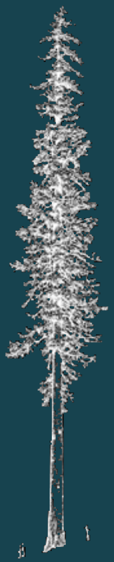
The Case for Active Management of Dry Forest Types in Eastern Washington: *Perpetuating and Creating Old Forest Structures and Functions*



September 2008

This document was created at the request of the:

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

The Case for Active Management of Dry Forest Types in Eastern Washington: *Perpetuating and Creating Old Forest Structures and Functions*

September 2008

Jerry F. Franklin
University of Washington

Miles A. Hemstrom
USDA Forest Service
Pacific Northwest Research Station

Robert Van Pelt
University of Washington

Joseph B. Buchanan
Washington Department of Fish and Wildlife

Sabra Hull
Project Manager
Washington State Department of Natural Resources

Table of Contents

Acknowledgements

The authors would like to thank the DNR members of the Eastside Old Growth Definition Team whose involvement over a three-year period both in the office and in the field contributed to the development of this report:

Sabra Hull, Angie Cahill, Rex Crawford, Steve Curry and Walt Obermeyer

Thanks also to Cassandra Koerner for her time and expertise in the layout of this report, to Richard Bigley and Rex Crawford for their assistance with plant association groupings and appendix A, to Karen Ripley for her contributions on pathogen/tree relationships, to Tami Miketa for her contributions on DNR's current management strategies in eastern Washington, and to the many DNR reviewers whose insights helped to refine the report through several drafts:

Bob Aulds
Angus Brodie
Angie Cahill
Jane Chavey
Rex Crawford
Steve Curry
Aaron Everett
Roy Henderson
Pete Holmberg
Sabra Hull
Cassandra Koerner
Fred Martin
Charles McKinney
Scott McLeod
Ken McNamee
Tami Miketa
Gretchen Nicholas
Walt Obermeyer
Bob Redling
Jeff Ricklefs
Karen Ripley
Kevan Roberts
Clay Sprague
Peter Stocks
Tim Vugteveen
Eric Watrud
Steve Wetzel

Executive Summary

This report is a scientific review of ecological information relevant to state forests managed by the Washington Department of Natural Resources (DNR) east of the Cascade crest including: 1) an overview of historic and current older forest conditions and fire regimes, emphasizing dry forest types; 2) important ecological aspects of old forest attributes in dry eastside forests; and 3) general principles for sustainable management of dry eastside forests with old forest attributes.

This report makes the case for active management of dry forest types in eastern Washington in order to preserve and perpetuate older forest structures and functions. Specifically, this report:

- *Details the values of large old trees and older forest structures in these dry forests,*
- *Presents the scientific evidence that substantiates sustainable active forest management, and*
- *Offers management guidelines for the restoration and maintenance of older forest conditions.*

This review was part of an analysis of historical and current conditions of older forests on DNR-managed forested state lands in eastern Washington. It supplements an earlier report, "Extent and Distribution of Old Forest Conditions on DNR-Managed State Trust Lands in Eastern Washington" (Franklin et al. 2007), which provided an estimate of the current extent and distribution of old forest attributes on these forests based on existing inventory data.

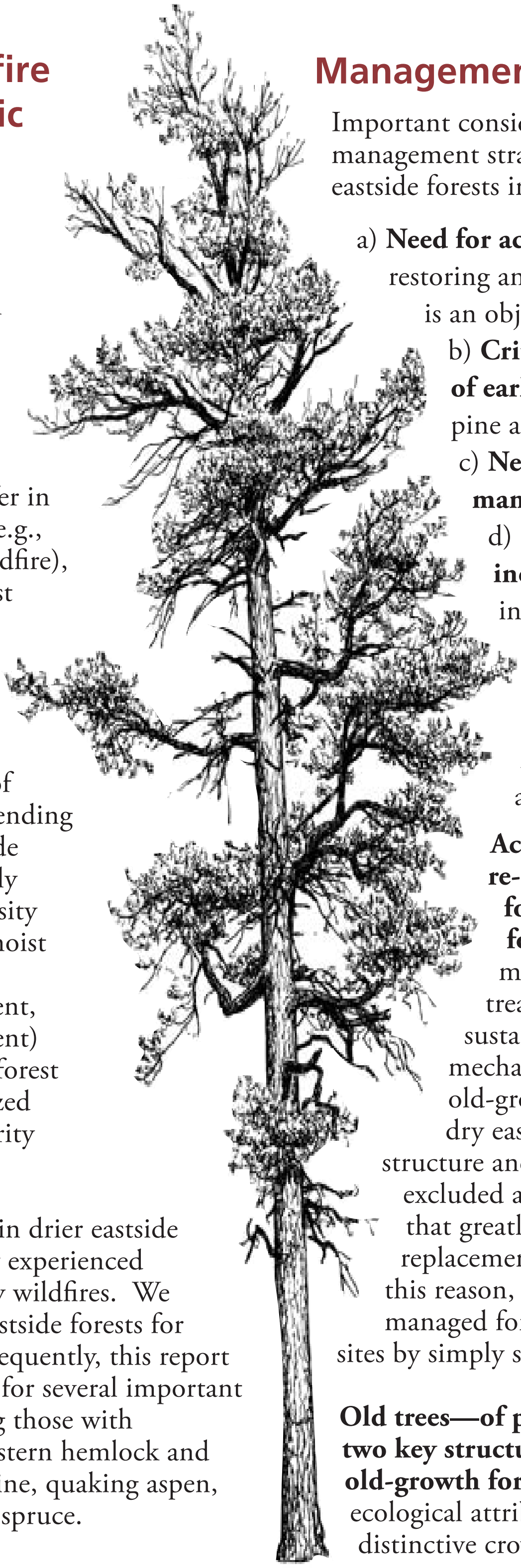
Executive Summary

Plant associations, fire regimes, and historic conditions

Eastside forests are diverse in composition, structure, and productivity reflecting the diversity in environmental conditions and historic and current disturbance regimes. Potential vegetation types are a useful tool for stratifying eastside forests into major categories that differ in historic disturbance regimes (e.g., frequency and intensity of wildfire), characteristic old-growth forest conditions, and appropriate management policies and practices.

Plant associations in eastside forests exist along a gradient of environmental conditions extending from hot, dry sites (dry eastside forests), which were historically subject to frequent, low-intensity wildfire to moist, cool sites (moist eastside forests), which were historically subject to infrequent, high-severity (stand replacement) wildfires. Many intermediate forest environments were characterized predominantly by mixed-severity disturbance regimes.

This report focuses on forests in drier eastside environments that historically experienced mostly low and mixed-severity wildfires. We occasionally mention other eastside forests for context or comparison. Consequently, this report does not provide information for several important eastside forest types, including those with substantial components of western hemlock and western redcedar, lodgepole pine, quaking aspen, subalpine fir, and Engelmann spruce.



Management considerations

Important considerations in development of management strategies for DNR management of dry eastside forests include recognizing the:

a) **Need for active management** on sites where restoring and maintaining older forest attributes is an objective;

b) **Critical roles played by large old trees of early successional species** (ponderosa pine and western larch);

c) **Need for planning and implementing management at the landscape scale**;

d) **Potential of climate change to increase the risk** of forest loss to fire, insects, and storms; and

e) **Need to consider Northern Spotted Owls and other elements of biodiversity** in restoration and management of older forest structures and functions.

Active management is imperative to re-establish and maintain sustainable forest conditions, including older forest structure and function. Active management includes silvicultural treatments to create and maintain sustainable forest conditions using both mechanical and fire treatments. Unlike old-growth forests on moist sites, forests on dry eastside sites develop uncharacteristic structure and fuel loadings where fire has been excluded and in the absence of management, that greatly increase the risk of stand-replacement wildfire and insect epidemics. For this reason, it is not feasible to sustain existing or managed forests with older forest attributes on dry sites by simply setting them aside as preserves.

Old trees—of pioneer tree species—are one of two key structural elements historically present in old-growth forests on dry forest sites. Important ecological attributes of these old trees include distinctive crown structure, bark thickness, heartwood content, and decadence. They are the source of the large snags and large downed wood which, along with the live trees, provide critical habitat for wildlife. The large old trees have the highest probability of surviving wildfire events and subsequently functioning as foci for ecosystem recovery. Historically, old-growth forests on dry sites were dominated by large old ponderosa pine and western larch trees that typically accounted for the majority of the total basal area. Current densities of large trees of pioneer species are much less than historic levels.

Spatial heterogeneity is the second key structural element historically present in old forests on dry sites. In their historic condition, such old forests were characteristically mosaics of small structural patches rather than uniform stands with an even distribution of structural elements. Most existing stands are not only denser than they were historically but also are much more uniform in terms of tree species and tree sizes.

Managing eastside forests for old forest attributes requires a plan to create, expand, or maintain a population of old trees and to restore the structural heterogeneity of the stand. The most logical candidate sites for old forest management are, therefore, sites that still have a population of large and/or old trees of pioneer species. Hence, we focused on identifying such stands on DNR-managed state lands in the analysis of forest inventory data.

Landscape-scale considerations

During the last 150 years, dry eastside forest landscapes have undergone dramatic changes as a result of human activities. At a scale larger than stands or patches, changes include the shift of dry forest landscapes from mosaics of open and dense forests, shrublands, and grasslands to dense forest stands that are now contiguous over large areas, thereby creating the potential for intense stand-replacement fires throughout entire drainage basins.

Management activities in such dry forest landscapes, including forests with older forest attributes, have to be planned and implemented at the landscape level in order to be effective. Treating or attempting to preserve isolated forest patches has a low probability of success in dry forest landscapes that are composed predominantly of dense closed forests. Such isolated patches and, indeed, the entire landscape, are at high risk of stand-replacement wildfire and insect outbreaks. Therefore, planning and implementation of management activities have to occur at the landscape scale. Planning and managing at this scale can:

a) Reduce the potential for large-scale stand-replacement fire (e.g., by creating fuel breaks) or insect outbreaks,
b) Allow strategic location of areas of management emphasis (such as sites for old forest features or habitat for Northern Spotted Owls), and
c) Be a basis for prioritizing areas for treatment.

Potential impacts of climate change need to be considered in developing management strategies, particularly in dry eastside forests. Forests in the Pacific Northwest are highly vulnerable to projected changes in climate because the summer dry period critically influences ecosystem attributes (e.g., tree composition and forest productivity) and disturbance regimes (e.g., fire). Climate changes predicted in the Pacific Northwest are an increase in the length and intensity (severity) of the summer dry period and reductions in the amount and duration of winter snow pack. Evidence exists for such shifts and of their influence in increased intensity and size of wildfires and large-scale and unusual outbreaks of native and naturalized pests and pathogens.

Management strategies for dry forest landscapes and old forest attributes also must consider habitat requirements of the Northern Spotted Owl and other elements of biodiversity. The Northern Spotted Owl and its prey species require relatively dense stands that are at high risk of stand-replacement fire for nesting, roosting, and foraging habitat. Such habitat is most likely to be sustainable when it is embedded as habitat islands within a landscape matrix that has been managed to reduce the potential for stand-replacement fire. The increased open forest areas on the landscape, particularly those with large, old trees, will provide habitat for a suite of species strongly associated with these conditions.

Management for re-establishment and maintenance of older forest ecosystem attributes also needs to consider understory communities. Elements include encouraging native vegetation, managing invasive plants, and maintaining appropriate ground fuels.

Site-specific management principles

General principles for active management to restore and maintain older forest structures and functions are:

- Planning and implementation as part of a landscape-level plan;
- Silvicultural treatments that shift stands toward lower overall stand densities, larger mean tree diameters, and more drought- and fire-tolerant tree species while encouraging structural heterogeneity within a stand; and
- Treating ground fuels created by silvicultural activities.

Encouraging re-establishment of older forest functions in eastside dry forest landscapes managed by DNR. Older forest functionality is highly dependent upon the density and dominance of large and/or old trees. Restoring and maintaining a small population of large old trees in forest stands managed primarily for wood production can contribute to re-creating structures that were historically characteristic.

Sites that already have significant populations of old and/or mature trees provide the best opportunity for restoring sites to an approximation of historic old-growth forest structure, including dominance by old trees and spatially heterogeneous stands. Stands managed in this way can perform numerous important roles in DNR-managed landscapes, including providing habitat for many dependent plant and animal species, shaded fuel-breaks in landscape-level plans, and continuing sources of income.

Two- or multi-cohort silvicultural approaches provide a broadly applicable approach to incorporate older forest structure and function as an element of many managed stands. This involves restoring/maintaining a population of old or large trees as part of a stand that is managed primarily for wood production in a younger cohort.

Additional considerations

Using existing inventory data, a qualitative overview has been developed of older forest attributes on eastside forests managed by DNR (Franklin et al. 2007). However, inventory data provide only an approximate mapping of older eastside forests and a statistical estimate of existing older forest attributes on dry eastside DNR lands. Consequently, DNR natural resource managers will need to assess older forest attributes and the potential for maintaining or expanding such attributes during on-the-ground stand examinations related to management activities. Much scientific information exists on older forest attributes and management strategies to guide managers and a detailed illustrated guidebook to eastside old trees and forests (Van Pelt 2008) will help managers accurately assess older forest conditions and identify old trees.

Other recommendations are that DNR should:

1) Make development of detailed landscape-level management plans a high priority on dry eastside forest landscapes;
2) Identify an initial set of sites for restoration of a sustainable future condition, including a population of older trees;
3) Develop and experimentally test some approaches to two- or multiple-cohort management systems that include an old tree population; and
4) Aggressively explore adaptive approaches to dealing with the effects of climate change, which include the potential increases in risk of large-scale wildfire and insect outbreaks.

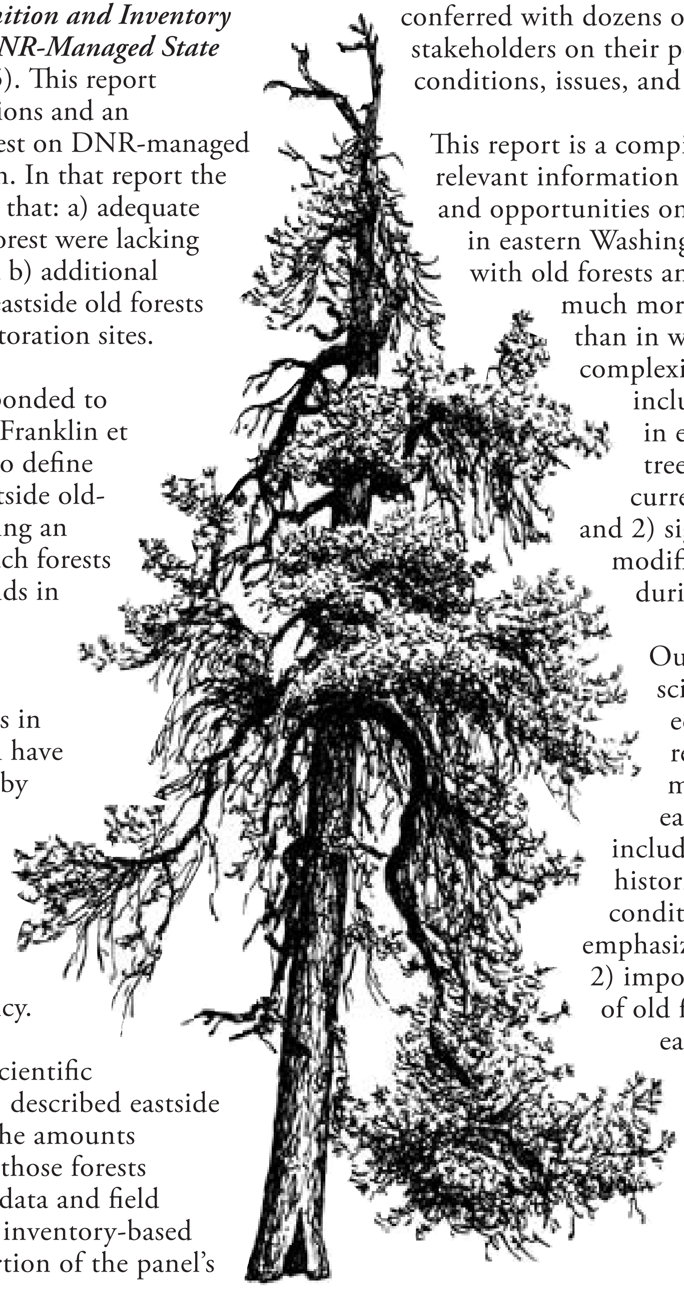
Introduction

Introduction

The 2004 Washington State Legislature asked the Washington State Department of Natural Resources (DNR) to inventory and map old trees and forests on the lands that it manages using an old-growth definition developed by an independent scientific panel (ESHB 2573 Section 905). In June 2005 DNR published the panel's report on old-growth forests in western Washington, ***"Definition and Inventory of Old Growth Forests on DNR-Managed State Lands"*** (Franklin et al. 2005). This report included old-growth definitions and an inventory of old-growth forest on DNR-managed lands in western Washington. In that report the panel advised the legislature that: a) adequate definitions for old-growth forest were lacking for eastside forest types, and b) additional work was needed to define eastside old forests and to identify potential restoration sites.

In 2005, the legislature responded to recommendations made by Franklin et al. (2005) by asking DNR to define reference conditions for eastside old-growth forests and conducting an inventory of the status of such forests on DNR-managed forestlands in eastern Washington (ESSB 6384 Section 189). Interest was focused particularly on old-growth forest conditions in the drier forest types, which have been significantly modified by human activities during the last 150 years. A scientific panel was convened by DNR in 2006 that included scientists and technical experts from outside and within the agency.

An initial report from the scientific panel (Franklin et al. 2007) described eastside old forest conditions, and the amounts and general distribution of those forests using analysis of inventory data and field examination. However, the inventory-based report represents only a portion of the panel's activities during its two years of existence. The panel reviewed existing eastside forest literature and spent many days in the field examining forest conditions and management practices on DNR-managed forestlands throughout eastern Washington, including five 3- to 5-day field trips. During these trips and other meetings, which included two stakeholder sessions, the panel conferred with dozens of scientists, managers, and stakeholders on their perspectives about forest conditions, issues, and possible solutions.



This report is a compilation of additional relevant information on old forest conditions and opportunities on DNR-managed lands in eastern Washington. Issues associated with old forests and their attributes are much more complex in eastern than in western Washington. This complexity is due to many factors including: 1) greater diversity in environmental conditions, tree species, and historic and current disturbance regimes; and 2) significant and widespread modification of eastside forests during the last 150 years.

Our objective is to provide scientific review of ecological information relevant to state forests managed by the DNR east of the Cascade crest including: 1) an overview of historic and current older forest conditions and fire regimes, emphasizing dry forest types; 2) important ecological aspects of old forest attributes in dry eastside forests; and 3) general principles for sustainable management of dry eastside forests with old forest attributes.

We intend to make the case for active management of dry forest types in eastern Washington in order to preserve and perpetuate older forest structures and functions. Specifically, we intend to:

- Detail the values of large old trees and older forest structures in these dry forests,
- Present the scientific evidence that substantiates sustainable active forest management, and
- Offer management guidelines for the restoration and maintenance of older forest conditions.

This report emphasizes conditions found on drier sites characterized by ponderosa pine and mixed-conifer forests. These forests, which generally experienced frequent low- and mixed-severity fires under historical conditions, have been profoundly altered by human activities during the last 150 years (e.g. Hessburg and Agee 2003). The dominant management challenge on these drier sites is that of tree, forest, and landscape sustainability given the high risks of uncharacteristic stand-replacement fires and large-scale insect outbreaks—threats that may be intensified by effects of climate change. Since

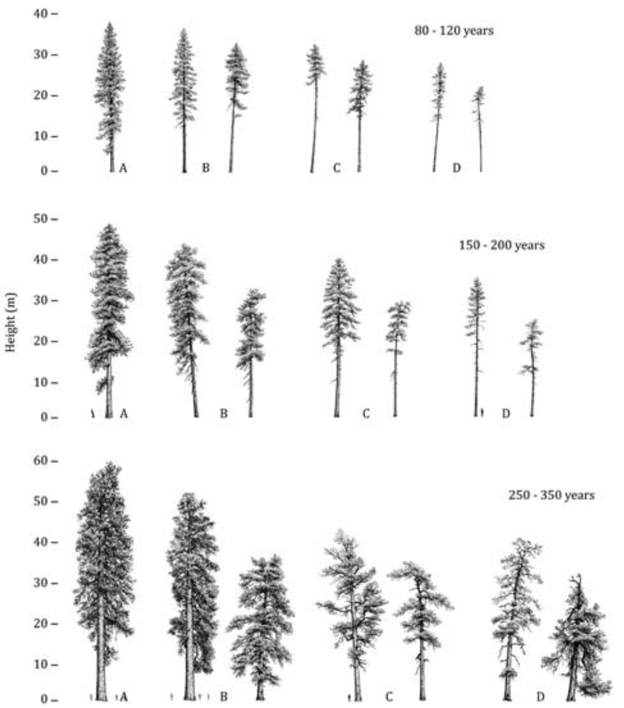
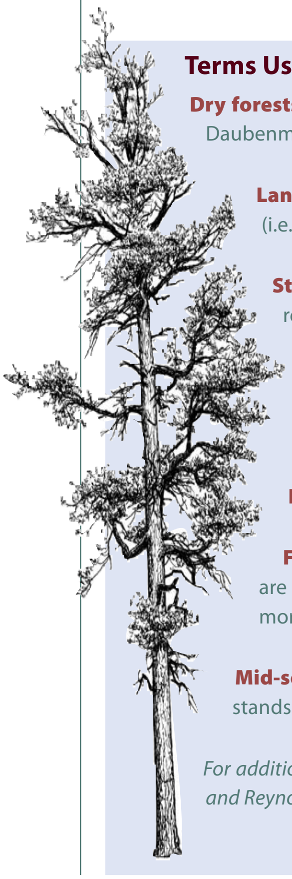


Figure 1. Crown form and tree vigor through time for ponderosa pine with four vigor categories (A-D) and three age ranges (rows 1-3) (from Van Pelt 2008).



