trees. Evaluations of the current and alternative strategies are needed to determine whether the current reserve-matrix approach is the best strategy to meet plan goals in these dynamic landscapes.*

Key Words: ecosystem management, fire, forest dynamics, Northwest Forest Plan

Conservación de la Diversidad de Bosques Viejos en Paisajes Propensos a la Perturbación

Resumen: *A una década de su creación, el Plan Forestal del Noroeste está contribuyendo a la conservación de bosques viejos en terrenos federales. Sin embargo, el éxito y la perspectiva del plan son cuestionables en las provincias áridas, donde las pérdidas de bosques viejos por fuego han sido relativamente altas y donde persisten los riesgos de pérdidas mayores. Resumimos el estatus del conocimiento sobre bosques viejos en el área del plan, identificamos retos para su conservación y sugerimos algunos métodos de conservación que pueden ayudar al cumplimiento de las metas del plan. Históricamente, los bosques viejos en estas provincias variaron de parches abiertos, irregulares, mantenidos por frecuentes incendios de baja severidad a un mosaico de parches densos y abiertos mantenidos por incendios de severidad mixta. La estructura y composición de los bosques viejos era espacialmente heterogénea, variaba notablemente con la topografía y elevación y estaba moldeada por un complejo régimen de perturbación por fuego, insectos y enfermedades. Con la supresión de*

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*fuego y del corte de árboles grandes (*Pinus *spp.y* Pseudotsuga menziesii *[Mirbel] Franco), la diversidad de los bosques viejos ha declinado y se han desarrollado sotobosques densos en extensas áreas. Los retos para la conservación de estos bosques incluye la carencia de definiciones requeridas para la planificación de parches y paisajes de bosque viejo dependientes del fuego, así como conflictos en las metas de conservación que sólo pueden ser resueltos a nivel de paisaje. La supresión de fuego ha incrementado el área de bosques densos, más viejos que son favorecidos por* Strix occidentalis caurina *pero también ha incrementado la probabilidad de incendios de alta severidad. El plan permite la reducción de combustible en reservas en sucesión avanzada; sin embargo, los tratamientos de combustible no han ocurrido a una tasa suficientemente alta o no han sido aplicados con un enfoque a nivel de paisaje. Se requieren estrategias a nivel de paisaje que prioricen tratamientos de combustible por zonas de vegetación, desarrollen guardarrayas sombreadas en posiciones estratégicas y apliquen fuego prescrito para reducir combustible alrededor de los árboles viejos. Se requieren evaluaciones de las estrategias actuales y alternativas para determinar si el actual método de matriz de reservas es la mejor estrategia para lograr las metas del plan es estos paisajes dinámicos.*

Palabras Clave: dinámica forestal, fuego, gestión de ecosistemas, Plan Forestal del Noroeste

Introduction

A central goal of the Northwest Forest Plan (USDA Forest Service & BLM 1994) is the "maintenance and/or creation of a connected or interactive old-growth forest ecosystem . . . " on federal lands within the range of the Northern Spotted Owl (*Strix occidentalis caurina*). Historically, old-growth forests were a significant component of the diversity of forest ecosystems in this region. By 1994, when the plan was enacted, more than a century of wildfires and logging had significantly reduced the area of old-growth forests (Bolsinger & Waddell 1993; Wimberly et al. 2000) and threatened the viability of species associated with them. During the first decade of the plan, however, the rate of loss of existing old-growth forests declined and new areas of older forest developed on most federal lands (Moeur et al. 2005). These trends suggest that a central goal of the plan is being accomplished. A closer look, however, reveals that this early progress is not uniform throughout the plan area. Outside of the moist, coastal Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco)/western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) region, old-growth forests continue to suffer large losses to wildfire (Moeur et al. 2005). Although losses of older forests to stand replacement fire for the entire plan area are consistent with early assumptions (Spies 2006), rates of loss to fire in the drier provinces (Fig. 1) are high and threaten the existence of these forests and the species associated with them.

Another concern in the dry provinces is that one of the primary goals of the plan, "maintenance and/or restoration of habitat for the northern spotted owl . . . " may be in conflict with the goal to restore old-growth forest types. To many people, old-growth forests and Northern Spotted Owls are synonymous. In the dry provinces, however, where old-growth forest diversity is high, open old-growth types are not suitable owl habitat and many areas of the dense old-growth types, favored by the owl, have developed as a result of fire exclusion and are now at risk from high-severity fire (Lee & Irwin 2005).

Our conceptual basis of the ecology and conservation of old growth is not as developed in the dry, fire-prone provinces as it is in the wetter provinces. For example, the primary research and synthesis efforts on forest development and old growth ecology in the region (e.g., Franklin et. al. 2002) have focused primarily on Douglas-fir/western hemlock forests in the western and northern parts of the plan area. Although much has been learned about the fire history of forests in the dry provinces (Agee 1998; Hessburg et al. 2005), few studies have examined these forests through a lens of old-growth forest ecology and conservation (Youngblood et al. 2004). Much basic work needs to be done to learn how our general models of old growth and its conservation (Spies 2004; Franklin & Van Pelt 2004) apply in dry, fire-prone landscapes.

We provide an overview of the current understanding and gaps in knowledge of the conservation of old-growth forests with historically short to moderate return intervals of fire (ranging from 5 to about 75 years) and low- to mixed-severity disturbance regimes. Our objectives were to (1) characterize what is known about the presettlement and postsettlement ecology of these forests, (2) identify conservation challenges, and (3) identify some conservation strategies that might more effectively meet plan goals.

Overview of Forests of Dry Provinces

The dry provinces span a large north-south gradient of environment, species composition, and disturbance regimes (Fig. 1). Within these provinces, we focus on the vegetation zones in the driest and warmest environments: ponderosa pine (*Pinus ponderosa* Dougl.), Douglas-fir, grand fir (*Abies grandis* [Dougl.] Forbes), white fir (*A. concolor* [Gord. & Gord.] Lindl.), and mixed conifer and

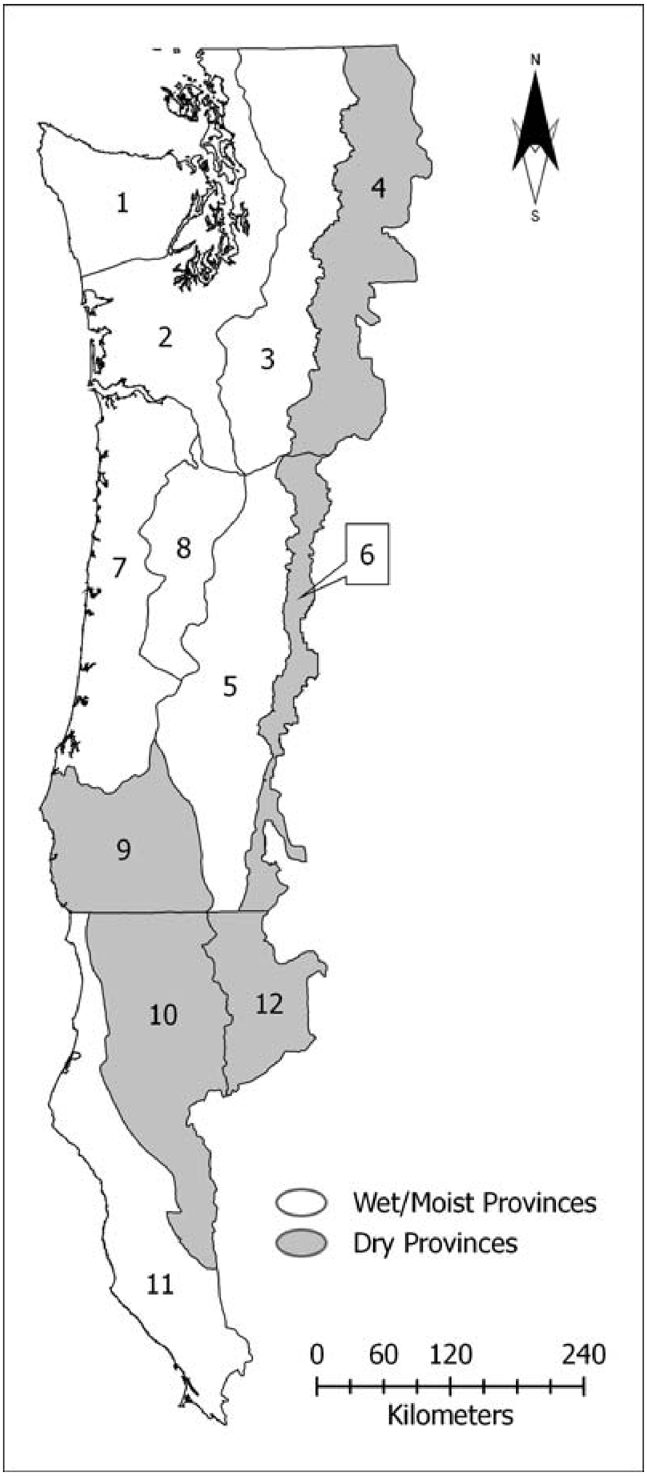

Figure 1. Map of Northwest Forest Plan area with physiographic provinces identified: 1, Washington Olympic Peninsula; 2, Washington Western Lowlands; 3, Washington western Cascades; 4, Washington eastern Cascades; 5, Oregon western Cascades; 6, Oregon eastern Cascades; 7, Oregon Coast Range; 8, Oregon Willamette Valley; 9, Oregon Klamath; 10, California Klamath; 11, California Coast Range; 12, California Cascades.

mixed evergreen (Franklin & Dyrness 1988). These forest zones, which represent a gradient of increasing site moisture, are strongly differentiated by topography and elevation (Franklin & Dyrness 1988) and by climate gradients that run east to west in the Cascade Range and north (Washington) to south (California) within the plan area. The mix of tree species in these zones varies geographically, but large ponderosa pine and Douglas-fir are the primary long-lived seral dominants in all the zones where they have not been removed by logging or other disturbances. Although we have a relatively good basis for understanding the environment and composition within these zones, our knowledge of the structure, dynamics, and processes of them is too limited and uneven to treat them separately. Consequently in our discussion we group these into three major types: ponderosa pine, mixed-conifer/evergreen on dry sites (includes the Douglas-fir zone and driest parts of the other zones), and mixed-conifer/evergreen on mesic sites.