Terms Used in this Report

Dry forests – Land classified as ponderosa pine, Douglas fir or dry grand fir plant associations as defined by Lillybridge et al. (1995), Daubenmire and Daubenmire (1968), Williams et al. (1995), and others.

Landscape – An area of land used for analysis of vegetation and disturbance characteristics, generally larger than one watershed (i.e., hundreds or thousands of acres or more).

Stand – An area of vegetation that would normally be mapped as a vegetation polygon when using aerial photography or remotely-sensed images. Vegetation conditions are relatively homogeneous at the scale of several to hundreds of acres.

Patch – An area of vegetation that is relatively homogeneous when viewed from high-resolution aerial photography or from field sampling. Conditions are relatively homogeneous at the scale of portions of an acre or larger; sometimes synonymous with stands.

Edge – The transition area between one stand or patch and another.

Fine-scale mosaic – The arrangement of smaller structural patches of trees and openings that occur within stands. Conditions are relatively homogeneous at scales of one-tenth to one-half acre, generally speaking. Fine-scale mosaics often arise from mortality of overstory trees, which creates gaps that provide space and light for cohorts of seedlings to establish.

Mid-scale mosaic – The arrangement of patches or stands resulting from environmental conditions or disturbances that generate stands within a landscape.

For additional information on spatial terms consult: Forman and Godron (1986), Allen and Hoekstra (1992), Bradshaw and Spies (1992), Li and Reynolds (1995), Peterson and Parker (1998), Franklin and Van Pelt (2004) and Hessburg et al. (2005).

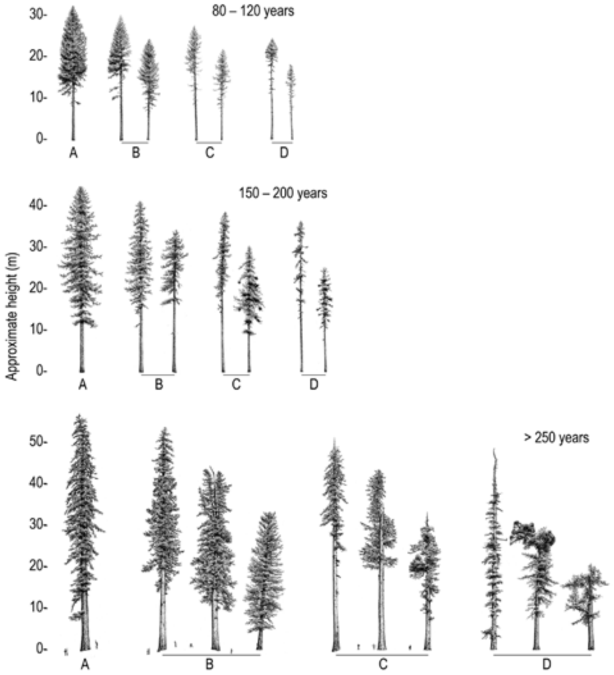


Figure 2. Crown form and tree vigor through time for western larch with four vigor categories (A-D) and three age ranges (rows 1-3) (from Van Pelt 2008).

we focus on forests in drier eastside environments, especially those that historically experienced mostly low- and mixed-severity wildfires, we do not dwell on other eastside forests. We occasionally mention other eastside forests for context or comparison. However, when we refer to "moist mixed conifer" forests we mean relatively mesic forests within the generally dry eastside forest environment.

Older forests on dry sites in eastern Washington did not historically have the kind of stand structures associated with old-growth forests in western Washington. Old-growth forests on westside sites typically had multiple canopy layers and numerous snags and fallen trees. Most evidence suggests that the dominant condition in drier forest was quite different — that is, dry eastside forests were characterized by a relative lack of snags, fallen trees and other elements of decadence due, in part, to frequent fire. Dry eastside old forests were complex, fine-scale patchworks that included variably spaced old trees, denser patches of regeneration, gaps, and intermediate conditions.

Arguably the most important component of dry eastside old forests is the old trees themselves. Van Pelt (2008) provides visual characteristics that can be used to identify old ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), and western larch (*Larix occidentalis*) trees, minimizing the need for time-consuming increment coring and ring counting in many cases (Figures 1 and 2). We do not use tree diameter to indicate age because of the poor relation between tree age and diameter (Figure 3).

We have generally used the term "old forest" to describe the oldest condition of dry eastside forests and "old forest attributes" or "characteristics" to refer to individual elements related to older forests. In addition, the "stand" concept can be difficult to apply in dry eastside forests because the patchy distribution of forest conditions makes it difficult to determine where a given stand begins and another ends. Stand boundaries that would occur due to variability of site-potential and could be expressed in the species composition and structure of the forest are often masked by highly varied harvesting and fire histories. While we do refer to stands in this document, it is worthwhile to bear in mind that stands are conceptually different on eastside dry forests than they are in moister or higher elevation settings. This is because, unlike stands in moister environments, which most often originated following a single stand-replacing disturbance event, dry eastside stands have evolved with frequent, low-severity disturbance and it is, consequently, more difficult to delineate spatial boundaries.

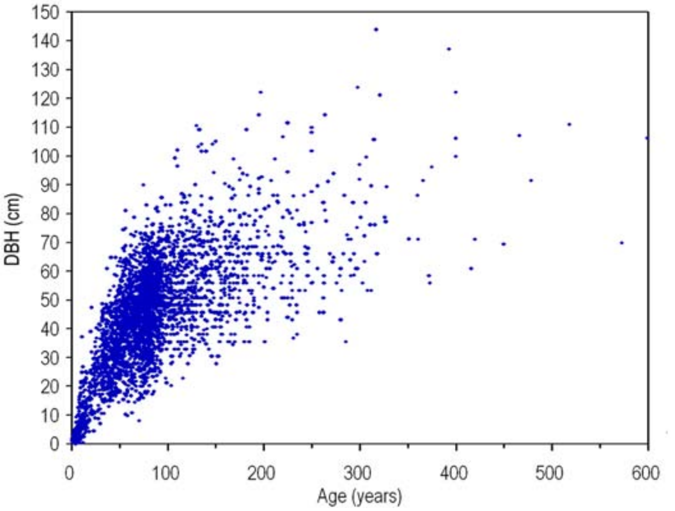


Figure 3. Poor correlation between size and age for ponderosa pine (from Van Pelt 2008).

This report is presented in sections. The first section is a review of historic fire regimes and reference conditions for different forest types. Next, important issues in developing and implementing management strategies and silvicultural prescriptions for dry eastside forests are presented including the necessity for:

1) Active management on sites where restoration of fire and insect resistance, maintenance of old forest attributes, or both are goals;
2) Recognizing the importance of large and old ponderosa pine and western larch trees in older forest function;
3) Planning and implementing activities at the landscape level to reduce the potential for losses to stand-replacement disturbances from fire and insects, including consideration of the role of climate change in intensifying disturbances; and
4) Providing for other elements of biodiversity, including Northern Spotted Owls and understory plant species, in management activities while also considering the impact on forest health and sustainability.

Silvicultural approaches for incorporating older forest attributes and ecosystem functions are reviewed in the third section. The report concludes with observations and suggestions regarding management strategies on DNR-managed forest in eastern Washington.

The Eastside Setting

The Eastside Setting

2.1. Definitions

2.1.1. Plant associations

DNR-managed forestlands in eastern Washington are very diverse in terms of the biota (including constituent tree species), environmental conditions and site potential, and disturbance regimes (especially wildfire). Environmental conditions (e.g., moisture and temperature regimes) vary greatly from grass- and shrub-dominated steppe at low elevations, through lower timberline into dry conifer forests or oak woodlands, up an elevation gradient of increasingly cool, moist, and snowy conifer forests to and through upper timberline and, finally, into alpine vegetation (Van Pelt 2008). In addition, the Cascade Range creates a profound rain shadow on and adjacent to its eastern slopes but precipitation gradually increases moving eastward into the Okanogan Highlands and Selkirk mountains of northeastern Washington. This diverse macroclimatic regime interacts with complex mountainous topography and geologic and edaphic diversity to produce a range of forest site potentials, as measured by such variables as productivity and constituent tree species.

Tree species diversity is high across the entire eastside forested area. Distributions of individual species are strongly correlated with environmental conditions and fire regimes (Van Pelt 2008). Ponderosa pine and, in the southeastern Cascade Range, Oregon white oak (*Quercus garryana*) characterize the driest forest sites. Douglas fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), grand fir (*Abies grandis*), and lodgepole pine (*Pinus contorta*) appear with improving moisture conditions (e.g., elevation) and along with ponderosa pine form forests of mixed composition. On cool to cold moist sites, western white pine (*Pinus monticola*), Engelmann spruce (*Picea engelmannii*), and subalpine fir (*Abies bifolia*) make significant appearances. Where conditions permit, more characteristically westside species, such as western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Pacific silver fir (*Abies amabilis*), and mountain hemlock (*Tsuga mertensiana*), may be present. Except for Pacific silver fir, these Cascadian species also occur in northeastern Washington. Nearly pure lodgepole pine forests may form following intense wildfires on upper elevation cold sites, only gradually giving way successionally to other species. Whitebark pine (*Pinus albicaulis*) and alpine larch (*Larix lyallii*) characterize some timberline forests.

Potential vegetation provides a convenient environmental stratification for discussing overall severity and frequency of wildfires and other natural disturbances. Vegetation zones incorporate the potential vegetation and are named for the shade-tolerant tree species most likely to succeed in a disturbance-free environment (Figure 4). Vegetation zones in eastern Washington are most strongly correlated with elevation and a soil moisture gradient (Figure 5).

Plant associations are a higher-order classification within a given vegetation zone, based on plant community composition, including grasses, forbs, shrubs, and trees. Plant associations are named for certain indicator plants, which are species of plants that are sensitive to a narrow range of environmental conditions. Thus, plant associations are highly correlated with the productivity, moisture regime and ultimately the fire regime within a given vegetation zone.

Fortunately, a comprehensive classification of plant associations and habitat types is available for the forests of eastern Washington. This is a result of extensive field surveys and analysis by ecologists employed by DNR and federal agencies, as well as academic scientists. A complete list of plant associations found on DNR-managed forestlands is provided in Appendix A of this report.

Figure 4. Vegetation zones in eastern Washington. Zones are named after the potential vegetation, which gets its name from the most shade-tolerant tree species (from Van Pelt 2008).

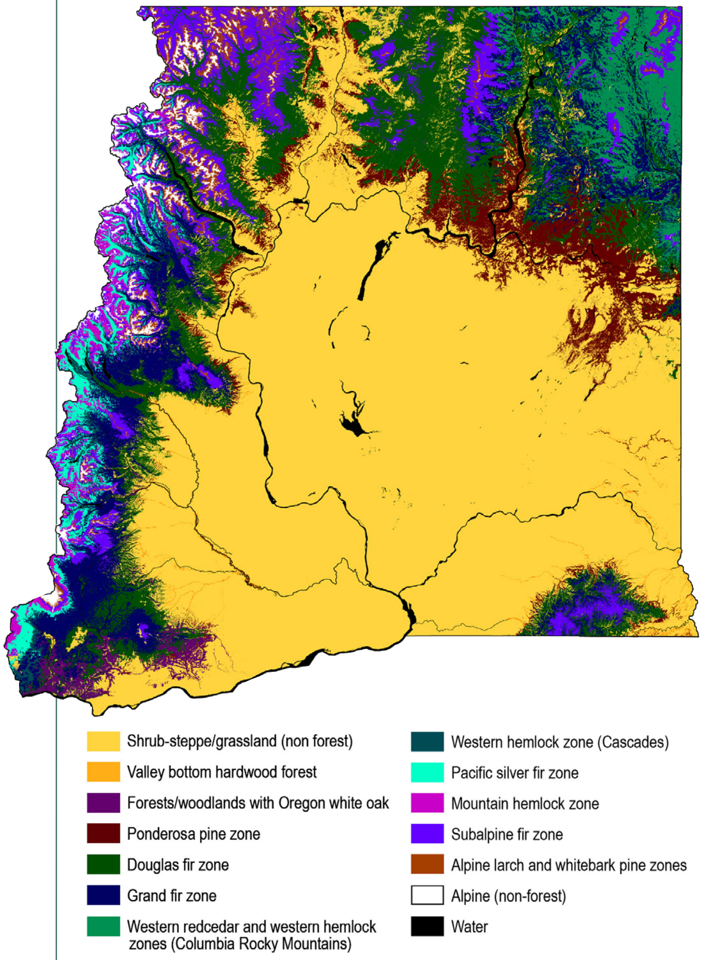
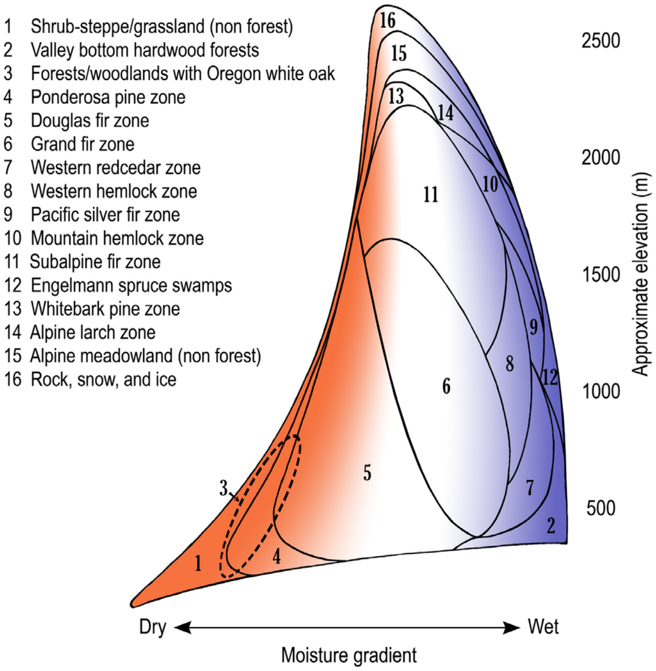


Figure 5. Moisture and elevation gradient for eastern Washington vegetation zones. Each of the shapes in the figure represents the environmental space occupied by a given vegetation zone. The species for which the zone is named (e.g. Douglas fir or ponderosa pine) may grow, but do not represent site potential, beyond zone boundaries. With the exception of the shrub-steppe/grassland zone, which occupies the bulk of eastern Washington, the size of each polygon is proportional to the area occupied by that forest zone (from Van Pelt 2008).



Plant associations can be aggregated into groups based on similarities in environment, disturbance regimes, or other attributes of particular ecological or management interest (Table 1), and are known as potential vegetation types (PVTs). Depending on objectives, PVTs may span more than one vegetation zone.

2.1.2. Fire regimes

Historically, fire regimes in the forest landscapes of eastern Washington varied greatly with climate, which, in turn, was influenced by geographic location, elevation, landform, slope and aspect. Historically, wildfires generally became less frequent but more severe with increasing elevation and on cooler, moister landforms and aspects (Camp et al. 1997). Historical wildfire regimes of interior Pacific Northwest forest types are typically described as low-, mixed-, or high-severity (Figure 6, Table 2), although it is recognized that the regimes exist along a continuous gradient (Hessburg and Agee 2003).

Low-severity fire regimes have frequent fire return intervals (usually 1 to 25 years), with fires generally killing less than 25 percent of trees, small patch size, and relatively low contrast between adjacent stands.

Mixed-severity fire regimes exhibit less frequent fire return (usually 25 to 100 years), fires that kill between 25 percent and 75 percent of trees, and include both ground and stand-replacement fire intensity in mixed mosaics, intermediate patch sizes, and significant contrast between patches.

Table 1. Major eastside vegetation zones by dominant fire regime for forests on DNR-managed lands in eastern Washington (adapted from Hessburg and Agee 2003).

Vegetation zone	Potential vegetation type (PVT)	Severity of fire regime	Range of fire return intervals from various studies (years)[1]
Ponderosa pine[2]	Dry ponderosa pine	Low	16-38, 17-20, 11-16, 3-36
Douglas fir[3]	Dry to moist mixed conifer	Low to Mixed	7-11, 10, 10-24, 14, 8-18
Grand fir[4]	Dry to moist mixed conifer	Low to Mixed	16, 47, 33-100, 17, 100-200
Lodgepole pine[5]	Lodgepole pine	Mixed	60
Western redcedar-western hemlock[6]	Western redcedar-western hemlock	High	50-200+, 50-100, 150-500
Subalpine fir[7]	Engelmann spruce-subalpine fir	High	25-75, 109-137, 140-340, 250, 50-300

High-severity fire regimes are characterized by infrequent fires, which generally kill more than 75 percent of trees, have large patch sizes, and intermediate amounts of contrast between adjacent stands. High-severity regimes are often called "stand-replacement" regimes because most or all of the above ground vegetation is killed by the infrequent (generally more than 100 year interval), severe wildfires.

For simplicity, we categorize each of our major forest types as having low-severity, mixed-severity, or high-severity natural wildfire regimes even though any of the forest types can experience a variety of fire behavior. While we describe historical wildfire regimes for all eastside forest types, the focus in this report is on forest structure and composition in dry forest environments that were historically dominated by relatively open forests and historically experienced predominantly low- to mixed-severity fire regimes (Hessburg and Agee 2003). Descriptions of high-severity fire regime forests are provided to illuminate the contrast between these and the low- and mixed- fire severity regime forest types.

2.1.3. Reference conditions

Reference stands were sought to characterize old forest conditions in dry eastside environments. Unfortunately, only a handful of stands that met the criterion of "largely unaltered by human activities" were found on dry forests on DNR-managed lands

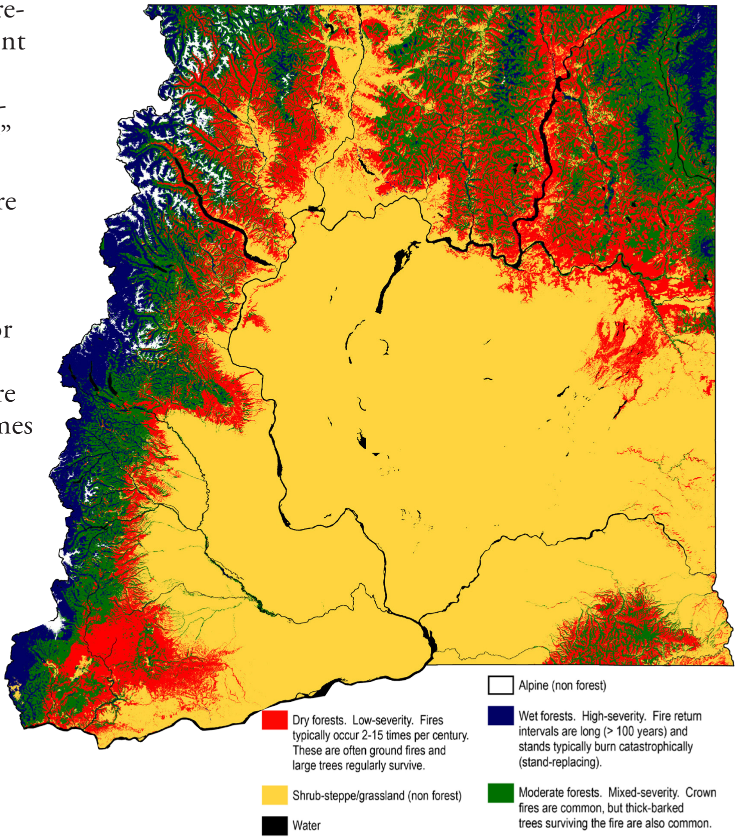


Figure 6. Pre-Euro-American settlement fire regimes in eastern Washington. Fire regimes are the result of influences by precipitation, slope and aspect, productivity, and vegetation type (Van Pelt 2008).