The disturbances that shape forests, particularly fire, insects, and disease, also vary across the plan area, coincident with environmental conditions. Before about 1900 wildfire was the dominant disturbance agent in many forests of the drier provinces (Agee 1993; Hann et al. 1997; Hessburg et al. 1999). Fire severity ranged from high (fires kill more than 75% of the aboveground vegetation) to moderate (25 to 75% killed) to low or surface fires (< 25% killed) (Agee 1993). In addition to fire, insects and pathogens are important disturbance agents (Hemstrom 2001). Fire-suppression policies of the twentieth century, coupled with logging practices and grazing, have altered forest structure, composition, and dynamics relative to presettlement times (Hessburg et al. 2005).

Ecological Characteristics

Potential Forest Vegetation Zones

The ponderosa pine zone, which represents the driest of the dry forests, is relatively uncommon in the plan area, occurring primarily in a narrow band on the east side of the Cascade range in Oregon and in limited areas within southwestern Oregon and northern California (Franklin & Dyrness 1988). It is often found on coarse-textured soils, where annual precipitation ranges from 350 to 850 mm. Of the three types, it has the lowest productivity and the least diverse tree layer; ponderosa pine is the major canopy and understory species (Fig. 2).

Dry mixed conifer/evergreen forests occur in low-to mid-elevations in the eastern Cascades and southwestern Oregon and northern California (Franklin & Dyrness 1988). These forests lie above either pure ponderosa pine forests or open valley bottoms and may grade into grand fir, white fir, and western hemlock types at higher elevations. Average annual precipitation ranges from about

Figure 2. Old-growth ponderosa pine forest with open understories maintained by frequent surface fire.

800 to 1300 mm. Ponderosa pine and Douglas-fir are often the early seral dominant species, but western larch (*Larix occidentalis* Nutt.) and lodgepole pine (*P. contorta* Dougl.) may be common in some parts of the area. Understory regeneration typically contains Douglas-fir or incense cedar (*Calocedrus decurrens* [Torr.] Florin), with grand fir becoming more common in the eastern Cascades in Oregon. In southwestern Oregon and northern California, tree species diversity increases, white fir replaces grand fir, ponderosa pine is less common, and evergreen hardwoods, especially tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehd.) and Pacific madrone (*Arbutus menziesii* Pursh), form dense midstory layers.

Mixed-conifer/evergreen forests on mesic sites occur throughout the plan area at higher elevations or in moister topographic settings than dry forest types (Fig. 3). They still contain dominant ponderosa pine and Douglas-fir but are distinguished compositionally by a relatively large proportion of shade-tolerant true firs and sometimes western hemlock in all strata. Under these mesic conditions shade-tolerant species can form dense multistoried forests that have similarities to the structure of old growth in the wetter parts of the plan area.

The natural disturbance regimes of all three forest types are characterized by the combined effects of insects, disease, and fire. Insects and pathogens, especially those that attack ponderosa pine and Douglas-fir, contribute to structural and composition heterogeneity in old-growth forests. Defoliations of pine by the pandora moth (*Coloradia pandora*) cause reductions in radial growth (Speer et al. 2001) and may contribute to increased sunlight, water, and nutrients available for understory trees and associated vegetation. Mortality associated with low levels of western pine beetle (*Dendroctonus brevicomis*) and the Douglas-fir beetle (*D. pseudotsugae*) results in widely scattered snags. When regional droughts affect tree vigor across entire watersheds and contiguous blocks of host are available, beetle populations can build and attack trees across whole landscapes. Large fires can also trigger large outbreaks of beetles. Comandra blister rust (*Cronartium comandrae* Pk.), a native disease of pine, develops cankers high in the bole, eventually killing the top and producing excessive resin flows. Top-killed trees survive many years, eventually developing a resin-soaked, case-hardened snag that persists for decades. Heart rot fungi (*Phellinus* spp.) can be common in old-growth Douglas-fir and lead to stem breakage, creating heterogeneity in canopies and large-wood substrates.

Frequent, low-mixed severity fires are generally thought to be characteristic of presettlement conditions in the ponderosa pine and dry mixed conifer/evergreen groups, with a tendency for more low-severity surface fire to occur in the ponderosa pine zone (Kilgore 1981; Agee 2003). Natural fire intervals in old-growth ponderosa pine forests range from 4 to 11 years in central Oregon (Bork 1984), 7 years on the eastern slope of the Washington Cascades (Everett et al. 2000), and 11 years in the Blue Mountains (Heyerdahl et al. 2001). Fire-return intervals for dry mixed conifer forests in eastern Washington range from 6 to 24 years (Agee 2003).

Under historical disturbance regimes the structure of ponderosa pine and dry mixed conifer/evergreen forests would have been characterized by an open, park-like appearance, with large live and dead trees in aggregated or sometimes random distributions (Fig. 2). In ponderosa pine forests these clumps ranged from 20 to 25 m in diameter (Youngblood et al. 2004). Shrubs grew between clumps and rodents cached pine seeds that resulted in new tree cohorts. Ponderosa pine needles and twigs would have been the primary carrier of surface fires, and these sparse fuels often burned in a patchy pattern. Some areas, often 1 ha or smaller and scattered throughout the old forest, would not have experienced fire for several decades. Small trees and surface fuels accumulated in these patches, which made them susceptible to more severe fire. As a result, vegetation structure at the scale of several hundred hectares or more would often have been a mosaic of tree sizes and ages within a generally similar matrix of large, widely spaced, fire-tolerant trees. Because the dry mixed-conifer/mixed-evergreen forests are more productive than forests of the ponderosa pine zone, fuels and tree regeneration would have accumulated more rapidly on these more productive sites.