---

[1] Summary data are taken from studies cited in Agee (1993) and some newer studies. Data were collected using a wide variety of fire history methods, which influences the fire return intervals cited. Some of the variability is therefore methodological, and some is inherent within the fire regime.

[2] Bork (1985), Weaver (1959), Soeriaatmadja (1966), Heyerdahl (2001).

[3] Wischnofske (1983), Hall (1976), Finch (1984), Everett (2000).

[4] Weaver (1959), Wischnofske (1983), Arno (1976), Antos (1981).

[5] Agee (1981), Stuart (1984).

[6] Arno and Davis (1980), Davis (1980).

[7] Barrett (1991), Agee (1990), Fahnestock (1976), Arno (1980), Morgan (1990).

Potential vegetation type	Historic fire regime[1]	Historic fire return interval (years)	Current fire regime
Ponderosa pine- oak	Low	16-38, 7-20, 11-16, 3-36	Mixed
Dry mixed conifer	Low	7-11, 10, 10-24, 14, 8-18	High
Moist mixed conifer	Mixed	16, 47, 33-100, 17, 100-200	High
Aspen	Mixed	Unknown, probably <150	Mixed
Lodgepole pine	Mixed	60	High
Western redcedar-western hemlock	High	50-200+, 50-100, 150-500	High
Douglas fir- subalpine fir	Mixed	140-340, 250, 50-300	High
Subalpine fir-Engelmann spruce	High	Unknown, probably >150	High
Subalpine parklands	Mixed	Unknown	Mixed

Table 2. Potential vegetation types (PVTs), historic fire regimes, historic fire return intervals (adapted from Hessburg and Agee 2003), and estimated current fire regime on DNR-managed lands in eastern Washington. Fire regimes reflect the dominant fire severity class. Please note that every fire severity type will occur in some manner in all PVTs; the dominant type is the characteristic condition that generated or generates the majority of stand/forest conditions.

[1] Low = 0-25 percent stand mortality. Mixed = 25 percent-75 percent stand mortality. High = >75 percent stand mortality.

in eastern Washington. All dry eastside forests that we examined are well outside their normal fire return intervals; many dry forests have not experienced wildfires for decades. Consequently, both their structure and composition have been significantly modified.

Historic conditions were synthesized from historic reference conditions for dry forest types since there is a near absence of suitable reference stands. Historic conditions were based upon old photographs, historic descriptions, and accounts of tree ages, stand structures, inventories, and modeling efforts derived from the scientific literature.

Sustainable future conditions can be developed by silvicultural treatments designed to reduce within-stand tree densities and fuel loadings and shift stand composition toward more drought- and fire-tolerant species. Silvicultural approaches to achieve such conditions are described in section 3 of this report. We believe that many of the ecological attributes of eastside dry-site old forests can be restored and subsequently maintained through site-specific treatments designed to improve fire and pest resistance.

2.2. Relationship of Forest Types and Plant Associations to Fire Regimes

2.2.1. Forests historically characterized by stand-replacement fire regimes

In total, DNR-managed lands in high-severity fire regimes account for approximately 108,000 acres (43,706 hectares), including high elevation sites that are not managed for timber production. Engelmann spruce-subalpine fir forests occur at upper elevations in environments dominated by long winters, deep snow, and relatively continental climates throughout the eastside (Barbour and Billings 2000, Hemstrom 2003). Extensions of several more-typically westside forest types with stand-replacement fire regimes occur just east of the Cascade crest, including mountain hemlock, Pacific silver fir, western hemlock, and western redcedar-western hemlock forests (Figure 7).

Historical fire return intervals in these forest types typically exceeded 100 years to several centuries. High-severity (stand replacement) wildfire often dominated with significant areas of mixed- and low-severity fire. Resulting old forest structures included multiple canopy layers, abundant large old trees, abundant large snags, and abundant down wood (Figure 6).

Lodgepole pine forests occupy large areas at middle to high elevations in eastern Washington, including in the Cascade Range, Okanogan Highlands, and Selkirk Mountains of northeastern Washington. Lodgepole pine forests generally experienced high-severity, stand-replacement wildfire regimes under historical conditions. However, lodgepole pine forest structures are not as well developed as those in spruce-fir forests due to the generally short life-span of lodgepole pine, low site productivity, and relatively frequent high-severity fires. Historically, most lodgepole pine forests experienced fire return intervals of less than 100 years with predominantly high-severity fire regimes (Hessburg and Agee 2003) as well as epidemic-level insect outbreaks (Agee 1993). Forests dominated by lodgepole pine in Washington seldom exceed 125 years in age, in contrast to lodgepole forests in the Rocky Mountains and elsewhere (e.g., Kaufmann 1996).

Figure 7. In the wettest portions of eastern Washington, such as near the Cascade crest, western hemlock forests similar to those in western Washington occur (Robert Van Pelt).

Figure 8. Pure stands of lodgepole pine frequently give way to more shade tolerant species (e.g. subalpine fir) in the absence of stand-replacement fire or insect outbreaks (Robert Van Pelt).

Lodgepole pine forests are usually successional to other forest types and lack a well-defined old condition in eastern Washington. Other tree species, such as Engelmann spruce, subalpine fir, and mountain hemlock, invade aging lodgepole pine forests but frequent high-intensity wildfires often prevent progression to an older forest condition (Figure 8). We did not define old lodgepole pine forests since lodgepole pine forests tend to be transitional to other forest types (e.g., subalpine fir-Engelmann spruce) that do have well-defined old states. It is important to note that there are some sites, usually of limited extent, where lodgepole pine is the only species that can grow. Lodgepole pine is the climax species on such sites and constitutes whatever form of old forest can develop there.

Eastside riparian forests and aspen (*Populus tremuloides*) forests are highly variable, but they are a very small part of most eastside landscapes and we have not included characterizations for old forests for them in this document. Those dominated by conifers are similar in fire regime to upland forests within the same vegetation zone, but those dominated by a mix of conifers and/or hardwoods (cottonwood or species of alder, birch, maple, or willow depending on environment) may be more likely to burn at low- to moderate severity.

Moist forests found on DNR-managed lands in the Selkirk Mountains and eastern Okanogan Highlands of northeastern Washington appear quite distinct from other moist forests in eastern Washington. These northeastern Washington forests are typically a diverse mixture of 6 to 8 tree species, including various combinations of western white pine, grand fir, Douglas fir, western larch, ponderosa pine, lodgepole pine and Engelmann spruce, often with western hemlock and western redcedar (Figure 9). Landscapes are typically dominated by dense stands, which appear to have originated following predominantly stand-replacement fire events, i.e., they tend to be even-sized and have few or no older residual trees. Although there are many large trees in older stands, trees older than 200 years appear to be relatively rare and are often limited to fire refugia such as riparian areas and topographically sheltered areas. Productivity appears relatively high and moisture conditions favorable compared to many other eastside forest sites, such as those encountered in the rain-shadow of the Cascade Range. We interpreted the historic disturbance regime in these forests to be high-severity wildfire with a relatively long return interval of 150 to 250 years.

Figure 9. Up to 10 conifer species share dominance in the moist, mixed-conifer forests in the Selkirk Mountains in far northeastern Washington (Robert Van Pelt).

2.2.2. Forests historically characterized by low- and mixed-severity fire regimes

The structure of old forests on sites characterized by low-severity fire offers a marked contrast with old forest structures on sites subject to high-severity, stand-replacement disturbance regimes (Franklin et al. 1981, Franklin and Van Pelt 2004, Van Pelt 2008). The chronic low-intensity disturbance regimes of these sites meant that large, old trees of fire-resistant species were essentially present in perpetuity across much of the landscape. In addition, frequent low-intensity events regularly cleared the understory by eliminating many of the smaller trees and consuming shrubs and coarse woody debris. Hence, older forests on dry eastside sites contrasted structurally with old forests developed on sites subject to stand-replacement events. Specifically, older forests on dry eastside sites had: 1) relatively few large old trees per acre, 2) relatively small old trees, 3) relatively few large snags (standing dead trees), 4) generally sparse coarse woody debris, and 5) often simple canopy structure (Agee 1993, Covington and Moore 1994, Hann et al. 1997, Hessburg et al. 1999a, Hessburg and Agee 2003) (Figure 10).

Our summarization of historical old forests in dry environments in eastern Washington comes from studies published for local environments and similar settings in the interior west (e.g., Munger 1917, Soeriaatmadja 1966, White 1985, Savage 1991, Covington and Moore 1994, Arno et al. 1997, Hann et al. 1997, Harrod et al. 1999, Hessburg et al. 1999a, Hessburg et al. 1999b, Everett et al. 2000, Agee 2003, Hessburg and Agee 2003, Youngblood et al. 2004, Hemstrom et al. 2007). Large, old, widely-spaced ponderosa pine, western larch, or Douglas fir dominated old forests under historical conditions. In many cases there may have been 8 to 12 old trees per acre. On poorer sites with soil or other environmental limitations, there may have been only a few (e.g. 2-5) old trees per acre, while on more productive sites, there were perhaps 20 or more. In addition, old ponderosa pine and western larch trees vary considerably in size, ranging from 16 inches (40 centimeters) DBH or even smaller to well over 36 inches (about 91 centimeters) DBH at 150 years, again depending on site conditions. Thick bark on these old trees allowed them to survive most low- and moderate-severity wildfires (Figure 11). Down logs were generally not abundant, since frequent wildfires consumed much of the coarse woody debris. Large snags were present but generally not abundant. Older forests were highly variable across stands and typically existed as fine-scale, low-contrast structural mosaics.

This spatial heterogeneity was largely a result of fine-scale patchy mortality and regeneration processes within larger landscapes that contained abundant old forest characteristics (Figure 12). One way to visualize this is to imagine looking down on the historical landscape from an airplane flying at 2,000 feet (610 meters). The landscape would have looked somewhat homogeneous with denser forests on more northerly aspects, open forests on drier sites, and frequent meadows and non-forested areas. Most (perhaps 40-60 percent or more) of the potentially forested landscape in dry environments would have been dominated by older trees. Walking on the ground, however, would reveal clumpy to randomly spaced old trees with embedded patches of smaller trees and regeneration.

Figure 10. The open stand structure of an old ponderosa pine forest. While the wide distribution of tree sizes is similar to westside old-growth forests, the open nature of the stand is not. Fine-scale patchiness within the stand was historically characteristic of such stands, where clumps of younger trees or saplings were interspersed with open areas and groupings of old trees (Miles Hemstrom).

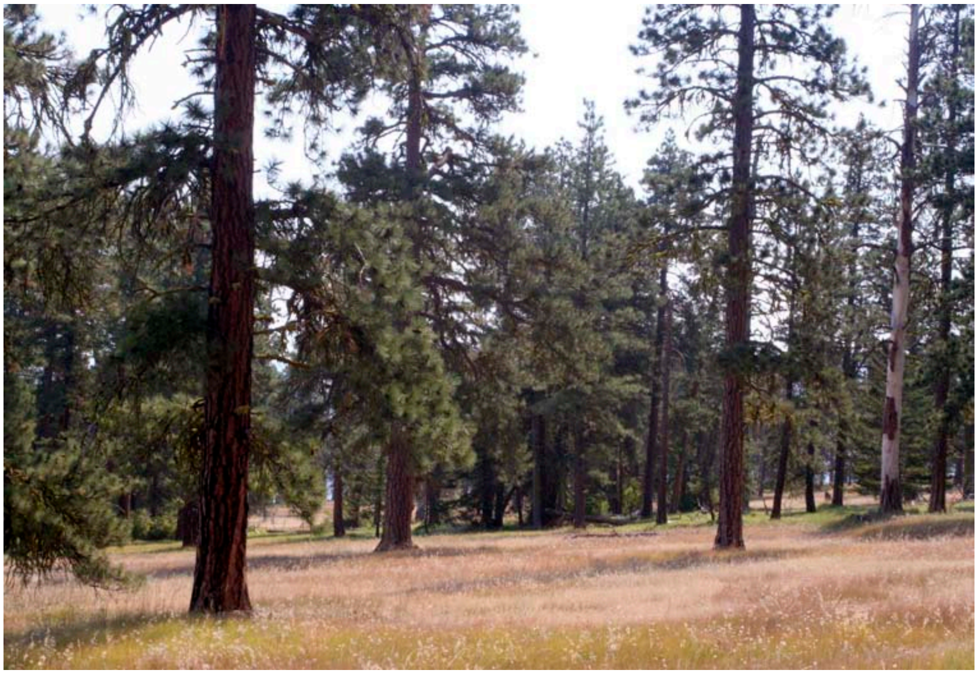


Figure 11. Old stands that developed under low-severity, frequent fire often have low fuel abundance and large, thick-barked trees which can survive surface fires (Miles Hemstrom).

Decades of fire suppression, forest management (including selective logging of large old trees), wildfires, insect outbreaks, and other factors have altered the structure of the remaining dry old forests (Agee 1993, Covington and Moore 1994, Hann et al. 1997, Hessburg et al. 1999a, Hessburg and Agee 2003). Compared to historical conditions, existing forests in dry eastside environments are predominantly characterized by: 1) having few or no old trees, 2) often having multiple canopy layers and

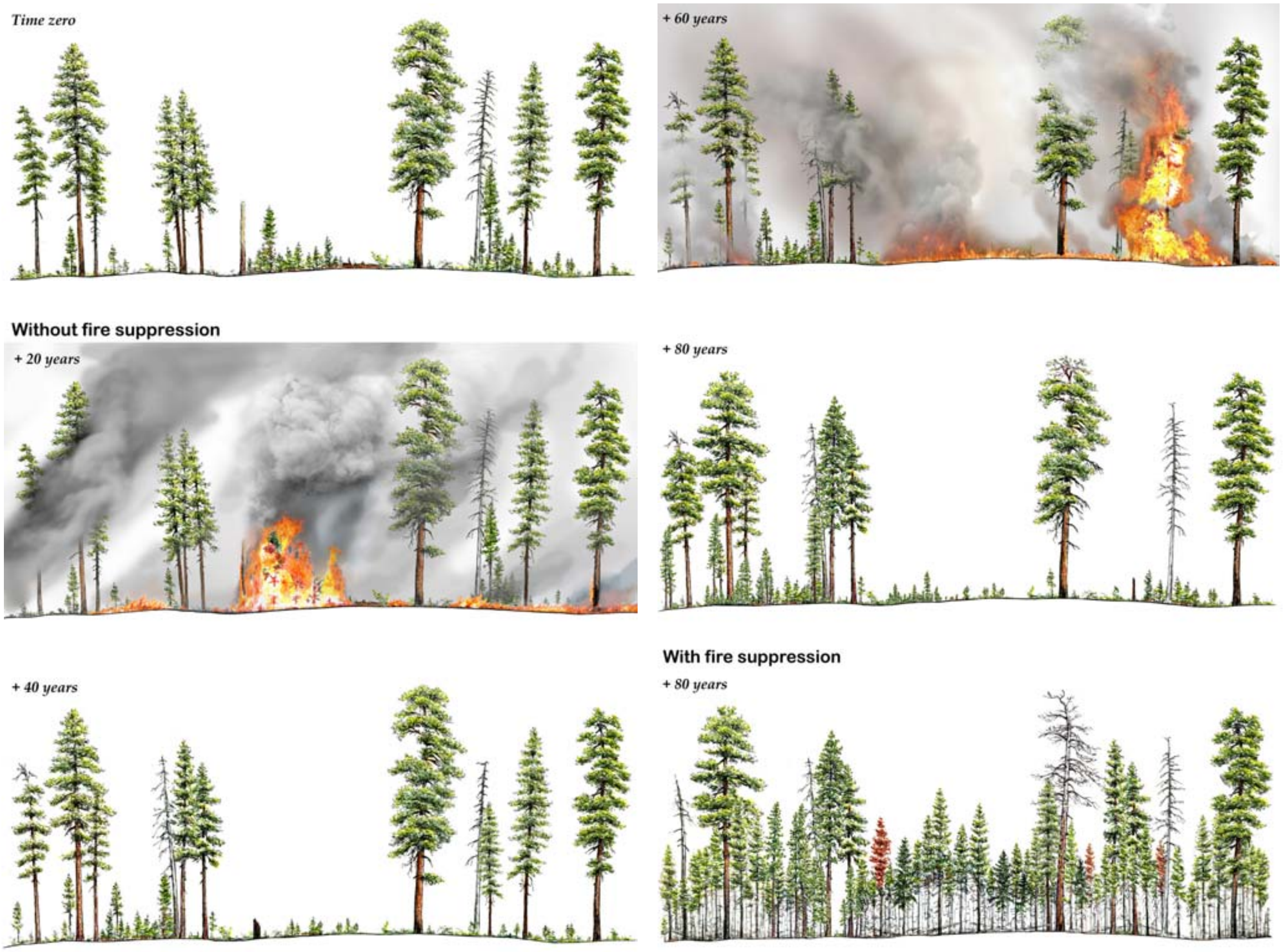


Figure 12. Eighty years in the life of an old ponderosa pine forest. Historically, 2-15 fires could occur during a century within a given stand. While crown fire occasionally occurred, the frequency of fires and the open nature of the stands made crown fires uncommon. The upper panel is the profile of a hypothetical old pine stand. The next four panels illustrate a possible scenario in which fire maintains the open nature of the stand. Note that although the *+ 80 years* panel looks superficially like *Time zero*, there have been significant changes. The final panel is a hypothetical illustration of the same forest where fire has been excluded (from Van Pelt 2008).

dense forest structure, 3) often existing in homogeneous landscapes with continuous and high fuel levels, and, consequently, 4) being highly susceptible to loss due to stand replacement wildfires or insect outbreaks (Figure 12 – last panel). In general, many areas that once experienced mixed- to low-severity fire regimes are now subject to high-to mixed-severity fire regimes (Figure 13). Furthermore, these forests typically exist within essentially homogeneous landscapes, which have abundant, continuous fuels, and, consequently, a high potential for loss to stand-replacement wildfires or insect outbreaks — a landscape-level circumstance that seldom existed in the past.

Several forest and woodland potential vegetation types characterized by low- to mixed-severity fire regimes may occur on DNR-managed lands, including those dominated by western larch, ponderosa pine, Douglas fir, grand fir, and ponderosa pine-Oregon white oak (Table 2). We collapsed these into general categories (Tables 1 and 2) that reflect major environmental characteristics and old forest variants.

DRY PONDEROSA PINE FORESTS

Ponderosa pine is the sole dominant early and late successional tree species in the driest forested environments, except in the southern Washington

Figure 13 (left). Stands with old pines or larches in them often developed in a low-severity fire regime, but moved into a mixed or high severity regime during the past century. This old ponderosa pine (left center) is surrounded by a dense young forest of Douglas fir and grand fir (Jerry Franklin).

Cascade Range where Oregon white oak may be an associate (Williams and Lillybridge 1983b, Lillybridge et al. 1995b, Williams et al. 1995). Dry ponderosa pine forests (i.e., climax ponderosa pine sites) are uncommon on DNR-managed lands in eastern Washington, but do occur at the low-elevation forest fringe (Figure 14). In fact, climax ponderosa pine forests are scarce throughout eastern Washington but are abundant in eastern Oregon and other parts of the interior west (Hopkins 1979a, b, Williams and Lillybridge 1983b, Volland 1985, Johnson and Simon 1987, Johnson and Clausnitzer 1992, Lillybridge et al. 1995b, Williams et al. 1995). In total, DNR-managed ponderosa pine series forests account for approximately 39,000 acres (15,783 hectares). Historically, wildfires were relatively frequent and generally of low severity (Hessburg and Agee 2003) (Table 2). When fires did occur, flammable materials were often present only as small trees, branches, and needle litter, which allowed for the persistence of the larger trees (Figure 15). However, most forest landscapes, even in dry ponderosa pine environments, included some level of mixed- and high-severity wildfire under natural conditions. Fires and insect

Figure 14 (right). Pure ponderosa pine forests in eastern Washington are often present only at or near the lower forest fringe (Jerry Franklin).

Figure 15. Fire in dry ponderosa pine forests often consumed fuels on the ground. Small to medium-sized ponderosa pine, western larch, and Douglas fir often survived resulting low-intensity fires (Robert Van Pelt).

outbreaks typically generated a patchy landscape consisting of mosaics of open forests of large trees, denser patches of small trees, and openings (Hann et al. 1997, Hessburg et al. 1999a) (Figure 16).