In the dry mixed conifer/evergreen forests of southwestern Oregon and northern California historical fire regimes were characterized by fire-return intervals of about 10 to 25 years, depending on aspect, topography, and soil moisture (Taylor & Skinner 1998; Beaty & Taylor 2001; Wright & Agee 2004). Fires tended to have a mixture of severities, with the most severe fires on upper

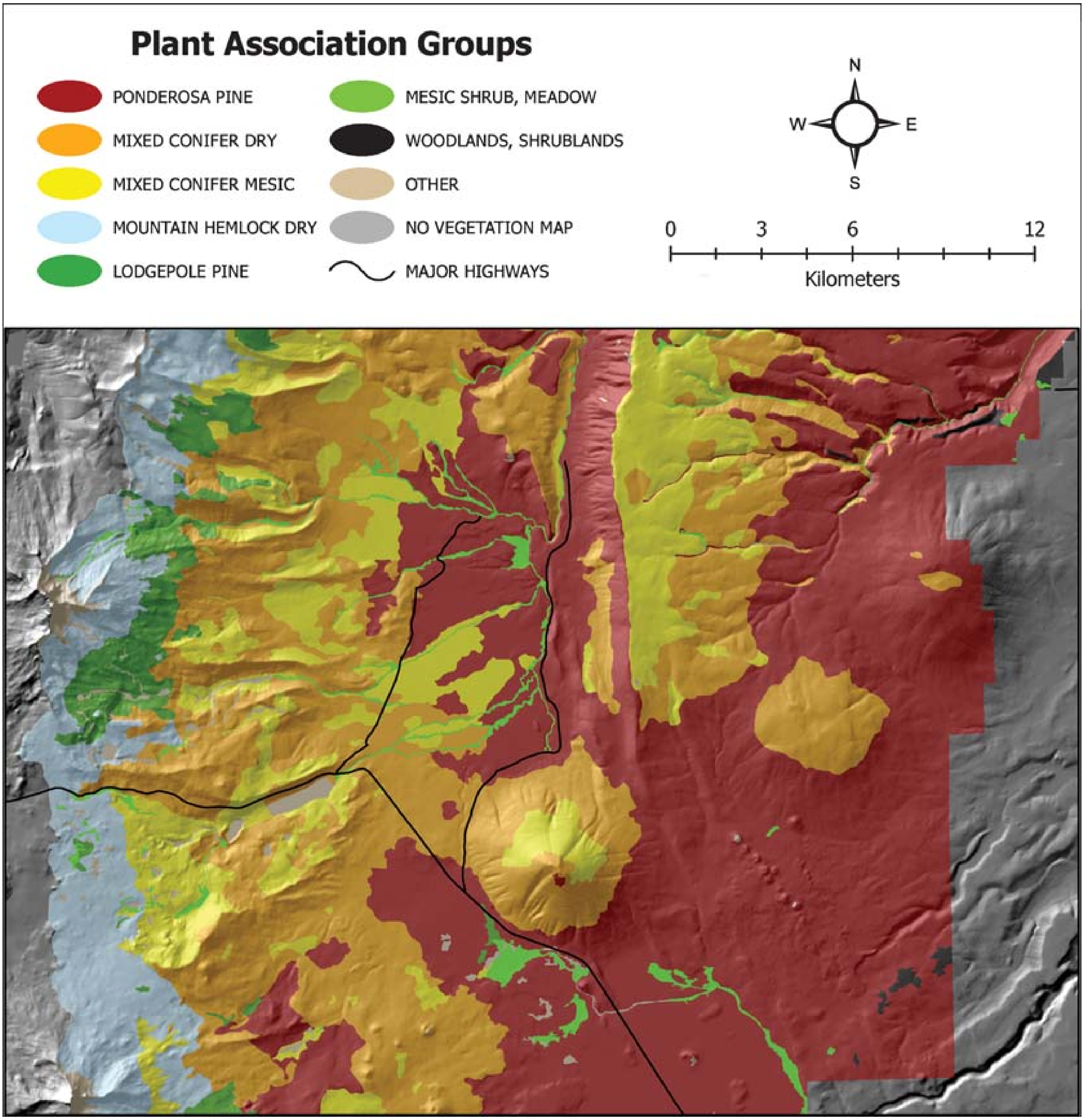

Figure 3. Distribution of major plant association groups in relation to topography in a portion of the Deschutes National Forest in the eastern Cascades of Oregon.

slopes and the least severe on lower slopes. Also, fires were patchy and relatively small, although size was highly variable. Mean fire sizes typically ranged from about 40 to 80 ha, but fires that burned many thousands of hectares were not uncommon.

The historical fire regime of more mesic mixed conifer/evergreen types was characterized by longer return intervals, a high proportion of high-severity patches, and larger patch sizes than the two drier groups. For example, Camp et al. (1997) estimated that some northerly aspects on relatively moist, cool sites within the Swauk Lake Late Successional Reserve in the eastern Cascades of Washington did not experience fire for 130 to 150 years during the presettlement period. Agee (2003) estimated fire return intervals of 75 years for mesic grand fir sites in Washington. The structure of these forests would have been a product of a mixture of low-, moderate-, and high-severity fires that created a complex patchwork of stands at multiple spatial scales. Compared with the drier forests, mesic forests would have larger patches of even-aged stands and greater development of multilayered canopies with shade-tolerant, fire-sensitive species, and scattered emergent ponderosa pine, Douglas-fir, and large true firs. Stem density was relatively high, and when fires did occur, fire severity was probably high because of the dense ladder fuels that could transmit fire into the canopies.