The driest forest environments grade into woodlands of ponderosa pine, western juniper (*Juniperus occidentalis*), and Oregon white oak, depending on location and environment. Oregon white oak and ponderosa pine form locally extensive woodland plant communities in the southern Cascade Mountains and near the Columbia Gorge. Woodlands were maintained in open structure by summer drought and frequent wildfire, including burning by Native Americans (Hemstrom et al. 1987, Agee 1993). As in dry forests, woodlands are currently denser compared to historical conditions as a result of fire suppression.

Figure 16. Cross-section of an old ponderosa pine stand. Horizontal variability is visible in the form of gaps, regeneration patches, and open groves of big trees (Robert Van Pelt).

Figure 17 (left). Even though several tree species may be present in the dry mixed-conifer forests, ponderosa pine is often still the dominant species (Jerry Franklin).

DRY MIXED-CONIFER FORESTS

Douglas fir, grand fir, and ponderosa pine can regenerate beneath the low-density canopies of old ponderosa pine on slightly moister sites, which are often referred to as "dry mixed-conifer sites" (Williams and Lillybridge 1983b, Lillybridge et al. 1995b, Williams et al. 1995) (Figure 17). Under historical conditions, frequent low- and mixed-severity wildfires with fire return intervals of 10 to 50 years or more eliminated most regeneration and maintained relatively open stand structures dominated by large ponderosa pine and western larch (Agee 1993, Agee 2003, Hessburg and Agee 2003) (Table 2). Dry mixed conifer-forests occur on sites that are moister and more productive than those occupied by climax ponderosa pine forests. Hence, dry mixed-conifer forests historically had higher densities of old trees and greater total and large tree basal areas than climax ponderosa pine sites. Otherwise, old forest structure and composition in dry ponderosa pine and dry mixed-conifer sites was similar. Because of higher productivity and somewhat longer fire return intervals, dry mixed-conifer forests also develop fuel loadings more rapidly than forests on climax ponderosa pine sites. DNR manages approximately 375,000 acres (151,757 hectares) in dry-mixed conifer potential vegetation types.

Figure 18 (below). Trees can often reach mammoth proportions within moist mixed-conifer forests, most of which are found within the grand fir zone (Robert Van Pelt).

MOIST MIXED-CONIFER FORESTS

Grand fir and Douglas fir often dominate current conditions in relatively mesic mixed-conifer forests within dry eastside forest environments, although ponderosa pine and western larch may also be important (Table 2). We call these relatively mesic forests "moist mixed-conifer" forests even though they are moist only within the broader context of dry eastside forests (i.e., no more than about half way toward the moist end of the broader eastside forest environmental gradient in Figure 5). Moist mixed-conifer forests occur in areas of somewhat higher precipitation, which tend to be at higher elevations or on cooler and moister aspects or landforms, compared to the dry ponderosa pine and dry mixed-conifer forests. Generally, forest productivity is also higher and historical wildfire return intervals longer than on the drier types (Figure 18). Consequently, old forests in moist mixed-conifer sites historically had larger trees, higher basal area of large trees, and more abundant small trees and standing and down dead wood compared to those on drier sites. At the most mesic end, moist mixed-conifer forests grade into types in which old forest characteristics more closely resemble those in westside old forests (Table 2). Moist mixed-conifer forests typically experienced a higher proportion of mixed- and high-severity wildfire compared with forests on drier sites and fire return intervals ranged from less than 10 to over 100 years.

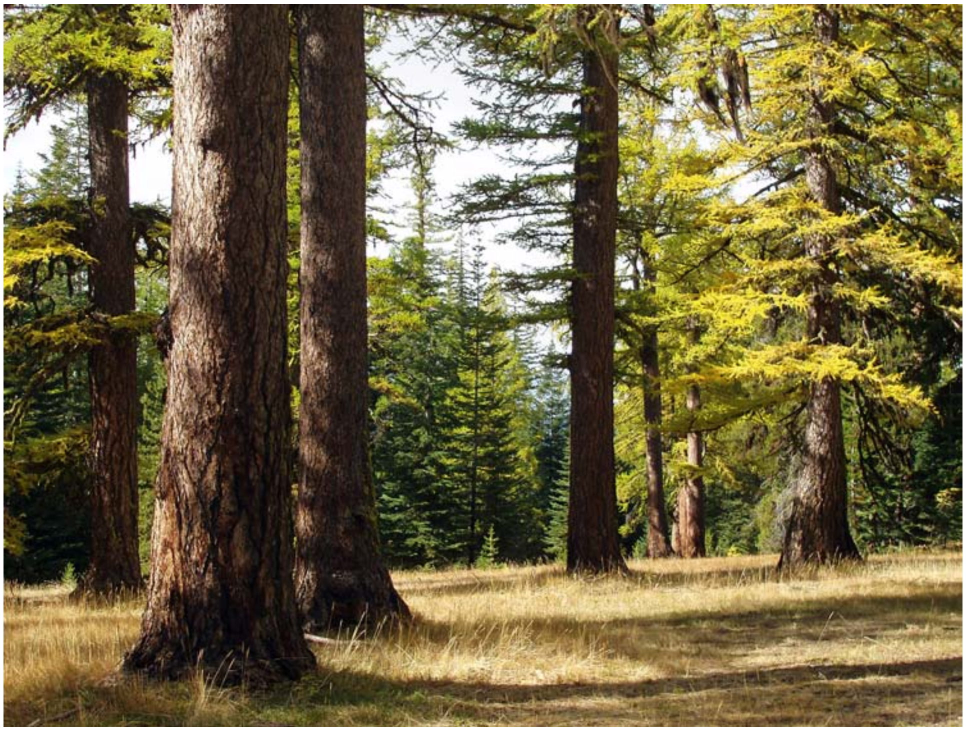


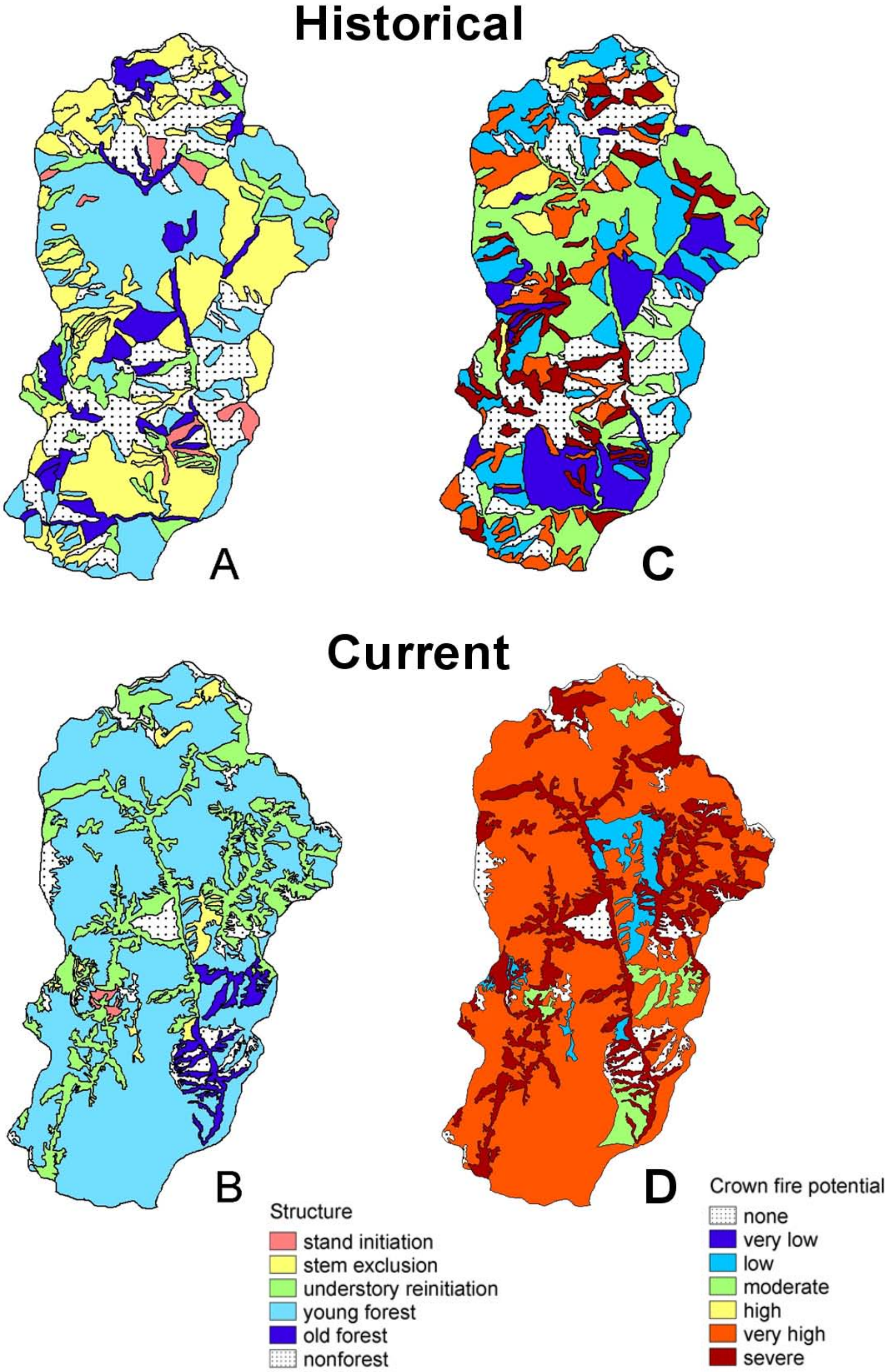
Figure 19. Open stands of old larch are rare, but can be thought of as a snow-adapted version of the open pine forests found at lower elevations (Robert Van Pelt).

Western larch is often an important component of dry eastside forests at higher elevations (Williams and Lillybridge 1983b, Lillybridge et al. 1995b, Williams et al. 1995) including the dry and moist mixed-conifer types. Large, old western larches have thick, fire-resistant bark and frequently survive low- to moderate-intensity wildfires. Under historical conditions, western larch filled an ecological role in dry forests at upper elevations similar to that of ponderosa pine at lower elevations (Figure 19). Because western larch forests occurred at higher elevations, fire regimes were dominantly mixed-severity because fuel loads were higher and fires less frequent. Otherwise, old forests dominated by western larch under historical conditions had structures similar to those found in eastside moist mixed-conifer environments. Moist mixed-conifer forests account for approximately 52,900 acres (21,407 hectares) on DNR-managed forest lands on the eastside.

2.2.3. Changes in forest conditions on dry sites during the last 150 years

The structure and composition of old forests in dry eastside environments changed dramatically following Euro-American settlement in the nineteenth and early twentieth centuries (Harrington and Sackett 1992, Covington and Moore 1994, Hessburg et al. 1999a, Hessburg et al. 2000, Hemstrom et al. 2001, Agee 2003, Hemstrom 2003, Hessburg and Agee 2003, Vavra et al. 2007). Fire suppression, timber harvest, livestock grazing, introduced diseases, and plantation establishment were important influences. These and other factors altered disturbance regimes, forest structure and composition, the mix of stand structures across landscapes, understory regeneration rates, and the mixture of regenerating tree species following disturbances (Figure 20).

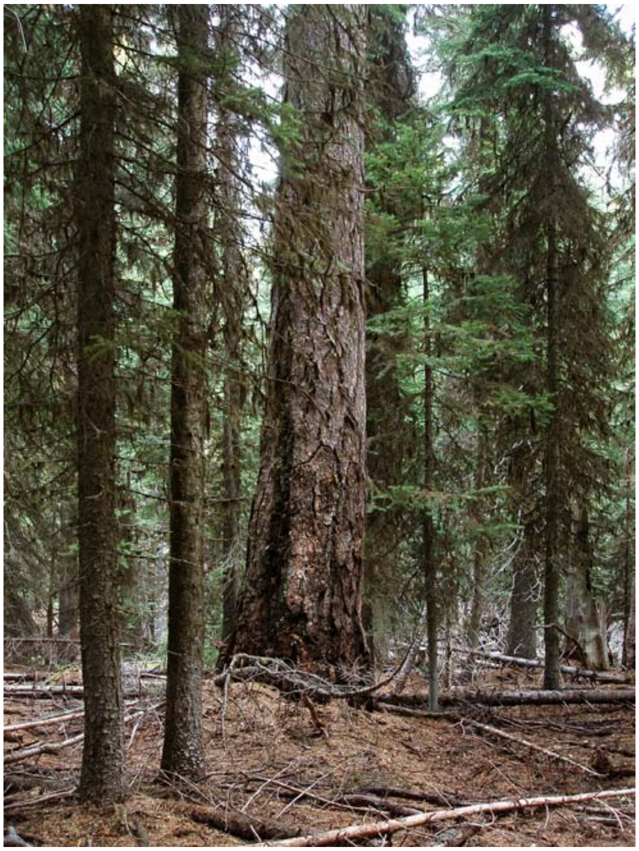
Figure 20. Dramatic changes in forest structure and susceptibility to crown fire have occurred since Euro-American settlement (from Hessburg et al. 2005).



Grazing by native and domestic ungulates can have a variety of effects on vegetation Depending on grazing intensity and season, effects can range from positive to negative for the resources of interest. However, historic overgrazing is thought to have contributed to the dense stands existing today. Overgrazing can produce conditions comparable to a "hot spot" in a wildfire where native understory grasses are completely eliminated. Elimination of the grasses creates a seedbed favorable to establishment of dense tree seedlings, which subsequently persist as a result of fire suppression (White 1985, Covington and Moore 1994, Riggs et al. 2000, Vavra et al. 2007).

Fire suppression obviously affected wildfire frequency and, consequently, fuel levels and subsequent wildfire intensity. Fire suppression reduced wildfire frequency to the extent that nearly all dry-site eastside forests have missed one to many expected wildfire returns since the early twentieth century. Decreased fire frequency allowed tree seedlings to survive and become dense understories of small to medium- sized trees in most stands (Figure 21). In many cases, the developing multi-layered stands consist of a sparse overstory of old ponderosa pine, western larch, or Douglas fir with an increasingly dense understory of grand fir, Douglas fir, or ponderosa pine (Figure 22). Increasing stand density has several implications: 1) wildfires, when they occur, are more intense due to high fuel levels; 2) the dense understory competes for moisture and nutrients with large old overstory trees, which become stressed and increasingly susceptible to insect and disease-related mortality (Kolb et al. 2007); and 3) forest cover and structure across large landscapes have become more homogeneous, leading to the potential for larger and more contiguous wildfires and insect outbreaks (Hessburg et al. 2005).

Figure 21. In the absence of frequent fire, many historically open stands of moist mixed-conifer forest have filled in with shade-tolerant species such as grand fir. Increased fuels put such stands in high-severity fire regimes where wildfire would likely kill most or all trees (Robert Van Pelt).



Early logging activity throughout this region focused on the valuable wood of old ponderosa pine, western larch, and to a lesser extent, Douglas fir. The open nature of many of these stands allowed easy access to individual trees, so selective logging of the best trees was commonplace. As more scientific management of the forests developed, the selection of trees for harvest was typically based on assessments of potential risk of loss to western pine beetle attack. The resulting stands were often allowed to recover without reseeding or planting, frequently resulting in a shift in composition to more shade-tolerant species, such as Douglas fir and grand fir. Not only did these practices increase density and reduce mean diameters at the stand level but they also eliminated the fine-scale structural mosaic present in these pre-settlement landscapes.

Characteristic eastside old forests have become very uncommon as a result of these altered disturbance regimes and other human activities, especially on dry ponderosa pine and dry mixed-conifer sites. Old forests dominated by widely spaced, large ponderosa pine and western larch, which were abundant in most eastside forested landscapes prior to 1850, are now minor or missing landscape components in most places. While estimates vary, old forests seem to have occupied 40 percent to 60 percent or more of the historical landscape (Agee 1993, Covington and Moore 1994, Hann et al. 1997, Agee 2003, Hessburg and Agee 2003, Hemstrom et al. 2007). Many dry forest landscapes contain little or no old forest structure since the large old ponderosa pine and western larch trees have been logged or killed in severe wildfires or by bark beetles over the last 100 years. Most stands that do contain large old ponderosa pine and larch also currently have dense understories; in many cases these dense understories are now codominant in the canopy with the residual old forest trees, putting the remaining large old trees at significant risk of loss to wildfire or insects (Figure 23).

Ponderosa pine and western larch do not regenerate well in closed forests and often require 150 or more years to become large enough to contribute to old forest structure. Unfortunately, these key old forest structures now are easily lost to wildfire or attacks of pests or pathogens due to high stand densities. Many stands that might otherwise have high levels of old forest attributes increasingly lack desired numbers of large old trees.

Figure 22 (above). Post-Euro-American settlement infilling of grand fir (nearly all of the green in this photo), has dramatically changed the character of open old larch stands (leafless in this early spring photo) to dense conditions in which the larches are vulnerable to fire (Jerry Franklin).

This situation highlights a key concept: active management is required to protect or re-establish old forest conditions in dry eastside environments. Mortality of large, old ponderosa pine and western larch as a consequence of changes to disturbance regimes can quickly result in the loss of old forest structure in dry eastside forests. Suitable management can take many forms, including various combinations of stand thinning, prescribed fire, and wildfire for resource use (prescribed natural fire) (Stephens and Moghaddas 2005c). The key ingredients in all management to produce, enhance, or conserve dry eastside old forest are the retention and/or generation of characteristic numbers of large, old ponderosa pine, western

Figure 23 (right). The development of dense understories during the 20th century has added stresses on the residual old ponderosa pine and larch through below-ground competition for water and nutrients, putting the trees at risk to bark beetle attacks (Jerry Franklin).

larch, and (in some cases) Douglas fir and the creation and maintenance of fine-scale patchiness (structural heterogeneity) within stands.

2.2.4. Sustainable future conditions for the dry forest types

Our reference conditions for dry eastside old forests in Washington focus on conditions we believe are sustainable for decades or more under present climatic conditions. Because the same factors that sustained particular old forest composition and structure in the past operate today, our reference conditions resemble those that occurred in the past. Key features of sustainable dry eastside old forests include: 1) several-to-many trees (generally 8 or more per acre or 20 or more per hectare) of large, old ponderosa pine or western larch, 2) dominance of the stand basal area in large, old ponderosa pine or western larch, 3) canopy generally open (usually less than 60 percent and often less than 40 percent canopy cover), 4) large snags and large down dead trees present but not abundant, 5) patches of smaller trees present as a fine-scale mosaic with the dominant old trees, 6) stands large enough to be manageable as individual entities and, as will be seen 7) landscapes that are heterogeneous enough to reduce the potential for large-scale wildfires and insect outbreaks. More detailed considerations for managing old forest attributes are provided in Section 3.

Management Considerations

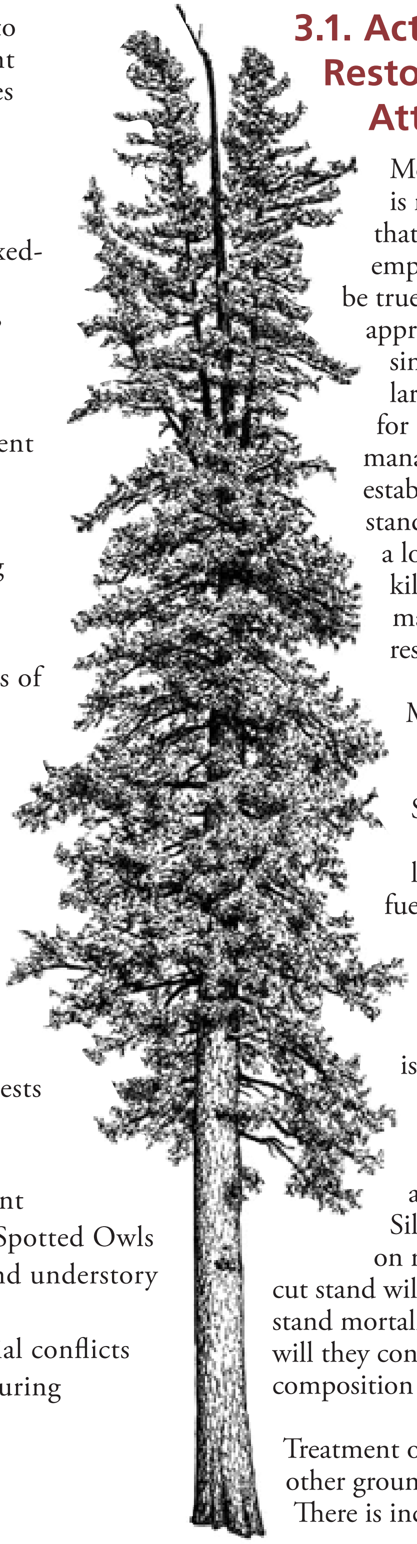
Important Considerations in Managing Dry Eastside Forests and Landscapes for Old Forest Attributes

Management Considerations

There are several important issues to consider in developing management strategies where old forest attributes are a concern on DNR-managed dry forests in eastern Washington. These considerations are relevant to all eastside forest sites that were historically subject to low- and mixed-severity fire regimes, including dry ponderosa pine, dry mixed-conifer, and moist mixed-conifer sites.