Altered Landscapes

The composition, structure, and disturbance regime of these landscapes has been altered in several ways since Euroamerican settlement of the region (Hessburg et al. 2005). Fire suppression, repeated selection logging, clearcutting, plantation establishment, grazing, road construction, grassland conversion to agriculture, and development have all directly or indirectly influenced landscape structure and fire and biotic disturbances (Oliver et al. 1994). Forests with large, old ponderosa pine are currently at lower levels of extent than during presettlement times (Youngblood et al. 2004). Many of the ponderosa pine stands were repeatedly harvested throughout the twentieth century to provide wood products and were regenerated as even-aged stands with uniform spacing.

With fire suppression in the mid-1900s, stands with well-developed multiple canopy layers became more common. Studies in California, southwestern Oregon, and the eastern Cascades of Oregon and Washington document an increase in shade-tolerant understory tree basal area and density (Table 1, Fig. 4). For example, the basal area in an old-growth mixed evergreen stand in the Siskiyou Mountains increased by more than 142% since the early 1900s (Sensenig 2002). Increased densities of fuels and development of ladder fuels increase the probability of high-severity fire and the risk of loss of individual old pines, Douglas-firs, and other canopy dominants. High-severity fire may create a positive feedback toward high-severity fire because post-fire stands are probably more uniform and susceptible to future high-severity fire than are stands that develop with repeated low-severity fires. Increased buildup of litter layers around the base of old pines probably makes their root systems more susceptible to damage from wild and prescribed fires than under the historical fire regime. The homogeneous stand conditions that have developed as a result of clear cutting and high-severity fires are a "nonsustainable" condition (Wright & Agee 2004).

Despite the widespread agreement on the threats of fire exclusion, the degree to which fire exclusion has actually affected the severity of recent fires has not received much study. Hann et al. 1997 (cited in Hessburg et al. 2005) report a doubling of the area of high-severity fire in the interior Columbia River Basin from the early 1800s to the late 1900s. Taylor and Skinner (1998) report that 14% of presuppression-era fires were of high severity in a late-successional reserve in the Klamath of California. They also report that for the fires of 1987 and

Table 1. Current and simulated[a] historical percentage of lands administered by the Bureau of Land Management and U.S. Department of Agriculture Forest Service in dry provinces within the Northwest Forest Plan (data from Hann et al. 1997).

ERU[b]/plan province[c]	*Forest environment*	*Structure[d]*	*Current (%)[e]*	*Historical (%)[e]*
Northern Cascades/ECW	dry	MS	24	19
		SS	0[f]	71
	moist	MS	18	33
		SS	<0.5	7
	cold	MS	6	25
		SS	1	3
Southern Cascades/ECO	dry	MS	21	16
		SS	25	57
	moist	MS	8	16
		SS	19	9
	cold	MS	47	24
		SS	1	4
Upper Klamath/ECO	dry	MS	47	15
		SS	34	65
	moist	MS	66	33
		SS	21	9
	cold	MS	ND[f]	ND
		SS	ND	ND

[a] *Simulated with transition matrix model based on expert opinion of historical fire regime.*
[b] *Ecological reporting unit as described by Hann et al. (1997).*
[c] *Northwest Forest Plan province in which the majority of the ERU lies: ECW, eastern Cascades of Washington; ECO, eastern Cascades of Oregon.*
[d] *Abbreviations: MS, multistoried; SS, single storied.*
[e] *None detected but possibly present.*
[f] *ND, no data available.*

Figure 4. Old-growth ponderosa pine forest with dense understory (background) developed as a result of fire exclusion and open understory (foreground) created by recent prescribed fire.

1994 the proportion of high-severity fire was only 12% and 18%, respectively. Odion et al. (2004) found that fire size increased in recent decades in the Klamath Mountains in California, but high-severity fires accounted for only 12% of the total area burned between 1977 and 2002. In the 2002 Biscuit fire in southwestern Oregon and northern California, the proportion of high-severity fire was 49% (USDA Forest Service & BLM 2004). It is difficult to compare the distribution of severity in the Biscuit fire with the estimates of severity from other studies of presuppression-era fires because the distributions of forest types are not necessarily the same. The higher percentage of high-severity fire in some modern fires may be in part a result of fire-suppression efforts that may restrict the spread of low- to moderate-severity fires more effectively than of high-severity fires, which spread uncontrollably during extreme fire weather (Taylor & Skinner 1998).

Old-Growth Concepts and Characteristics

Old growth as a structurally heterogeneous successional or stand development stage (Franklin & Van Pelt 2004; Spies 2004) is most distinctive in landscapes where large, infrequent, high-severity disturbances create a contrasting pattern of young, relatively uniform forests and older, structurally diverse forests. Such contrasting conditions occur in the wetter and cooler parts of the plan area and increasingly in the drier provinces where fire exclusion has increased the occurrence of high-severity fire and the cumulative effects of cutting have simplified stand structure. In the drier, fire-prone landscapes, where historical disturbances were patchy and low to moderate in severity, much of the forest would have been in an old-growth condition or contained some elements of old growth such as large old pines and Douglas-firs, small patches of large standing dead and down wood, canopy gaps, and open understories with clumps of regenerating conifers. For example, Agee (2003) estimates that under the historical range of variation the eastern Washington Cascades, 44 to 92% of ponderosa pine and dry mixed conifer forests would have contained patches of trees > 40 cm diameter and <5–10% would have been in early successional open-canopy stages.