Important issues to consider in developing strategies for management of eastside forests include the:

1) Necessity for active management where restoring and maintaining old forest attributes is a goal;
2) Critical role of large old trees of fire tolerant species;
3) Need for planning and implementing activities at the landscape level in order to reduce the potential for large-scale loss of stands to wildfire and insects;
4) Potential effects of climate change, particularly the heightened risk of loss of forests to fire, insects, and storms;
5) Consideration of elements of biodiversity in management activities, such as Northern Spotted Owls (*Strix occidentalis caurina*) and understory communities; and
6) Consideration of the potential conflicts in providing habitat and ensuring sustainability.



3.1. Active Management to Restore and Maintain Old Forest Attributes

Most fundamentally, active management is necessary in all stands on dry forest sites that are to be managed with some level of emphasis on old forest attributes. This will be true whether goals are restoration to a near approximation of historical conditions or simply incorporation of a population of large, old trees in stands otherwise managed for economic and other goals. Active management will be required both to: 1) re-establish sustainable conditions—i.e., to restore stand structures and fuel loadings that have a low probability of fire intensities that will kill the large old trees, and 2) subsequently maintain them in a more fire and insect resistant condition.

Management activities may include either silvicultural (mechanical) manipulations of stands, prescribed fire, or both. Silvicultural activities typically will include: 1) reducing overall stand densities and fuel loadings, particularly of ground and ladder fuels, 2) increasing the mean diameter of trees in stands, and 3) shifting composition toward the more drought- and fire-tolerant species, such as ponderosa pine and western larch. Prescribed fire is potentially important as a part of fuel treatments as well as in achieving various other ecological objectives associated with fire, such as creation of seedbeds and restoring understory conditions. Silvicultural activities that focus primarily on removing dominant trees from a partially cut stand will not reduce potential fire intensities and stand mortality (Stephens and Moghaddas 2005), nor will they contribute to creation of forest structure and composition characteristic of drier eastside older forest.

Treatment of smaller non-commercial trees, slash, and other ground fuels will be necessary on most sites. There is increasing scientific evidence (Ager et al.

2007b) that thinning stands without dealing with the ground fuels that are generated by the thinning activity can increase the intensity of subsequent wildfires in the short-term. Prescribed fire is one technique for dealing with slash, small residual trees, and other ground fuels. Prescribed fire may take the form of broadcast burning or burning fuel concentrations, such as slash piles. Mechanical forms of fuel treatment, such as mastication, may be an alternative where fire cannot be used. Treatments should be designed to reduce fuels, retain old forest attributes, and generate a characteristically heterogeneous stand-scale patch mosaic rather than focusing only on fuel reduction. Exceptions to the principle of integrated approaches will occur only where one management goal is of overriding importance, such as is sometimes the case when treating fuels in the wildland-urban interface.

Figure 24. Old ponderosa pines are characterized by thick, colorful bark, large branches, open and often complex crowns, and several decadence features important to wildlife – hollows, rot cavities, and dead branches (Jerry Franklin).

3.2. Structural Attributes of Dry Older Forests, including Large Old Trees

3.2.1. Large and old trees

Old trees are the most critical structural attribute of eastside older forests, playing unique functional and habitat roles. Old trees have distinctive attributes related to crown structure, bark thickness and color, heartwood content, and decadence (wounds, rots, brooms, etc.). Depending upon site productivity some of these attributes may begin appearing at around 150 years of age but are usually well developed by 200 years (Figure 24). Old trees also generate other key old forest structures — large snags and downed logs — when they die (Figure 25). Old ponderosa pine, western larch, and Douglas fir

Figure 25. Large standing dead trees (snags) are characteristic of old forests and are important elements for many wildlife species (Miles Hemstrom).

Figure 26. Many forests in eastern Washington have lost their old forest components through selective logging, which in many areas has also served to homogenize large areas (Jerry Franklin).

are also the trees that are most likely to survive wildfire and play important roles in post-fire recovery processes (Covington et al. 1997, Allen et al. 2002). For the purposes of this report, old trees are considered to be those that originated prior to 1850.

Old-growth trees exist in much reduced densities or are completely absent in current dry eastside forests and forest landscapes as a result of past logging activities (Figure 26). Large old trees were the exclusive focus of early, selective logging. Of course, large old trees were eliminated entirely from managed stands where clearcutting and even-aged management were utilized, except where explicitly protected from harvest.

Managing eastside forests where old forest attributes are a management objective requires creating, maintaining, or expanding a population of old trees. The most logical candidates for old forest management are, at least in the short term, stands that still have a component of large and/or old trees. A few recommendations describe tree size class distributions that might be used in moving dry mixed-conifer forests toward historic or sustainable conditions (Fule et al. 1997, Harrod et al. 1999, Huffman et al. 2001, Allen et al. 2002, Johnson et al. 2007, Kolb et al. 2007).

Identification and retention of old trees where they exist is a reasonable first step in maintaining old forest structure and functionality in eastside forests where this is a management objective. Stand inventory data, where data exist, can be screened to help identify general areas that might contain existing old forest conditions in eastside DNR-managed forests (Franklin et al. 2007). Since the inventory is a sample and was not designed to detect individual old trees on every acre, current inventory data will not provide information on the locations of all important areas of old trees on eastside DNR-managed lands. Hence, managers working in the eastside forests will have to assess some sites for old trees during routine on-the-ground examinations to get a more accurate inventory. A guide to identification of old forest attributes in DNR-managed eastside forests has been developed to assist managers in this task (Van Pelt 2008).

Dry eastside sites with the highest numbers of large, old trees are the best candidates for management to restore sustainable conditions. Managers intending to create sustainable old forest conditions should consider not only the conservation of existing large, old trees but also the need to provide for a flow of mature trees that can provide replacements for the old trees as they die.

3.2.2. Structural patchiness of dry eastside forests

Forests on dry sites in eastern Washington commonly consisted of a complex mosaic of patches, ranging from patches of dense reproduction to open groves of old trees (Figure 27). Management activities, such as fire suppression and logging, commonly have moved these stands toward homogeneous conditions consisting of higher density, smaller trees, and few old trees across large landscapes (Everett et al. 1994, Hann et al. 1997, Hessburg et al. 1999a, Hessburg et al. 2000). Restorative management activities should be designed to move stands back toward historical spatial patterns at both landscape and fine-scales.

3.3. Planning and Implementing Activities at the Landscape Level

Dry forest landscapes have undergone dramatic changes in the last century as a result of human activities, including fire suppression; changes that are comparable in intensity and importance to those that have occurred within the dry forest stands themselves (Everett et al. 1994, Hann et al. 1997, Hessburg et al. 2005, Hessburg et al. 2007). Historically, the majority of dry forest watersheds consisted of mosaics of open and dense forest, shrublands and grasslands. As a result of fire suppression, logging, and other human activities, many of these drainages are now dominated by a more nearly continuous cover of dense forest.

These landscape-level changes in vegetative cover have had large and undesirable impacts on both ecological function and vulnerability to large disturbance events. With regards to ecological function, the historic mosaic of contrasting conditions provided habitat for a large variety of biota. Much of this diversity of stand conditions has now been lost (Hann et al. 1997, Hessburg et al. 1999b, Hessburg et al. 2000, Hessburg et al. 2005) (Figure 28). In addition, the shrublands and grasslands and the stands of quaking aspen and other hardwoods associated

Figure 27. Gaps, regeneration patches, areas with dense trees, as well as open groves of big trees all contribute to the horizontal variability present in an old pine forest (Jerry Franklin).

Figure 28. Many mountain landscapes are a mixture of valleys, riparian areas, knolls, rock outcrops, and forested slopes that once supported a great diversity of forest types. Land use changes since Euro-American settlement have greatly simplified forest complexity (Miles Hemstrom).

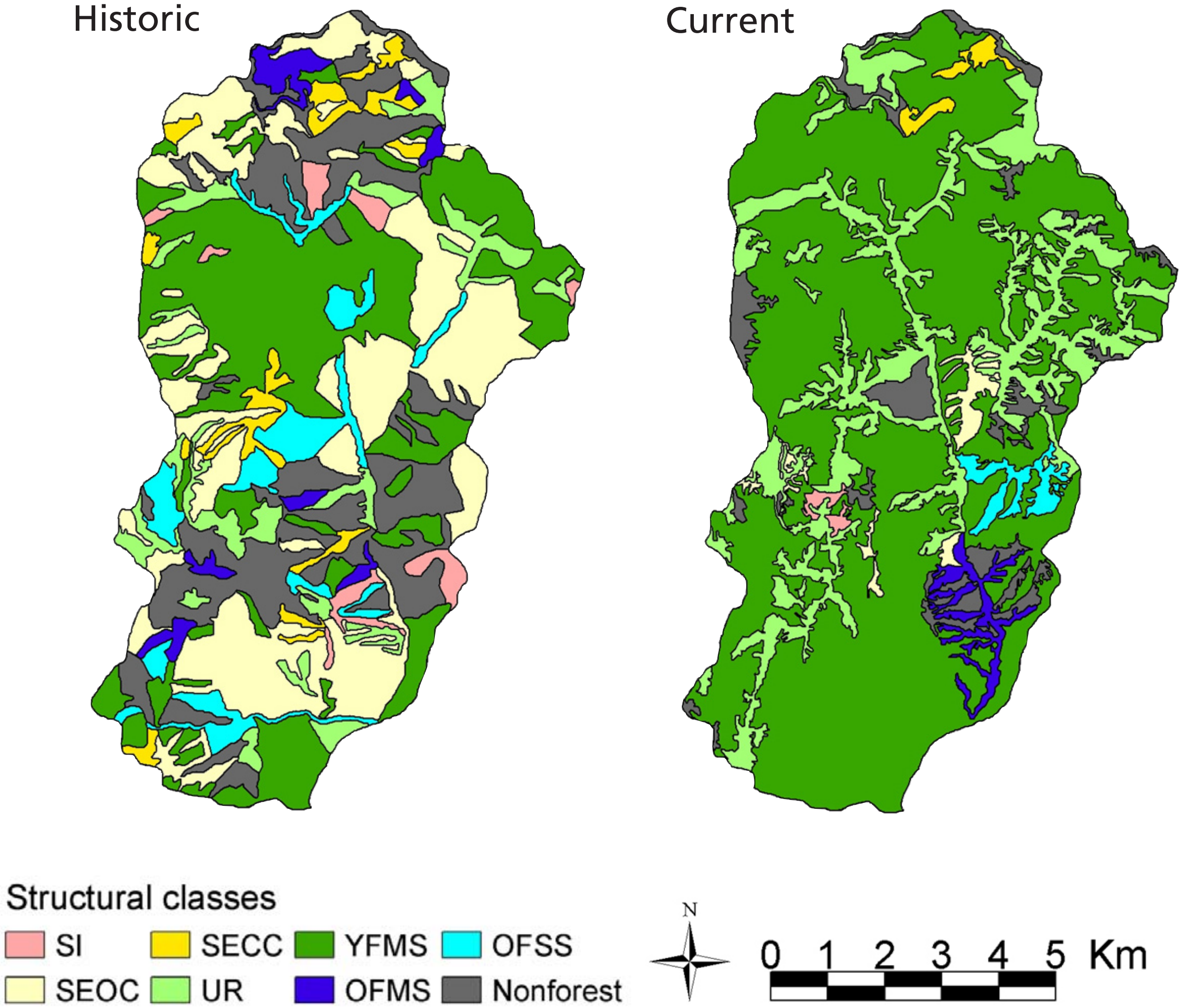


Figure 29. Forest patch sizes at the landscape level have greatly increased in size since Euro-American settlement, homogenizing and simplifying whole drainages. The first two letters of the codes indicate stand development stage, the second two indicate canopy condition: SI – stand initiation; SEOC – stem exclusion, open canopy; UR – understory reinitiation; YFMS – young forest, multi-storied; OFSS- old forest, single storied and OFMS – old forest, multi-storied (from Hessburg et al. 2005).

with riparian habitat have undergone significant loss or degradation; these vegetation types provided important landscape-level diversity in habitat and biota and their restoration is therefore important to create a more functional landscape.

In spite of highly variable environments, vegetation types, and topography, dry eastside landscapes have become dominated by dense, largely continuous forest that has profoundly increased forest vulnerability to wildfire and insect outbreaks compared to historical conditions (Hessburg et al. 2005) (Figure 29). In many cases, these disturbance agents now have access to largely unbroken closed canopy forests extending from ridge-top to ridge-top. When wildfires occur, they now encounter few or no natural fuel breaks; effectively, large wildfires and insect outbreaks can move across landscapes in ways that were uncommon in the past (Figure 30).

In such landscapes, restorative management has to be planned and implemented at the landscape level to be most effective. Since entire large landscapes cannot reasonably be treated in short periods, stand treatments should be designed with overall landscape objectives in mind. This means that individual treatments to

Figure 30. The loss of many natural fuel breaks such as open stand conditions allow wildfires to be larger and more severe than in the past (Miles Hemstrom).

reduce fuels, for example, should consider landscape locations and orientations to achieve the highest level of benefit for areas treated. While this is not a new concept, the need to develop coordinated plans to manage for old forest and other ecological characteristics is particularly important in dry forest environments. Treating fuels in a small stand that contains old forest conditions may be relatively ineffective if that stand is embedded in a large landscape of contiguous, dense fuels. In addition, landscape treatment patterns to slow fire spread may or may not slow insect spread. It seems likely that not every hazard can be minimized or reduced at the same time because they operate differently.

Advantages of landscape level planning include opportunities to: 1) conduct strategic planning related to large-scale fire behavior, such as appropriate location and implementation of fuel breaks (Agee and Skinner 2005, Ager et al. 2007a); 2) identify and strategically place areas of management emphasis, (e.g. forest products, Northern Spotted Owl habitat, etc.); 3) conduct risk assessments and appropriately prioritize areas for treatment; and 4) provide a financial balance between areas/treatments having contrasting costs/returns (Johnson et al. 2007).

Since disturbance events, such as wildfire and insect outbreaks, do not respect ownership boundaries, landscape-level planning in coordination with adjacent landowners is also important. Differences among landowners in their management objectives can make such collaborations challenging however. Nonetheless, uncertainty about management on other ownerships can be evaluated in a model environment, and subsequent model output may help inform management decisions in the face of uncertainty.

3.4. Potential Effects of Climate Change on Forest Sustainability

The Pacific Northwest is highly vulnerable to projected changes in climate (Franklin et al. 1991; Keeton et al. 2007; Keeton et al., in press). The region has a temperate maritime to continental climate with highly seasonal precipitation and relatively warm and dry summers. Consequently, summer moisture deficits are very influential in the distribution and productivity of forests in the Pacific Northwest. ***Any climatic change that intensifies the summer dry period will have significant impacts by either lengthening the summer dry period or by intensifying it, such as by increased temperatures without compensating increases in precipitation.***

In fact, winter snow packs may decline and the duration and severity of the summer-dry period may increase based on projections of existing climatic models (Bachelet et al. 2001, Mote et al. 2003, McKenzie et al. 2004). Eastside forests are particularly dependent on winter snow pack, which is predicted to disappear earlier in the spring and return later in the fall. Consequently, climate change is expected to have significant direct and indirect effects on forest health in eastern Washington (Mote et al. 2003, Keeton et

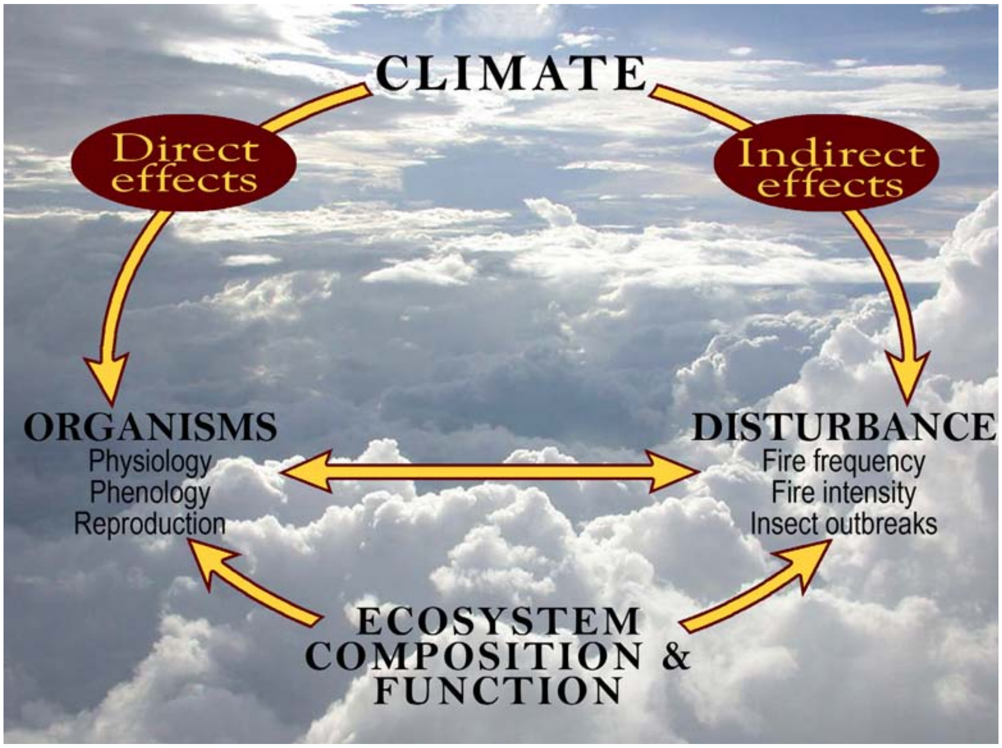


Figure 31. Climate change can have both direct and indirect effects on forested ecosystems (modified from Franklin et al. 1991).

al. 2007, Keeton et al. in press) (Figure 31). Direct effects include the impacts of increased temperatures and summer moisture deficits on the physiology and ecology of organisms, including trees and forest pests (insects and diseases). Elevational distributions of species and forest communities are likely to shift in response to these changes and there may be significant reductions in the total area of forestland in eastern Washington and Oregon (Figure 32). In some cases, increased moisture stress in living trees will result in decreased vigor and increased vulnerability to insects or diseases. Such problems will be greatest on the driest sites as well as in densely-stocked stands. There may also be direct effects on the physiology and reproductive capacity of the pest organisms, resulting in altered host-pest interactions, some of which may be without precedent.

Increased summer drought may generate lengthened fire seasons and larger and more severe wildfires. A statistical relationship between climatic warming, lengthened snow-free seasons, and the frequency and size of wildfires has already been established for some parts of western North America (Westerling et al. 2006). This issue is probably greater in forests belonging to the mixed-conifer than to the ponderosa pine plant associations, because the greater productivity of the mixed-conifer forests results in both higher fuel levels and fuel structures that encourage stand-replacement fires (e.g., extensive ladder fuels) (Figure 20).

A couple of examples illustrate potential effects when insect activity changes as a result of climate shift. In interior British Columbia and adjacent Alberta, an immense outbreak (perhaps eventually to reach 25 to

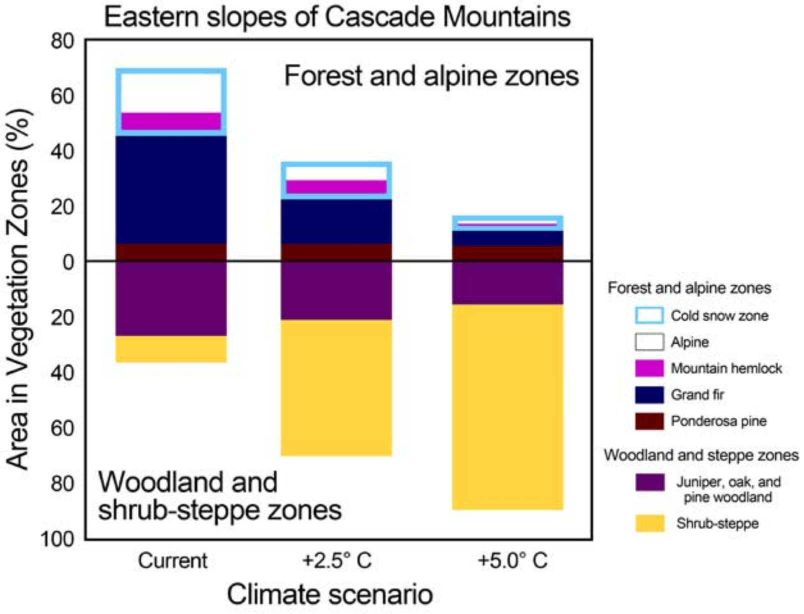


Figure 32. Major shifts in the areas occupied by vegetation zones are predicted for eastern Washington (modified from Franklin et al. 1991).