Our knowledge of the stand structure of old-growth forests in the ponderosa pine zone comes from a handful of sites that were allowed to function under natural disturbance regimes (Youngblood et al. 2004). The structure of these forests is characterized by relatively low densities (40 to 60 trees/ha) of live overstory trees (Fig. 2). Ages of these overstory trees vary within a stand and across landscapes, but trees 300 to 500 years old are common. Within a stand, trees representing several cohorts are in close proximity. Basal area is relatively low and ranges from 15 to 20 m^2/ha. Dominant and codominant trees become large over the centuries, exceeding 100 cm in diameter. Along with the live trees are about 10 dead trees or snags/ha averaging 60 cm in diameter. Our understanding of dead-wood dynamics in these ponderosa pine forests is less developed; the density of 50 large (average 38 cm in diameter at large end) logs/ha is less than in moist forests with less frequent fire regimes.

Old-growth forests on mixed conifer/evergreen sites are composed of scattered, large (>80 cm in diameter) living trees, including ponderosa pine, Douglas-fir, and incense cedar; two or more canopy layers (including hardwoods in the Siskiyou mountains), scattered large snags; and abundant downed wood (USDA Forest Service 1993; Hemstrom 2003). Age of a stand is not a very useful indicator of old growth in these forests. Ages of overstory dominants range from all ages, where disturbances have been fine grained and frequent (Sensenig 2002), to multiage, where disturbances have been of mixed severity and less frequent. Stand density is highly variable, basal areas range from 10 to 30 m^2/ha, and relatively few large trees occur, with or without thickets of smaller trees. The structure of these types of forests is characterized by relatively low stand densities (e.g., 50 to 80 trees/ha), low basal area (e.g., 13 to 15 m^2/ha), and large average tree sizes (Wright

Figure 5. Cross section of a mixed-conifer old-growth forest in the Sierra Nevada of California illustrating the spatial heterogeneity of understory and overstory trees (drawn by Robert Van Pelt).

& Agee 2004). Spatial variability in stem density is high. Amounts of dead wood are probably relatively low.

Dry old-growth forest types are best defined as a mosaic of young and old trees rather than an individual patch of old, large trees (Fig. 5). Agee (2003) suggests that in ponderosa pine and dry mixed forests small patches go through a somewhat predictable cycle: bark beetles kill a patch of old trees, the dead wood is consumed in subsequent fires, a patch of seedlings establishes, and some of the seedlings escape or survive subsequent fires and eventually develop into a group of large, old trees. Some authors, including Agee (2003), refer to old growth as the patch level; old-growth ecosystems are really a mosaic phenomenon, given the complexity of the system and spatial dependence of processes such as insect herbivory, regeneration, and fire. The grain and dynamics of this mosaic also depend on the pattern of the soil moisture and microclimate. Fine-grained patterns occur in the driest forest environments and coarser-grained patterns are found at higher elevations and in topographically complex environments, where forests are subject to mixed-severity fire regimes.

Several generalizations can be made about dry old-growth forest based on the previous descriptions of forest composition, structure, and dynamics:

- These forests exhibit a high degree of compositional diversity and spatial heterogeneity at stand, landscape, and regional levels as a result of variation in flora, climate, topography, and disturbance.
- Insects and disease are an important component of stand dynamics, and interactions occur with fire.
- Topography has a stronger influence on species composition and fire regimes in dry provinces in the region than in wetter provinces (Ohmann & Spies 1998).
- Under historical disturbance regimes a large portion of these landscapes would have been covered by a relatively fine-grained mosaic of relatively open, old-growth forest.
- Dense, multistoried, old-forest conditions in these environments can occur under the natural fire regime, but they tend to occur in particular topographic situations and to be relatively ephemeral within the ponderosa pine and dry mixed conifer types. In mixed severity regimes, such as in southwestern Oregon and northern California, multistoried old growth is relatively more common.
- The rate of understory development and fuel accumulation increases with decreasing moisture stress from ponderosa pine to mixed-conifer and mixed-evergreen forest types.
- Distribution of large woody debris is patchy and accumulations are less than in moist old-growth forests.
- Variation in tree species composition both within and among provinces creates diversity in disturbance severity and response to disturbance. For example, presence of hardwoods in evergreen forest types in the Klamath region may reduce fire severity (Odion et al. 2004), and following fire, hardwoods often recover rapidly by sprouting.
- Diversity of old-growth forest within and among stands is lost with fire exclusion and high-severity fire. Shade-tolerant understory species fill in open areas within stands and create ladder fuels that place large ponderosa pines and Douglas-firs at risk of death from fire. The high-severity fires that occur in these dense stands may result in more uniform postfire stands.