Pathogen/Tree Relationships and Climate Change

A competitive relationship between conifer trees and the pathogenic organisms, such as insects and fungi which eat them, has existed and co-evolved for millennia. Because eastside forests tend to be water limited and because the growth and reproduction rates of insects and fungi are directly influenced by moisture and temperature, this relationship is strongly influenced by weather and climate. Therefore, circumstances that influence the timing and magnitude of water availability and temperature may cause great changes in host-pathogen relationships from what is currently observed or has been inferred from the past. Three examples follow:

Pine trees rely on pitch to protect them from invasion by bark beetles (primarily *Dendroctonus* and *Ips* species). Trees require a great deal of water to manufacture pitch and keep it stored under pressure in resin canals beneath the bark. Bark beetles tunnel into the bark to feed and manufacture attractant chemicals that will signal more beetles to join the attack. If they intersect a pitch canal, the beetles can be killed and expelled by the components and force of the pitch, which also seals the wound. To avoid lethal volumes and surges of pitch, tree-killing pine bark beetles tend to attack their host trees during the time of year and time of day when the trees are most water stressed and least able to defend themselves with pitch. There is some evidence that extremely hot summer days can cause extreme stress to pine trees and contribute to exceptional amounts of tree mortality caused by bark beetles.

Tiny western spruce budworm (*Choristoneura occidentalis*) caterpillars emerge from overwintering shelters in early spring, seeking expanding tree buds to excavate and feed within. In cool weather conditions, the caterpillars may be ahead of the buds and, unable to chew into tightly closed buds, have to feed on less nutritious old needles until the buds swell and loosen sufficiently to allow penetration. Warm spring weather that makes the bud swelling coincide with caterpillar emergence provides ideal conditions for caterpillar survival and growth. If warm spring weather becomes more common, then improved vigor, survival and damage caused by western spruce budworm should be anticipated.

In contrast, many fungal organisms can benefit from cool, humid spring weather. High humidity contributes to increased survival of delicate spores and can also extend the time that new leaf tissues are succulent and vulnerable to penetration. Several conifer foliage diseases including *Lophodermella* spp. and *Elytroderma deformans* (which affect pines) and *Hypodermella laricis* and *Meria laricis* (which affect larch) benefit from humid spring weather. *Chronartium ribicola*, the organism which causes white pine blister rust also benefits from humid conditions. If stand or weather conditions change to cause more frequent or lengthy spring humidity then more foliage diseases could be expected.

Although some simple cause-effect relationships are assumed to be well-understood and predictable, the complexity of biological systems, our lack of detailed knowledge of the host/pathogen relationship, and the magnitude, diversity, and volatility associated with climate change may contribute to great unpredictability. The pathogens will probably be acting within what's already understood to be the range of their potential responses to stimuli. The damage that may be observed under a different climate regime will relate to the combination of host stresses, pathogen population dynamics, and changing environmental barriers. Ultimately, there will probably be "winners" and "losers" across the landscape and range of specific host trees, insects, and pathogens. For example: although the range of winter moth *Operophtera brumata*, a defoliating caterpillar, has increased in Norway's birch forests (bad); in England, eggs of the winter moth are hatching before leaves are available to eat so the caterpillars can't survive (good).

Even though we can't predict the exact outcomes of changing weather and climate, there are already high levels of certain stressors occurring as a result of changed disturbance regimes since 1850. Employing management techniques which restore appropriate stocking levels, species composition, stand architecture, and landscape diversity to levels more consistent with the conditions under which the host trees and insect/pathogen species co-evolved can improve forest resilience and resistance to current insects/pathogens and weather stresses. Restoration of insect-resistant stocking levels is a reasonable strategy to initiate preparation for what might be more significant climate stresses yet to come, and might forestall extreme or unprecedented effects that future environmental stress due to climate change could cause.

Information on host-pathogen interactions in relation to climate change was provided by Karen Ripley, DNR's forest entomologist.

Dendroctonus beetle & larvae

30 million acres (10 or 12 million hectares) of the mountain pine beetle is killing lodgepole pine stands as a consequence of warming winter temperatures. Warmer winters allow much larger broods of beetles to survive and emerge in the spring (Carroll et al. 2003). This is an example of the direct effect of climate in altering reproductive patterns of an existing native pest in landscapes dominated by a monoculture of a host species.

Piñon pine (*Pinus edulis*) populations are experiencing massive mortality throughout the Colorado Plateau region as the result of the direct effects of climate change (Mueller et al. 2005, Shaw 2006). In this case, a regional drought, which has been greatly intensified by elevated temperatures, has physiologically stressed the piñon pine. Pine bark beetle populations have responded to the stressed condition of the pine by killing the majority of the mature and old trees throughout the Colorado Plateau. Though such changes have been envisioned for some time (e.g., Franklin et al. 1991), an emerging issue is massive mortality of tree species throughout large portions of their ranges. In effect, we cannot assume that existing, endemic insects will continue to behave as they have in the past in any given location. Rather, we can reasonably expect changing patterns in insect behavior under altered climates.

We can conclude that climate change is likely to increase the challenges of sustainable forest management in eastern Washington, including issues associated with wildfire and forest pests. The extent of the dry forests is likely to increase as the regional climate warms and dries and snow pack declines. ***Fortunately, logical management responses to climate change – such as reducing stand densities and fuels, treating landscapes, and shifting to more drought-tolerant species – are consistent with management responses to other important issues, including forest health, wildfire control, older forest attributes, and protection of habitat for Northern Spotted Owls.*** Active management seems imperative to bring stands and landscapes into sustainable conditions. Management plans must consider the heightened intensity of summer drought as a result of climate change, perhaps going further in reducing stocking levels and landscape continuity than would otherwise be the case.

3.5. Biodiversity and Wildlife Habitat Considerations

Biodiversity considerations are important elements in development of management strategies for DNR's eastside forests, including older forests. Specific considerations relevant to restoration and maintenance of older forest attributes include the Northern Spotted Owl and other species dependent upon old trees and structurally complex forests and understory community composition and structure (see Appendix B). Information on aspects of the quality, distribution and likely use of habitat is an essential component of a comprehensive approach to manage landscapes to address a range of ecological and economic issues. Examples of forest habitat attributes, some of the bird and mammal species associated with them, and additional issues relating to biodiversity are briefly discussed in the sections below.

3.5.1. Wildlife associated with dry forests

Hundreds of vertebrate species are found in the forests east of the Cascade crest in Washington (Johnson and O'Neil 2001). Some of these species are generalists and occur in a wide range of forest associations or successional stages. Others, like the Lynx (*Lynx canadensis*) and Northern Spotted Owl, are more specialized in their use of forest types (Figure 33). This wide range of species and habitat associations (Sallabanks et al. 2001) reflects the breadth of forest types, successional stages, and disturbance histories represented in the region (O'Neil et al. 2001).

Although many vertebrate species are found in ponderosa pine forests a number of them are closely associated with the open mature or old ponderosa pine forest (sometimes including a Douglas fir or western larch component) in eastern Washington (Figure 35). These forests provide habitat for such species as: long-legged myotis (*Myotis volans*) (Baker and Lacki 2006), western gray squirrel (*Sciurus griseus*) (Linders and Stinson 2006), and several birds, including Flammulated Owl (*Otus flammeolus*), Lewis' Woodpecker (*Melanerpes lewis*), White-headed Woodpecker (*Picoides albolarvatus*) (Figure 35), White-breasted Nuthatch (*Sitta carolinensis*), Pygmy Nuthatch (*Sitta pygmaea*) (Figure 34), one call-type of Red Crossbill (*Loxia curvirostra*), and low-elevation populations of Clark's Nutcracker (*Nucifraga columbiana*) (Wahl et al. 2005).

Other species are associated with mixed-conifer forests with high levels of canopy closure. Prominent examples include northern flying squirrel (*Glaucomys sabrinus*) (Lehmkuhl et al. 2004, 2006), Northern Goshawk (*Accipiter gentilis*) (Desimone and Hays 2004) and Northern Spotted Owl (Buchanan et al. 1995). The number of vertebrate species found in mixed-conifer forests is quite similar to that in ponderosa pine forests and much greater than in lodgepole pine forests (Sallabanks et al. 2001).

From an ecological perspective one of the primary consequences of forest management, whether active or passive, is the manner in which forests are used by wildlife. The wildlife species found in the eastern Cascades exhibit a wide range of responses to varying conditions at multiple spatial scales: stand, aggregates of stands, and landscapes. These conditions reflect differences in forest type, site quality, seral stage, disturbance history, patch size and configuration, and landscape context. Because of the complexity of wildlife species associations with forests in the region we briefly summarized some conceptual information on habitat and its use by wildlife. Descriptions of a selection of species habitat relationships are presented in Appendix B.

Habitat can be defined as the "physical environmental

Figure 33. Northern Spotted Owls are closely associated with old, mature and relatively young forests characterized by complex structure and a generally closed canopy. Mistletoe is present in many nesting areas in the eastern Cascade Mountains and about one-half of the known nests in dry forests were built by Northern Goshawks. Spotted owl populations are continuing to decline (Denny Granstrand).

Figure 34. Pygmy Nuthatches are strongly associated with open-grown ponderosa pine forests where they forage on insects and seeds and nest in snags or trees. They are year-round residents and roost communally in cavities in all seasons. This roosting behavior allows them to withstand harsh winter conditions and likely explains their use of cavity trees and snags of moderate and large size (George Vlahakis).

Figure 35. White-headed Woodpeckers excavate their nests primarily in ponderosa pine trees (shown here) or snags of virtually all sizes. They are closely associated with older ponderosa pine forests and are uncommon in eastside forests. These year-round residents forage in typical woodpecker fashion during the nesting season, and in winter shift to a diet of pine seeds (George Vlahakis).

factors that a species requires for its survival and reproduction" (Block and Brennan 1993). Some habitat attributes have multiple important functions for wildlife species. For example, snags may serve as foraging, roosting and nesting substrates for woodpeckers. Habitat attributes can be described or measured at multiple spatial scales (Morrison 2001). For the purposes of this discussion, we consider habitat attributes that are measured or described at patch- and landscape-levels while recognizing that these scales are species-specific. Some species, particularly those with larger home ranges, require the presence of certain habitat attributes at both spatial scales. Features such as patch size and shape are described in the section on landscape attributes.

3.5.1.1. PATCH-LEVEL HABITAT ATTRIBUTES

The general descriptors of patch-level attributes we describe include tree size, understory structure, edges and openings, canopy closure, snags and downed wood. Although we did not summarize the number of species associated with each attribute, the presence of 233 wildlife species in eastside forests was positively correlated with closed canopies, 77 species with snags and 68 species with downed wood (Sallabanks et al. 2001). Examples of patch-scale habitat attributes are summarized in Table 3.

3.5.1.2. LANDSCAPE-LEVEL HABITAT ATTRIBUTES

Landscape features important to wildlife can be generalized to one of the following three categories: patch size, habitat quantity, and spatial arrangement of patches. For the purposes of this discussion, a patch is defined as an area of vegetation that is suitable to an individual or group of wildlife species. The existence of a patch implies that areas outside the patch are non-habitat or are of differing quality. The concepts of patch size and habitat quantity are different in some respects but are not mutually exclusive.

Patch size and shape are important for many wildlife species because these attributes may determine whether sufficient resources are present to support individuals or breeding pairs. Interactions within populations or communities can be influenced by the size of the patch. For example, a songbird's odds of attracting a mate may be greatly improved in a patch large enough to support multiple territories or individuals compared to a patch that is only large enough for a single territory (e.g., Stamps 1988). Patch size and shape influence the amount of area classified as "edge". Edge areas (e.g., boundaries between forest types or successional stages) tend to have different attributes than patch interiors that may affect habitat quality. Small patches have greater edge to interior ratios. Patch shape (while holding size constant) can also affect this ratio. Circles have the highest ratio of interior to edge area – all other patch shapes have lower ratios. Edge effects in closed canopy forests adjacent to openings, for example, include greater development of understory vegetation and microclimatic conditions that differ from those within the interior of the patch (Chen et al. 1992).

Table 3. Examples of patch-level habitat attributes found in eastside forests, and their importance to wildlife. Information on habitat relationships was taken from summaries presented by Irwin et al. (1991), Altman (2000) and Johnson and O'Neil (2001). Edges and openings are described here because they can occur within or otherwise characterize small forest patches in the eastern Cascades.

Attribute	Description of Function
Tree Size	Older and larger-diameter trees of many species have deep bark fissures that substantially increase the bole surface area available to invertebrate prey of bark foragers like the Brown Creeper. Larger, and particularly older, trees often produce greater quantities of seed than younger and smaller trees; these seed crops are important to a number of species including Douglas-squirrel, western gray squirrel, White-headed Woodpecker and Red Crossbill. Large trees typically have larger branches capable of supporting large and bulky stick nests above (various raptors including Golden Eagle, Red-tailed Hawk) and below (Northern Goshawk) the canopy. Large trees often have deep canopies that provide more foraging area for bark and foliage gleaners.
Understory Structure	Depending on the setting, patches of open forest support more productive conditions for ground foraging species such as Chipping Sparrow. Shrub-nesting birds such as Hermit Thrush are associated with high volume of understory shrubs in mixed conifer forest. Moderate tree densities in mixed conifer forests allow open flight space for Northern Spotted Owls and other species; densely spaced trees may limit movement through the patch by some species.
Edges and Openings	Edges are used by a number of habitat generalist species in a manner that allows them to utilize features of the diverse types of cover available. Olive-sided Flycatchers forage over open areas (recent clearcuts and fires) and perch and nest in edge areas. Flammulated Owls typically nest in open ponderosa pine forests that contain small areas of dense foliage that provides cover from predators.
Canopy Closure	Closed-canopy forests are thought to provide protection of nests or individuals (e.g. Northern Spotted Owl) from certain aerial predators. Microclimate is influenced by canopy closure, with closed canopy stands retaining more moisture, which may translate to greater truffle abundance (an important food source for northern flying squirrels). Open canopy structure, particularly if the understory is open, provides habitat for ground-foraging species like Chipping Sparrow.
Snags	Depending on size and decay class, snags provide nesting, foraging and roosting or den sites for cavity excavators and secondary users. Excavators include numerous species of woodpeckers, and secondary users include Flammulated Owl, Chestnut-backed Chickadee and Red-breasted Nuthatch. Brown Creepers and bats use areas under large pieces of intact but exfoliating bark. Vaux's Swifts use snags and live trees with large vertical openings at the top as nest sites. Small snags are generally suitable for nesting by smaller-bodied species, whereas larger species often are associated with larger-diameter snags; large snags generally decay more slowly and are more persistent than small snags.
Downed Wood	Small mammals and amphibians find cover and reproductive sites adjacent to downed wood. Pileated Woodpeckers are attracted to aggregations of carpenter ants in downed wood. Downed logs are used as plucking posts by Accipiters and as foraging and den sites by mustelids.
Tree Species Composition	Although relationships between wildlife species and specific tree species are not well understood, a number of species exhibit pronounced patterns of association. For example, White-headed Woodpecker, Flammulated Owl and Pygmy Nuthatch are strongly associated with ponderosa pine, Northern Spotted Owl and Northern Goshawk are strongly associated with Douglas fir and grand fir forests, and lynx are associated with lodgepole pine forests. Some of these relationships are explained by some attribute of the tree species or forest type in question (e.g. White-headed Woodpecker forages on seed from ponderosa pines).
Mistletoe	Clusters of branches infected by mistletoe provide den and nesting substrate for northern flying squirrels, Northern Goshawks, Northern Spotted Owls and other species.

In addition to the specific elements or attributes that make a certain geographic location suitable for a species, each species has a general threshold at which the amounts of those attributes are sufficient to support individuals or breeding pairs. The amount of habitat necessary to support individuals or pairs varies according to a variety of factors including habitat quality. Habitat quality can be related to the amount or characteristics of the specific attribute(s). In general, theory and empirical studies suggest that home ranges composed of high-quality habitat are smaller than those composed of low-quality habitat; the individual (or pair) in a "higher-quality" home range can occupy a comparatively smaller area because resources are more plentiful. It has been demonstrated that animals will use high-quality habitats in preference to habitats of lower quality (Fretwell and Lucas 1969). Low-quality habitats that have poor or limited resources in some or all years may be population "sinks" or areas in which populations cannot sustain themselves without a continuing influx of individuals from higher quality or "source" populations.

Species with large home ranges or that have the ability to move among patches may meet their life requisites by using multiple patches within or among seasons. Species have spatial requirements for habitat and when these habitat thresholds are not met (due to insufficient amount or quality) the species could experience a number of outcomes involving pair disruption and reproductive failure, conditions symptomatic of a population sink. A more extreme situation occurs when an area is not able to support even a non-reproductive individual. In such cases, although the patch is of sufficient quality, it is too small or too isolated.

For species with small home ranges, seasonal or annual life requisites may be provided largely or entirely within the patch, although the spatial distribution of patches across the landscape may greatly influence both habitat use and population dynamics. For example, localized extirpation of a population will result in the patch being unoccupied until it is recolonized. The rate of colonization is generally a function of patch size, distance of the patch from source populations, and the colonizing ability of the species. Models suggest that even patches associated with local extirpations can be important components of habitat because they can increase the likelihood of persistence of the overall population. Thus unoccupied patches may have continued value as habitat if they are used by floaters (non-territorial individuals) or are incorporated into existing home ranges.

The concept of threshold amounts of habitat has application in the spatial distribution of patches. In particular, where patches are overly dispersed or uncommon they may go unused. Even species with large home ranges may not be able to use some patches. A prime reason for this pattern is related to energetic constraints. The caloric return associated with ranging over a large area must equal the energy expenditure required to fuel the search effort. Breeding individuals must have greater return than expenditure (to provision a non-hunting mate and young) and this constraint is further magnified by the requirement that all prey procurement must occur in proximity to a seasonally fixed location (the breeding site). Disproportionate expenditure relative to caloric intake results in reproductive failure, area abandonment, or colonization failure.

3.5.2. Understory plant communities in old forests

Understory communities require attention in efforts to restore old forest function and structure. Although the tendency is to focus on tree composition and structure, understory communities have been as dramatically impacted as the overstory communities by 150 years of western civilization. Overgrazing by domestic livestock, logging, establishment of plantations, fire suppression, and introductions of invasive plant species are the primary activities that have altered forest understory communities. The richest understory communities in terms of plant species were historically in riparian zones and these are the most altered as the result of livestock overgrazing—overgrazing has also made the riparian habitats major locales for invasive species.

Understory community composition and structure play many important roles in the ecological functioning of dry eastside forests. Of course, the majority of the plant species diversity is found in the understory and this diversity itself is a management concern. Understory plant species play significant roles in providing habitat, sustaining forest food webs, and nutrient cycling. Some understory plant species, such as bitterbrush, are key browse species for wildlife, including important game species. Re-establishing native understory plant communities will contribute significantly to reducing opportunities for invasion and spread of noxious alien plant species.

Understory communities also play critical roles in dry forest ecosystems as ground fuels. Quantity, quality, and structure of ground fuels increasingly are recognized as critical variables in both wildfires and prescribed burning. The density, composition, and structure of the understory are important contributors to these ground fuels and those contributions can either be positive (e.g., in providing the fuels needed to carry prescribed fire) or negative (e.g., in fueling flame lengths that can kill trees even in absence of ladder fuels).

3.6. Fire Suppression, Landscape Management and Northern Spotted Owls

The area of forest suitable for habitation by Northern Spotted Owls has probably increased due to the effects of fire suppression over the last century (Agee 1993, Camp 1999); fire refugia appear to have provided habitat for Northern Spotted Owls prior to that time (Camp et al. 1997). Whether or not more Northern Spotted Owl habitat existed in the past, managing to conserve and provide habitat for the Northern Spotted Owl is an objective on some DNR-managed lands. While changes in the amount of habitat have been quantified in specific locations (e.g., relatively small study areas) the collective regional extent of additional suitable owl habitat has not been determined. As of December 2007, there were 345 known site centers of territorial Northern Spotted Owls in the eastern Cascade mountains, representing 32 percent of the known territorial sites in Washington (data source: Washington Department of Fish and Wildlife). These sites are distributed from the Cascade crest nearly to the eastern edge of the forest and range in elevation from 1,161 to 5,032 feet (354 to 1,534 meters). Many of these owl activity centers are located in dry-site forests (data source: Washington Department of Fish and Wildlife).