Challenges to Conserving Old-Growth Forests in Dry Provinces

No Clear Definitions

Although old-growth forests of the dry, fire-prone forests appear to fit into the general conceptual model of old growth (Franklin & Van Pelt 2004; Spies 2004), we lack a solid set of empirical studies to build definitions for inventory, planning, and restoration at multiple spatial scales. Definitions of old growth have been based on stand structural features such as number of large trees and large snags per hectare, number of shade-tolerant associates, canopy layering, amount of dead biomass, and number of large fallen trees (Old-Growth Definition Task Group 1986; Franklin & Van Pelt 2004). Similar definitions have been prepared by agency experts for all of the major potential vegetation types at the series level, but the ecological basis for these definitions in the dry forest types is weak. In most cases current definitions (USDA Forest Service 1993) for these dry forest types do not describe how fire exclusion, past cutting, and livestock grazing may have affected the structure of the stands that were used to develop the definitions. Definitions are also lacking at the landscape level, where complex topography (Fig. 3) and disturbance regimes create a dynamic mosaic of forest structure and composition.

Competing Objectives

Conservation goals within the plan focus on both at-risk species and old-growth ecosystem diversity. Although these may seem like the same goal, they are not necessarily equivalent, particularly for species associated with dense old-growth forests that develop following fire exclusion. Current forest structure in drier provinces is significantly different from historical structure (Table 1).

These changes benefit some species but negatively affect others. For example, the Northern Spotted Owl favors dense, multistoried forests in these provinces. Nesting owls select stands that have more large-diameter trees, higher densities of intermediate-sized (35 to 60 cm dbh) Douglas-firs, and higher stand basal areas (mean of 38.5 m^2/ha) than stands that are not selected (Buchanan et al. 1995). Owls do not use open ponderosa pine and open mixed-conifer types (E. Forsman, personal communication), which historically were widespread in many dry landscapes (Table 1). Other wildlife species, however, such as the White-headed Woodpecker (*Picoides albolarvatus*) and Flammulated Owl (*Otis flammeolus*) are associated with open, old-growth ponderosa pine (Sallabanks et al. 2001) and their populations probably have declined as a result of the loss of this forest type (Csuti et al. 1997). These types may contain additional distinctive species, but their species composition is generally not well known.

The plan recognized that without fuel reductions in late-successional reserves (LSRs), the risks of loss of owl habitat and late-successional forests to high-severity fire would be high. Consequently, the plan called for fuel reduction activities within LSRs. It appears, however, that this activity has not occurred at a high enough rate or with a landscape approach (Spies 2006). In fact the word "landscape" is not even mentioned in this section of the plan. A landscape perspective is clearly needed for at least three reasons: (1) owl populations are sensitive to the spatial pattern and distribution of habitat, (2) the potential to develop and sustain dense multistoried forests favored by owls varies with vegetation zone and topographic position, and (3) the spread of fire and insect outbreaks is sensitive to the pattern of topography and vegetation.

Conservation Implications

Definitions are needed to help inform a vision of the desired range of future conditions and dynamics at multiple spatial and temporal scales. Stand-level structural definitions should distinguish old growth that is maintained by frequent surface fires from old growth that develops under long periods without fire (e.g., Spies 2004). Definitions should also include characteristics of spatial patterns of live and dead trees within stands. Finally, managers need characterization of variation in forest conditions over time at landscape levels. New ways of describing desired future conditions or desired future dynamics (Hessburg et al. 2005) are needed that, for example, are based on the range of variation of landscape patterns and possible effects of climate change. Although knowledge of the historical structures and dynamics is incomplete, enough is known to begin laying out some first approximations. Definitions or classifications could also be developed for degraded stand types. These could then be used to prioritize restoration and fuel-reduction efforts when the goal is to increase fire resiliency.

It is time to revaluate the conservation strategy of the plan in the drier provinces. In particular, as the need for a landscape perspective becomes clear, a better understanding of the effectiveness of the current reserve-matrix approach is needed. The plan assumes that the area of large reserves (congressionally designated reserves and late-successional reserves) is sufficient to conserve old growth in the dry provinces despite expected losses to stand-replacement disturbances. For the dry provinces, 50 to 80% of the area is dedicated to producing old-growth forests on federal lands (Table 2). No analyses have been done to evaluate the assumption that old-growth forests can be sustained within these areas under different rates of loss to high-severity fire (i.e., Are the reserves large enough, positioned properly, or managed in the best way to achieve plan goals?). Although losses of older forest to stand-replacement fire for the entire plan area have been

Table 2. Percentage of federal lands in large-block reserves and decadal rate of loss of older forest to high-severity wildfire between 1994 and 2003 for dry provinces in the Northwest Forest Plan (NWFP) area (data based on Moeur et al. 2005).

Province	*Large reserve areas (%)*[a]	*Decadal rate of loss (%)*
California Cascades	51	2.3
California Klamath	70	3.0
Oregon Klamath	68	9.5
Oregon eastern Cascades	63	14.5[b]
Oregon western Cascades	60	1.4
Washington eastern Cascades	80	3.6

[a] *All NWFP reserves except riparian reserves.*
[b] *Includes estimated loss of older forest from 2003 B and B fire (ca. 10,000 ha).*

in line with expectations (Spies 2006), rates of loss in the dry provinces have been significant, ranging from 1.4 to more than 14% on a decadal basis (Table 2). If these rates continue for several decades, some provinces, especially the eastern Cascades of Oregon and the Oregon Klamath. will lose much of their existing old-growth pines and Douglas-firs.

The current reserve-matrix approach may limit the options too much in these dynamic and altered landscapes. Areas designated for reserves may not have the best inherent potential to produce a desired mix of open old-growth types and owl habitat, and they may not be large enough to sustain desired conditions under disturbance regimes in which large, high-severity fires are increasingly common. Likewise, areas designated for commodity production may not be located on sites that are best suited for timber production. If the current approach is found to be deficient, a more flexible and sustainable alternative might be to manage the entire land base for a forest pattern and disturbance regime that better matches the ecological potential of the landscape to produce forests with old trees and that reduces the risk of high-severity fire (Johnson et al. 2004). Areas of owl habitat and commodity production could be provided within this scheme on appropriate sites. Thus there would be no designated reserve or commodity lands, only the goal of particular forest structures and dynamics. Large old pines and Douglas-firs would be widespread in the landscape and managers could focus considerable attention on managing understories to reduce fuels and provide suitable owl habitat. At the same time they could restore populations of large old pines and firs. Timber production could result from removing some of the larger-diameter understory trees (>15 cm) where more open old-growth types are desired.

How can this goal be reached given the current situation? Hessburg et al. (2005) suggest a number of landscape strategies and silvicultural practices. First, prioritize fuel treatments by vegetation type and fire regimes. Highest priority for fuel reduction would be areas that historically supported low-severity fires. These would generally be landscapes dominated by dry mixed-conifer/evergreen types, where high levels of understory fuels have accumulated. Landscapes dominated by ponderosa pine types would have lower priority because understory fuel accumulations are less on these lower-productivity sites. Landscapes characterized by mixed-severity fires would also have lower priority because high-severity fire would have been a typical component in these biophysical settings.

Second, reduce green-fuel connectivity by creating shaded fuel breaks in topographic positions such as ridgetops and valley bottoms (Finney 2001; Agee & Skinner 2005). The fuel breaks would not stop fires, but they would reduce fire intensity and constrain fire behavior to facilitate fire suppression and restoration. Fuel breaks would be created by thinning from below to remove small trees that create fire ladders and by removing enough of the taller trees to decrease canopy cover to <35% to reduce the potential for crown fire. Such practices would have to be used carefully, however, because they would stimulate growth of understory fuels and create a structure that is not favorable for owls. Third, thinning from below coupled with prescribed burning could also be used on a more widespread basis to reduce ladder fuels around remaining large old pines and Douglas-firs (Fig. 4).

Meeting the habitat needs of the owl will probably require maintaining a higher proportion of dense, multilayered, old-growth forests than would have occurred historically in many of the dry provinces. One approach would be to develop islands of owl habitat within a matrix of open, old-growth types by thinning from below and using prescribed fire to create more fire-resistant forests. When those owl habitat areas are lost to fire, other areas within the matrix can be allowed to undergo successional change to increase stand density and layering. If larger pines and Douglas-firs are maintained in the matrix along with small patches of shade-tolerant trees, then denser types of old growth could probably develop on many sites in 50 years. Prioritization of stands for fuel treatments could be based on the occurrence and density of remnant old pines, Douglas-firs, and larches and on landscape characteristics. These elements of old forests take the longest time to develop and are critical habitat elements for wildlife species. Other elements such as dead wood and understory density and pattern develop more rapidly and are more easily created through management activities. Given the large degree to which landscapes have been altered by selection cutting and fire suppression, it will take considerable time and effort to change landscape patterns and dynamics toward conditions that are more likely to sustain owl habitat and the native diversity of old-growth forest types.

The costs of landscape conservation cannot be ignored because a lack of funding limits treatment options. Landscape-level objectives (e.g., reducing fire risk while maintaining owl habitat) can be supported through stand-level treatments that produce merchantable wood, offsetting costs of implementation and expanding options for conservation activities in other parts of the landscape where treatments would otherwise be financially unfeasible (Hummel & Calkin 2005). For example, Hummel and Barbour (2006) found that silvicultural activities designed to reduce landscape-level fire threat focused mostly on removal of shade-tolerant conifer trees from 18 to 40 cm dbh. Another option to generate revenue for landscape conservation activities might be dedicating some existing plantations to wood production.

Some of these fuel-reduction activities may have undesirable environmental effects (e.g., the need for periodic treatments, introduction of weeds, soil disturbance, or maintenance of some roads). The effects of no action, however—increased occurrence of high-severity fire and loss of old pines and other fire-resistant species—have a large impact on plan goals (Agee & Skinner 2005). The barriers to taking the correct action remain formidable, but in the case of conserving old-growth forests in the drier provinces, inaction is not the strategy with the highest likelihood of success.

Conclusions

The most threatened and degraded coniferous forest ecosystems within the Northwest Forest Plan are the old-growth forests and landscapes of the dry provinces. Conserving and restoring the biological diversity of these forests is a major challenge. Dry old-growth forests are diverse, dynamic, and shaped by the complex behavior of fire, insects, and pathogens. The historical structure and function of these forests have been extensively altered by fire exclusion, logging, and other activities, and their conservation requires a different approach than that for old-growth forests in wetter provinces of the plan. New structural definitions of old-growth forest types are needed that recognize their ecological variability and provide a vision of desired future conditions at multiple spatial and temporal scales. An additional challenge is that goals of old-growth diversity and Northern Spotted Owl habitat are potentially competing in these provinces. This conflict can be resolved only at landscape levels with new strategies for plan implementation that carefully reduce connectivity of fuels and create an ecologically based heterogeneity that better sustains owl habitat and promotes resiliency of forests in the face of disturbance and climate change.

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