Implementation of both the Northwest Forest Plan on federal lands and the *Department of Natural Resources' Habitat Conservation Plan on forested state trust lands within the range of the Northern Spotted Owl* (USDA Forest Service and USDI Bureau of Land Management 1994, Washington State Department of Natural Resources 1997) is contingent on managing Northern Spotted Owl habitat at a landscape scale. However, managing habitat for Northern Spotted Owls in the more xeric portions of the eastern Cascade Mountains is a challenge, since it involves maintaining owl habitat targets in a landscape with significant fire and forest health risks.

A passive management approach to maintaining habitat for Northern Spotted Owls in eastside forests—for example, setting aside habitat but limiting management to fire suppression efforts—is very likely to fail because of the high probability that stand-replacement fires will impact or eliminate suitable owl habitat (Courtney et al. 2008). While the spatial or temporal aspects of habitat loss can't be predicted with high certainty, the likelihood that such changes will occur is high; moreover, these changes may be exacerbated by effects of climate change.

Although there is uncertainty about the best specific approaches to managing landscapes for Northern Spotted Owls in fire-prone habitats, reasonable solutions seem to require four elements: 1) creation and maintenance of buffers around sufficiently-sized patches of owl habitat where fires originating from adjacent areas can be more effectively managed; 2) implementing a management strategy that allows for the replacement of suitable habitat patches over time, when existing patches are lost to wildfire or other disturbances, 3) targeting habitat to areas most likely to sustain denser forests over time (e.g. fire refugia); and 4) targeting habitat amounts in landscapes with consideration for overall environment and disturbance conditions. Larger patches and overall amounts of owl habitat will more easily be maintained in landscapes with more moist forest environments, and less so in more xeric landscapes.

Restorative treatment of landscapes inhabited by Northern Spotted Owls in the eastern Cascade Mountains has been limited, despite the risks to such landscapes from large wildfires and insect outbreaks. DNR currently has the ability to effectively address these risks on only certain portions of their ownership (e.g. in areas of large ownership blocks distant from other ownerships). An effective approach might incorporate a comprehensive landscape perspective based on an understanding of the inherent risks and values associated with a forest management strategy that addresses multiple objectives. Initial approaches to this process have been made in a few areas (e.g. the Klickitat Habitat Conservation Plan Amendment; DNR 2004). This process might involve landscape-level modeling that evaluates commodity production, fire risk, forest health, and the habitat needs of Northern Spotted Owls and other wildlife in an integrated fashion (Spies et al. 2002, Ager et al. 2007a). The output of such modeling would allow landowners in the region to understand the range of beneficial management actions that might be applied to attempt a balanced approach to these resource management issues across large landscapes. A new final recovery plan for the Northern Spotted Owl may provide management guidance and an opportunity to revisit the existing approach to provision of habitat in a manner that reduces risk of habitat loss to stand-replacement fire.

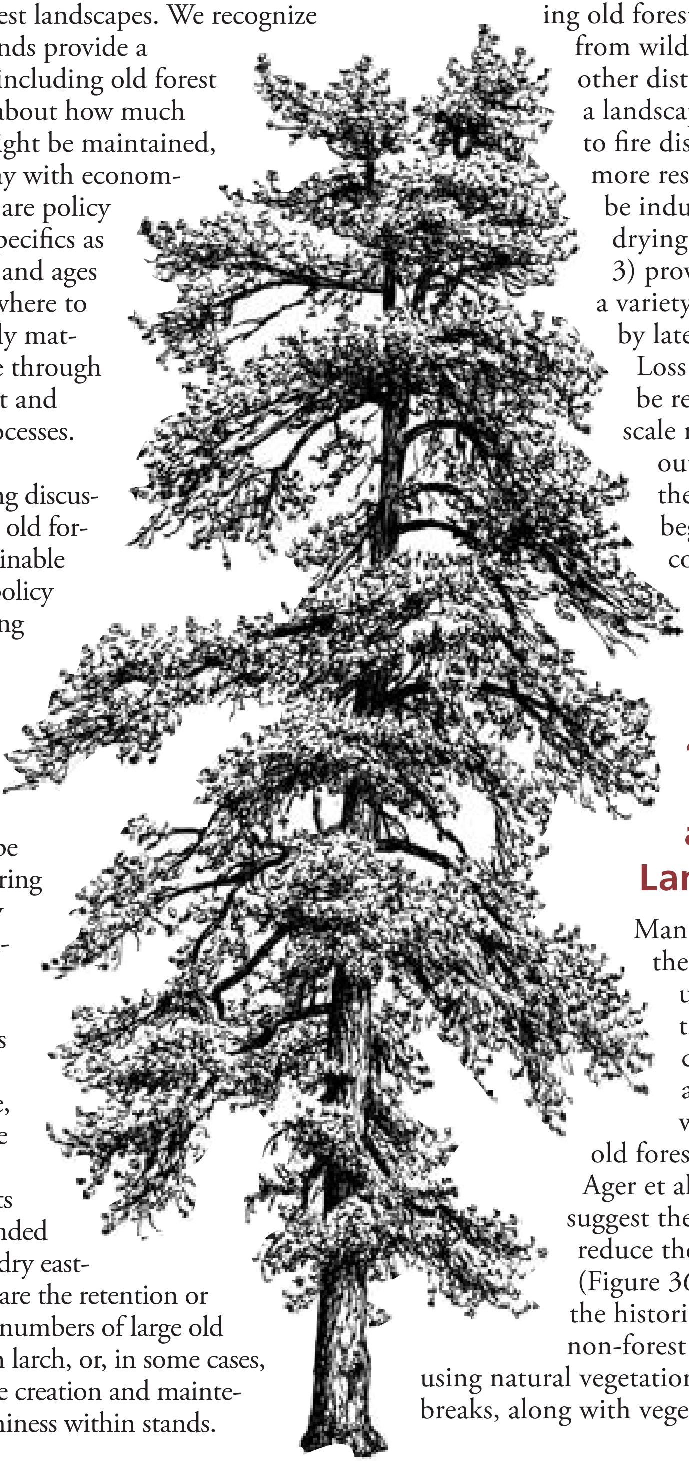
Older Forest Attributes

Management to Sustain Eastside Older Forest Attributes

Older Forest Attributes

In the following section we outline some approaches to restoring and sustaining varying levels of older forest function in the dry forest landscapes. We recognize that DNR-managed lands provide a broad range of values, including old forest conditions. Decisions about how much old forest condition might be maintained, where, and the interplay with economic and other objectives are policy matters. Operational specifics as to numbers, diameters and ages of trees to retain, and where to retain them are similarly matters for DNR to decide through procedure development and landscape planning processes.

We provide the following discussion to aid in managing old forest conditions in a sustainable fashion and to inform policy decisions about managing old forest conditions in dry eastside environments. Management designed to reduce wildfire and insect outbreak risks, at both stand and landscape scales, is critical to restoring resilience to existing dry eastside old forest conditions. Sustainable management can take many forms, including various combinations of stand thinning, prescribed fire, and wildlife resource use (e.g., prescribed natural fire). The key ingredients in all management intended to produce or conserve dry eastside old forest function are the retention or generation of sufficient numbers of large old ponderosa pine, western larch, or, in some cases, Douglas fir trees and the creation and maintenance of fine scale patchiness within stands.



Managing old forest characteristics in eastside dry environments has three major objectives: 1) providing old forest attributes in the face of loss from wildland fires, insect outbreaks, and other disturbances; 2) beginning to build a landscape that is resistant and resilient to fire disturbances in the short term and more resilient to alterations that might be induced by climatic warming and drying in the next several decades; and 3) providing for restored function of a variety of ecological services provided by late-successional and old forests. Loss of old forest characteristics can be reduced by careful landscape-scale reduction of wildfire and insect outbreak risks. Management of these risks in the short-term can begin near existing old forest conditions with the objective of buying time to implement landscape-wide management.

4.1. Managing Old Forest Conditions across Larger Landscapes

Management activities to reduce the contiguity of dense, relatively uniform forests can reduce the risks of losing old forest conditions by isolating patches and reducing the spread of wildfire into patches that contain old forest conditions (Agee et al. 2000, Ager et al. 2006). Agee et al. (2000) suggest the use of shaded fuel breaks to reduce the contiguity of landscape fuels (Figure 36). These could be modeled after the historical distribution of open forests, non-forest areas, and other lower-risk fuels using natural vegetation, landform, and topographic breaks, along with vegetation management.

Figure 36. This forest stand, which is in a wildland-urban interface, has been treated to remove ground and ladder fuels, and to reduce crown density (Jerry Franklin).

Mosaics of forest and other vegetation patches varying in size, composition, stand density, vegetation type, and fuel level could provide resilience and variability of resistance to wildfire and other disturbances, thereby reinforcing similar stand and patch size distributions in the future (Spies et al. 2006, Hessburg et al. 2007). Stands of contiguous canopy forest might range in size from less than an acre to a few thousand acres with some few very large stands and more abundant smaller stands and patches. Median size might be approximately 100 acres (40 hectares). Historical conditions might provide lessons about the sustainable kinds and sizes of patches in individual landscapes. Emerging methods to examine fire and other disturbance risks could be used to examine effects of treatment patterns on reducing wildfire risks to old forest conditions across many stands (Finney 2004, Ager et al. 2006) and many watersheds or larger areas (e.g., Hemstrom et al. 2007).

4.2. Restore Fire Tolerance

Decades of fire suppression, forest management, and other changes have altered the composition and structure of dry forests so they can no longer tolerate low- and moderate-severity wildfire. Restoration of fire tolerance within forest stands will be required to reduce landscape and stand-scale susceptibility to stand-replacing disturbance. The landscapes surrounding important forest areas (including, for example, Northern Spotted Owl habitat) should act as retardants to wildfire and insect outbreaks rather than as conduits. Many recommendations exist about the kinds of management activities that can be used to reduce fuels and fire risks in dry forests (Agee 2002, Hessburg and Agee 2003, Brown et al. 2004, Agee and Skinner 2005, Peterson et al. 2005, Stephens and Moghaddas 2005a, b, c). Agee's (2002) summary of *FireSafe* fuel treatment principles seems to provide a useful starting point:

1) **Reduce surface fuels**, especially volume in the 1-hour (herbs, litter, round wood less than 0.25 inch or less than 0.6 centimeter diameter), 10-hour (duff to 4 inches or 10 centimeters depth, and round wood 0.25 to 1 inch or 0.6 to 2.5 centimeters diameter), 100-hour (round wood 1-3 inches or 2.5 to 7.5 centimeters diameter), and 1000-hour (3 to 6 inches or 7.5 to 15 centimeters diameter) time lag classes. This will decrease flame lengths and fireline intensity.
2) **Increase the height to live crowns,** eliminating or greatly reducing fuel ladders, which means longer flame lengths are needed for tree torching. This action requires removal of some portion of seedlings, saplings, poles, small trees and sometimes medium sized trees, depending on objectives.
3) **Decrease crown density,** reducing crown fuel continuity, the propensity for canopies to trap heat, and thereby, the likelihood of running crown fires. Decreasing crown density is the least important if all other principles are applied.

Agee has also recommended the retention of the large, old fire-resistant trees as a fourth principle. These principles may be applied variably across the landscape to foster fire tolerance and construct more fire resistance around important habitat or old forest areas. They may or may not be useful within important dense old forest habitat, depending on habitat objectives.

4.2.1. Favor retention of fire tolerant tree species and restore fine-scale patchiness

In addition to simply treating fuels, restoration of fire tolerance should include restoration of fire tolerant tree species to prominent roles in dry forest landscapes. Large, old trees of ponderosa pine, western larch, and Douglas fir have thick, fire-resistant bark and other attributes that allow them to withstand most low- and mixed- severity wildfires. Large, old trees of these species provide the anchors for old forest conditions in dry environments, often surviving for centuries while smaller trees in the lower- and mid-canopy come and go with disturbance. Five additional stand restoration and fuel treatment principles seem applicable:

1) **Favor fire tolerant tree species during treatments, (ponderosa pine, western larch, and, sometimes, Douglas fir)**, thereby steadily improving the fire tolerance of stands, especially where fires are typically of low- or mixed- severity.
2) **Retain the large and very large fire tolerant trees.** These trees take 150 or more years to grow and are not easily replaced. They are key habitat features that can persist for centuries. Large trees of other species (e.g., grand fir and white fir (*Abies concolor*)) and younger, smaller trees of fire tolerant species could be removed, except as needed to meet other objectives, to reduce canopy fuels and provide economic benefits. Visual criteria including bark and canopy characteristics developed by Van Pelt (2008) can aid field recognition of old trees regardless of diameter.
3) **Apply treatments unevenly within stands**, creating fine-scale diversity within stands. Fuel and other stand-scale restoration treatments should produce a fine-scale mosaic of open patches of large trees, denser patches with mid-canopy trees, and regeneration within a landscape that generally meets *FireSafe* principles (above). Creating fine-scale diversity within stands provides for species and processes that operate at a smaller patch scale (ranging from less than 0.1 acre to 100 or more acres, or a fraction of a hectare to more than 40 hectares). Many plants, animals, and processes rely on a relatively fine scale pattern of patchiness that occurs at a tree, sub-patch, patch, patch-group, or neighborhood scale (see section 3.5.1.2).
4) **Apply treatments unevenly among stands**, creating mid-scale mosaics within regional landscapes.
5) **Develop landscape-level silvicultural prescriptions** that integrate fuel reduction objectives with those for maintaining or improving habitat for Northern Spotted Owls and other species and restoration of dry forest ecological processes and functions.

4.3. Approaches to Restoring Older Forest Function

It may be useful to consider a variety of management approaches to facilitate incorporation of old forest functionality in dry eastside forest landscapes while managing to meet objectives to produce trust income. The approaches taken in specific areas will involve many considerations including: 1) opportunities provided by existing stands, such as the presence of large old or mature trees of pioneer species; 2) landscape-level management objectives associated with development and maintenance of more sustainable and diverse landscapes, such as reduced vulnerability to large-scale disturbance events (e.g., creation of shaded fuel breaks), and maintenance of owl habitat; and 3) ownership category of DNR-managed lands (e.g., whether a specific tract is managed for trust responsibility or for other purposes).

In the following sections (4.3.1 and 4.3.2) we outline a range of levels and approaches to restoring and maintaining older forest functionality on DNR-managed lands. While these examples are neither comprehensive (variations on these themes will be nearly infinite, reflecting the reality of conditions on the ground) nor fully developed with regards to a silvicultural prescription, they do illustrate the spectrum of possibilities (see Appendix C for an outline of old forest management priorities and approaches).

4.3.1. Restoring high quality older stands to achieve a sustainable future condition

Restoration of older forests to a sustainable future condition that approximately resembles the historic reference condition is possible on many dry eastside forest sites (Sackett et al. 1993, Covington et al. 1997, Fule et al. 1997, Stephens 1998, Harrod et al. 1999, Huffman et al. 2001, Allen et al. 2002, Stephens and Moghaddas 2005a, b, c, Falk 2006, Noss et al. 2006) but likely requires a substantial commitment of resources. Situations where full older forest restoration might be applicable on DNR-managed lands include sites where:

1) Historic old forest structures could function as critical landscape-level fuel breaks (Figure 36);
2) Restored stands could provide critical habitat for dependent animal or plant species;
3) Significant existing populations of large old trees and historic structure are already present (e.g., Judy's Park in the Naneum block, Southeast Region) (Figure 19).

In any case, historic restoration should not be undertaken in situations where it is unlikely to be successful and sustainable at the landscape scale, such as in landscapes where restored sites will be embedded for the long-term in fire-prone untreated stands.

Many restoration projects and other efforts can provide models for older forest management on dry eastside forest sites (e.g., Stephens 1998, Harrod et al. 1999, Stephens and Moghaddas 2005a, b, c). Most restoration efforts begin not only with retention of the existing old tree population but with silvicultural treatments to reduce fuels and competing vegetation around these trees so as to improve their survival potential in case of wildfire or bark beetle attack. Additional elements of restoration prescriptions include:

1) **Tree removals** to:
    a) Move stand basal area toward a long-term sustainable level for the site (i.e., a basal area that approximates historic levels for the plant association),
    b) Shift species dominance toward more fire- and drought-tolerant species (e.g., ponderosa pine and western larch), and
    c) Increase the mean diameter of the stand;
2) **Incorporate spatial variability** in the intensity of the treatment, so as to enhance existing spatial heterogeneity (in addition to that associated with treatments around the old trees), such as that associated with existing natural canopy gaps and patches of regeneration; and
3) **Treatment of fuels** generated by the mechanical treatments.

Enhancing spatial heterogeneity in stand structure and composition with silvicultural activities is a significant challenge to re-establishment of older forest structure and composition on dry eastside forest sites. Some heterogeneity typically will already be present as, for example, irregularly distributed old trees and dense patches of tree reproduction (seedlings and saplings), and silviculturists can build on these patterns (Figure 27). Another strategy is to leave small areas of the stand completely untreated (i.e., skips) and to thin other areas heavily, thereby creating open canopies and opportunities for regeneration of shade-intolerant species.

Re-establishing characteristic understory community composition and structure is an important additional consideration in older forest management. This can present several and diverse challenges. For example, mechanical and prescribed fire treatments of stands will often provide opportunities for invasive plants to enter or expand their importance in stands. Re-establishment of desired native species, such as native grasses, can be difficult. Further, desired native understory species may be sensitive to either mechanical or fire treatments. The specifics of the desired future sustainable condition for a site generally can be keyed to particular plant series and, sometimes, plant associations (e.g., Johnson et al. 2007). Long-term management in older stands will involve continued active management to maintain them in a healthy, sustainable older forest condition. Activities will likely include: 1) periodic mechanical or burning treatments or both to keep fuels, basal areas, and tree composition near target levels; and 2) management of growing stock so as to increase (where necessary) and maintain (when desired old tree population densities are attained) the population of old trees.

4.3.2. Retaining old or large trees as part of a managed stand: multiple-cohort management

Old forest attributes can be incorporated in managed stands on dry eastside forest sites simply by maintaining a population of old, large trees while managing the co-dominant and understory trees for various purposes. Old, large trees of fire-tolerant species could be managed across several generations of smaller, younger trees to provide continuity of old forest characteristics while, for example, the younger trees provide economic benefits or desirable habitat attributes. This differs from current conditions that may indeed be multi-storied and of multiple tree cohorts. Current conditions generally lack sufficient old trees and smaller trees are so dense that old tree survival is threatened by intense wildfire or insect outbreaks. Several variables will influence level of older forest functionality, including the density of such trees and their level of age-related condition. This multiple-cohort management approach maintains both a population of older and larger trees and one or more populations of younger trees grown and harvested for economic purposes (e.g., Franklin et al. 1997). Many variations of multi-cohort management are possible depending upon site conditions and management objectives including the degree of older forest functionality that is desired. A portion of the younger cohort does have to be managed to provide trees to replace losses in the larger and older cohort. Of course, sustainability in the face of threats from fire and pathogens must be a consideration as in all management of dry eastside forest sites.

Dwarf Mistletoe

Factors such as heavy dwarf mistletoe infections in overstory trees may be a limitation on structural retention or require that retention be concentrated in aggregates. Larger trees may be heavily infected with dwarf mistletoe, particularly in the case of Douglas fir or, more locally, of ponderosa pine and western larch. Dwarf mistletoe may be at high levels because of past harvesting practices (which left infected trees) and fire suppression (which didn't cleanse sites of infected trees or branches). High stand levels of dwarf mistletoe infection are certainly not desirable from the standpoint of forest productivity, health and sustainability. On the other hand, dwarf mistletoe has an important habitat role in creating structural complexity and nesting sites for raptors and other organisms in the form of "brooms" and other structural deformities. Consequently, decisions regarding retention of trees with dwarf mistletoe infection will require professional judgment; i.e., occurrence of dwarf mistletoe is not a sufficient reason in itself to automatically require either removal or retention of an infected tree. As noted above, where trees with significant mistletoe infections are retained it may be best to concentrate the retention in aggregates rather than to disperse the retained trees over the harvested stand.

Many variations of the generalized multi-cohort management scheme are possible, depending upon site conditions and management objectives. An important consideration is whether all or portions of the large, old tree population are harvested periodically and replaced with members of the younger cohort or effectively maintained "in perpetuity". From the ecological perspective of older forest functionality and the time required to grow old tree characteristics, where older forest characteristics are a management objective, it is preferable to retain an existing older tree cohort rather than planning to replace it following timber harvest. However, since old trees eventually die, management should provide for replacement by maintaining sufficient younger large trees as replacements as necessary.

Management targets for tree density in the older cohort are also an important consideration and one that directly affects the level of wood production that can be expected in the younger cohort. Descriptions of old forests in dry eastside environments (Covington and Moore 1994, Arno et al. 1997, Agee 2003, Youngblood et al. 2004) indicate that large, old, widely-spaced ponderosa pine, western larch, or Douglas fir often averaged averaged 8 to 12 trees per acre (20 to 30 per hectare). the authors reported considerable range in these large tree densities, down to as few as 3 to 5 per acre (7.4 to 12 per hectare), depending on site. We suggest that the target levels for the older cohort in two-cohort management to achieve some meaningful level of old forest functionality are probably in the range of at least 8 to 12 per acre (20 to 30 per hectare), depending on site productivity. In many cases, higher densities of large, old trees may not be consistent with economic goals. On the other hand, retention of 2 or 3 trees per acre (4.9 to 7.4 per hectare) probably does not constitute credible multi-cohort management for older forest conditions either, although such levels of retention are still an ecologically significant practice as a part of single cohort management.

The spatial arrangement of the cohorts is a third important consideration. Spatial separation of at least a portion of the cohorts is a strategy that can be utilized to minimize negative impacts of the cohorts on each other. For example, the cohorts will compete with each other where they are intermixed, reducing growth in the younger cohorts and survivability of the older cohort. Spatially aggregating at least some of the older cohort in small groups is one way of reducing these potentially negative interactions by isolating them from areas of contiguous fuel.

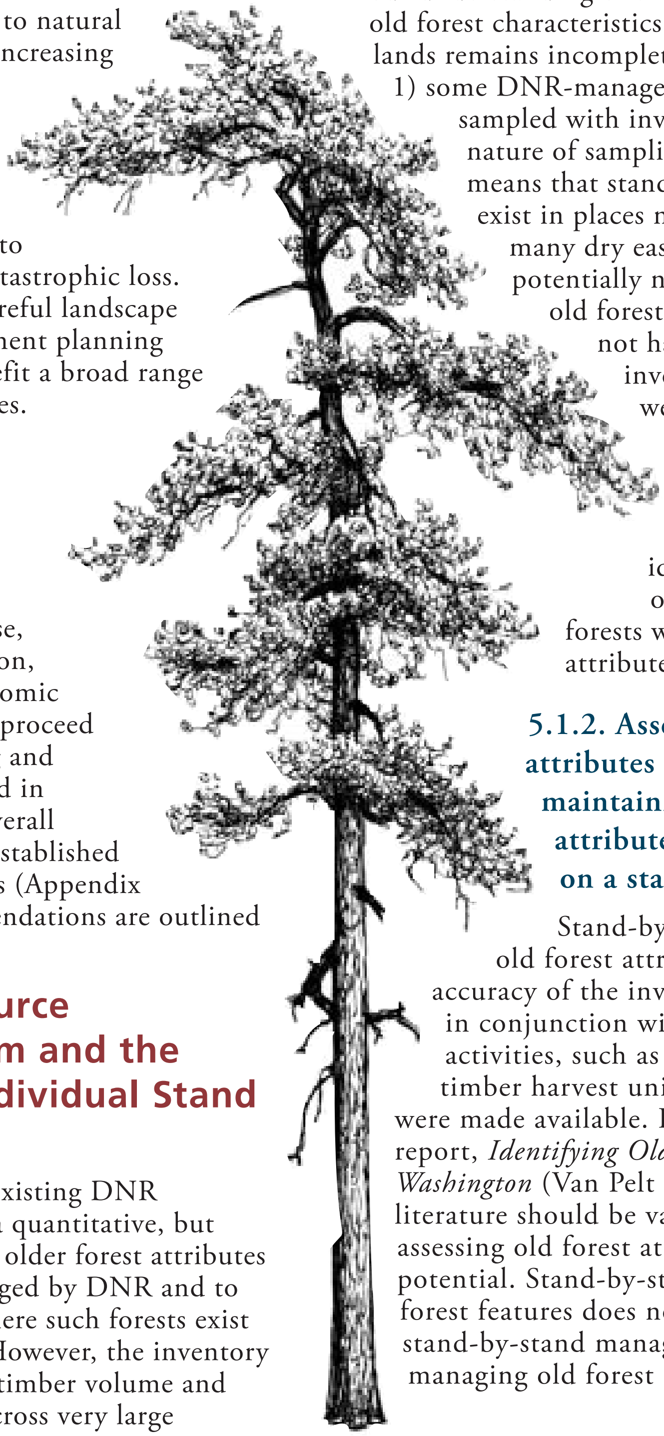
Perspectives

Perspectives and Additional Considerations

Perspectives

It is worthwhile to recognize that there is growing support for forest management in eastern Washington that can (1)restore resistance and resilience to natural disturbance regimes by increasing average diameters and basal areas of fire resistant species, and (2) surround closed canopy habitat types with shaded fuel breaks to reduce the chances of catastrophic loss. With the aid of some careful landscape planning, such management planning can encompass and benefit a broad range of management objectives.

Broad support for any particular approach to resource management is historically rare, and as such, highlights a rare opportunity. In this sense, we support a call to action, where funding and economic considerations allow, to proceed with landscape planning and management as discussed in this report within the overall management strategies established for DNR-managed lands (Appendix C). Additional recommendations are outlined below.



5.1. Forest Resource Inventory System and the Necessity for Individual Stand Assessments

We used data from the existing DNR inventory plots to gain a quantitative, but incomplete, overview of older forest attributes on eastside forests managed by DNR and to identify some locales where such forests exist (Franklin et al. 2007). However, the inventory was designed to sample timber volume and other forest attributes across very large landscapes, not relatively uncommon features like old forest conditions (Figure 37). Consequently, our understanding of the existing distribution of old forest characteristics on eastside DNR-managed lands remains incomplete. Reasons for this include: 1) some DNR-managed lands have not been sampled with inventory plots; and 2) the nature of sampling (rather than a census) means that stands with old forest attributes exist in places not sampled. In addition, many dry eastside forest stands contain potentially noteworthy old trees or other old forest attributes, which may not have been captured by the inventory screening methods we used. Hence, both the detail and extent of the current and any projected inventory is insufficient to allow comprehensive identification and mapping of the extent of dry eastside forests with significant old forest attributes.

5.1.2. Assessing existing old forest attributes and the potential for maintaining or expanding such attributes in dry eastside forests on a stand-by-stand basis

Stand-by-stand documentation of old forest attributes would increase the accuracy of the inventory. This could be done in conjunction with other management activities, such as assessments of proposed timber harvest units, if adequate funding were made available. Information from this report, *Identifying Old Trees and Forests in Eastern Washington* (Van Pelt 2008), and other scientific literature should be valuable to managers in assessing old forest attributes and management potential. Stand-by-stand examination for old forest features does not, however, imply that stand-by-stand management is sufficient for managing old forest characteristics.

5.2. Importance of Planning and Managing at the Landscape-level

As noted in this report, eastern Washington forest landscapes have been modified and put at risk to stand-replacing disturbance by human activities during the last 150 years (Figure 38). Efforts to establish more sustainable forests and minimize loss of trust assets to disturbance, let alone manage old forest attributes, are likely to be ineffective if they are implemented in an isolated fashion. Hence, we feel that development of plans and, eventually, the implementation of management activities at the landscape level are essential early steps in dealing with dry eastside forests and landscapes. The rapidly emerging influences of climate change make planning and implementation urgent.

Figure 37. The current inventory provides a good start in identifying old-growth forests but it will be necessary for DNR foresters to assess the existing old forest attributes as part of their detailed project planning (Jerry Franklin).

Figure 38. Management of dry forests needs to be planned and implemented at the landscape scale, if it is to be effective (Jerry Franklin).

5.3. Planning Responses to Climate Change

We conclude that climate change is almost certainly going to accentuate many of the issues regarding management of eastside forests including the risk of destructive large wildfires and outbreaks of pests and pathogens. Hence, any restorative management designed to incorporate old forest attributes – such as reduced stand densities and shifts to more drought tolerant species, are likely to also reduce risks associated with climate change.

5.3.1. Continuation of efforts to incorporate responses to climate change in management planning

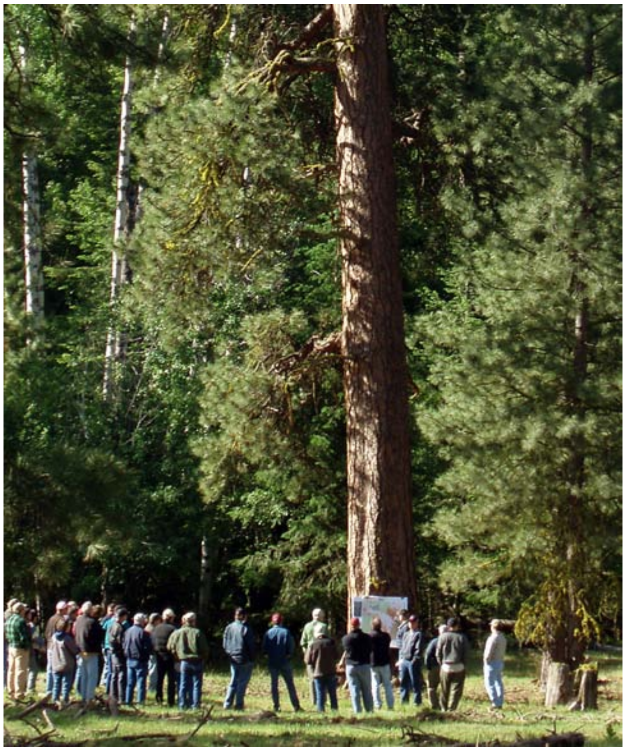
The potential for forest sites that were historically characterized by mixed-severity fire regimes to shift toward high-severity fire regimes under altered climate conditions needs to be considered in landscape-level plans and silvicultural treatment of individual stands. For example, sites may need to be targeted for lower overall densities and a higher component of drought-tolerant species than has been the case historically.

5.4. Development of Demonstration Sites for Old Forest Management

5.4.1. Identification of several high-priority sites to use in the development, testing, and public demonstration of approaches to restoration of sustainable old forest conditions on ponderosa pine and dry mixed-conifer sites

There are many unresolved issues associated with re-establishment of older forest attributes. We believe valuable experience would be gained from some focused near-term efforts in re-establishing sustainable conditions where older forest function is the objective. Furthermore, assuming that these are successful, they could become important public education opportunities (Figure 39).

Figure 39. The creation of some sites that demonstrate dry forest management activities would be useful in building understanding and acceptance of DNR's eastside dry forest program (Robert Van Pelt).



5.5. Scientific Study of Approaches to Two- or Multiple-cohort Management

5.5.1. Experimentation with two- or multiple-cohort silvicultural systems that incorporate an old tree component, especially in the dry mixed conifer potential vegetation types

There has been little formal study of silvicultural systems that incorporate two, three, or more cohorts of trees. There are many issues associated with such stands, such as timber yields and consequences of different cohort spatial arrangements (e.g., completely intermixed or homogenized vs. spatially aggregated). Some statistically designed silvicultural experiments (or, perhaps, one robust experimental design widely replicated) to examine tree and ecosystem responses to two or three important variables, would provide valuable information for assessing ecologic and economic cost/benefit analyses.

References

References

Agee, J.K. 1981. Initial effects of prescribed fire in a climax *Pinus contorta* forest: Crater Lake National Park. USDI National Park Service, Cooperative Park Studies Unit, Seattle, WA.

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Island Press, Washington, DC.

Agee, J.K. 2002. The fallacy of passive management: managing for firesafe forest reserves. Conservation in Practice **3**:18-26.

Agee, J.K. 2003. Historical range of variability in eastern Cascades forests, Washington, USA. Landscape Ecology **18**:725-740.

Agee, J.K., B. Bahro, M.A. Finney, P.N. Omi, D.B. Sapsis, C.N. Skinner, J.W. van Wagtendonk, and C.P. Weatherspoon. 2000. The use of shaded fuelbreaks in landscape fire management. Forest Ecology and Management **127**:55-66.

Agee, J.K., and C.N. Skinner. 2005. Basic principles of forest fuel reduction treatments. Forest Ecology and Management **211**:83-96.

Ager, A.A., M.A. Finney, B.K. Kerns, and H. Maffei. 2007a. Modeling wildfire risk to Northern Spotted Owl (*Strix occidentalis caurina*) habitat in Central Oregon, USA. Forest Ecology and Management **246**:45-56.

Ager, A., M. Finney, and A. McMahan. 2006. A wildfire risk modeling system for evaluating landscape fuel treatment strategies. Pages 149-162 *in* Fuels management - how to measure success. RMRS-P-41, USDA Forest Service, Rocky Mountain Research Station, Ft. Collins, CO.

Ager, A.A., A.J. McMahan, J.J. Barrett, and C.W. McHugh. 2007b. A simulation study of thinning and fuel treatments on a wildland-urban interface in eastern Oregon, USA. Landscape and Urban Planning **80**:292-300.

Allen, C.D., M. Savage, D.A. Falk, K.F. Suckling, T.W. Swetnam, T. Schulke, P.B. Stacey, P. Morgan, M. Hoffman, and J.T. Klingel. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. Ecological Applications **12**:1418-1433.

Allen, T.F.H., and T.W. Hoekstra. 1992. Toward a unified ecology. Columbia University Press, New York, NY.

Altman, B. 2000. Conservation strategy for landbirds of the east-slope of the Cascade Mountains in Oregon and Washington. American Bird Conservancy, Corvallis, OR.

Anthony, R.G., E.D. Forsman, A.B. Franklin, D.R. Anderson, K.P. Burnham, G.C. White, C.J. Schwarz, J.D. Nichols, J.E. Hines, G.S. Olson, S.H. Ackers, L.S. Andrews, B.L. Biswell, P.C. Carlson, L.V. Diller, K.M. Dugger, K.E. Fehring, T.L. Fleming, R.P. Gerhardt, S.A. Gremel, R.J. Gutiérrez, P.J. Happe, D.R. Herter, J.M. Higley, R.B. Horn, L.L. Irwin, P.J. Loschl, J.A. Reid, and S.G. Sovern. 2006. Status and trends in demography of Northern Spotted Owls, 1985-2003. Wildlife Monographs **163**:1-48.

Antos, J.A., and J.R. Habeck. 1981. Successional development in *Abies grandis* (Dougl.) Forbes forests in the Swan Valley, western Montana. Northwest Science **55**:26-39.

Arno, S.F. 1976. The historical role of fire on the Bitterroot National Forest. Research Paper INT-187. page 29 USDA, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Arno, S.F., and D.H. Davis. 1980. Fire history of western redcedar/hemlock forests in northern Idaho. Pages 21-26 *in* M.A. Stokes and J.H. Dieterich, editors. Fire History Workshop. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO.

Arno, S.F., H.Y. Smith, and M.A. Krebs. 1997. Old growth ponderosa pine and western larch stand structures: influences of pre-1900 fires and fire exclusion. Research Paper. INT-RP-495, USDA Forest Service, Intermountain Research Station, Ogden, UT.

Bachelet, D., R.P. Neilson, J.M. Lenihan, and R.J. Drapek. 2001. Climate change effects on vegetation distribution and carbon budget in the United States. Ecosystems **4**:164-185.

Baker, M.D., and M.J. Lacki. 2006. Day-roosting habitat of female long-legged myotis in ponderosa pine forests. Journal of Wildlife Management **70**:207-215.

Barbour, M.G., and W.D. Billings. 2000. North American terrestrial vegetation. 2nd edition. Cambridge University Press, Cambridge, UK.

Barrett, S.W., S.F. Arno, and C.H. Key. 1991. Fire regimes of western larch-lodgepole pine forests in Glacier National Park, Montana. Canadian Journal of Forest Research **21**:1711-1720.

Block, W.M., and L.A. Brennan. 1993. The habitat concept in ornithology. Theory and Applications. Current Ornithology **11**:35-91.

Bork, J. 1985. Fire history in three vegetation types on the east side of the Oregon Cascades. Oregon State University, Corvallis, OR.

Bradshaw, G.A., and T.A. Spies. 1992. Characterizing canopy gap structure in forests using wavelet analysis. Journal of Ecology **80**:205-215.

Brittell, J.D., R.J. Poelker, S.J. Sweeney, and G.M. Koehler. 1989. Native cats of Washington. Washington Department of Wildlife, Olympia, WA.

Brown, R.T., J.K. Agee, and J.F. Franklin. 2004. Forest restoration and fire: principles in the context of place. Conservation Biology **18**:903-912.

Buchanan, J.B. 1991. Spotted Owl nest site characteristics in mixed conifer forests of the eastern Cascade Mountains, Washington. Masters thesis. University of Washington, Seattle, WA.

Buchanan, J.B. 1996. Characteristics of Spotted Owl nests and nest sites in Klickitat County, Washington. Unpublished report. Olympia, WA.

Buchanan, J.B. 2005. Managing habitat for dispersing Northern Spotted Owls: are the current management strategies adequate? Wildlife Society Bulletin **32**:1333-1345.

Buchanan, J.B., and L.L. Irwin. 1998. Variation in Spotted Owl nest site characteristics within the eastern Cascade Mountains province in Washington. Northwestern Naturalist **79**:33-40.

Buchanan, J.B., L.L. Irwin, and E.L. McCutchen. 1993. Characteristics of Spotted Owl nest trees in the Wenatchee National Forest. Journal of Raptor Research **27**:1-7.

Buchanan, J.B., L.L. Irwin, and E.L. McCutchen. 1995. Within-stand nest site selection by Spotted Owls in the eastern Washington Cascades. Journal of Wildlife Management **59**:301-310.

Buchanan, J.B., R.E. Rogers, D.J. Pierce, and J.E. Jacobson. 2003. Nest-site habitat use by White-headed Woodpeckers in the eastern Cascade Mountains, Washington. Northwestern Naturalist **84**:119-128.

Buchanan, J.B., and P. Swedeen. 2005. Final briefing report to the Washington State Forest Practices Board regarding Spotted Owl status and forest practices rules. Washington Department of Fish and Wildlife, Olympia, WA.

Bull, E.L., and R.G. Anderson. 1978. Notes on Flammulated Owls in northeastern Oregon. Murrelet **59**:26-28.

Bull, E.L., A.L. Wright, and M.G. Henjum. 1990. Nesting habitat of Flammulated Owls in Oregon. Journal of Raptor Research **24**:52-55.

Camp, A.E. 1999. Age structure and species composition changes resulting from altered disturbance regimes on the eastern slopes of the Cascades range, Washington. Journal of Sustainable Forestry **9**:39-67.

Camp, A.E., C.D. Oliver, P.F. Hessburg, and R.L. Everett. 1997. Predicting late-successional fire refugia from physiography and topography. Forest Ecology and Management **95**:63-77.

Carroll, A.L., S.W. Taylor, J. Régnière, and L. Safranyik. 2003. Effects of climate change on range expansion by the mountain pine beetle in British Columbia. Pages 223-232 *in* T.L. Shore, J.E. Brooks, and J.E. Stone, editors. Mountain Pine Beetle Symposium: Challenges and Solutions. Information Report BC-X-399. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC, Canada.

Cassidy, K.M. 1997. Land cover of Washington State: description and management. *In* Cassidy, K.M., C.E. Grue, M.R. Smith, and K.M. Dvornich, editors. Washington State gap analysis. Volume 1. Washington Cooperative Wildlife Research Unit, University of Washington, Seattle, WA.

Chen, J., J.F. Franklin, and T.A. Spies. 1992. Vegetation responses to edge environments in old-growth Douglas fir forests. Ecological Applications **2**:387-396.

Cooper, D.B., K.E. Neiman, R. Steele, and D.W. Roberts. 1987. Forest habitat types of northern Idaho: a second approximation. General Technical Report GTR-INT-236. USDA Forest Service, Intermountain Research Station, Ogden, UT.

Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutiérrez, J.M. Marzluff, and L. Sztukowski. 2004. Scientific evaluation of the status of the Northern Spotted Owl. Sustainable Ecosystems Institute, Portland, OR.

Courtney, S.P., A.B. Carey, M.L. Cody, K. Engel, K.E. Fehring, J.F. Franklin, M.R. Fuller, R.J. Gutiérrez, J.F. Lehmkuhl, M.A. Hemstrom, P.F. Hessburg, S.L. Stephens, L. Sztukowski, and L. Young. 2008. Scientific review of the draft Northern Spotted Owl recovery plan and reviewer comments. Sustainable Ecosystems Institute, Portland, OR.

Covington, W.W., P.Z. Fulé, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Mast, S.S. Sackett, and M.R. Wagner. 1997. Restoring ecosystem health in ponderosa pine forests of the Southwest. Journal of Forestry **95**:23-29.

Covington, W.W., and M.M. Moore. 1994. Southwestern ponderosa forest structure changes since Euro-American settlement. Journal of Forestry **92**:39-47.

Daubenmire, R.; Daubenmire, Jean B. 1968. Forest vegetation of eastern Washington and north Idaho. Tech. Bull. 60. Pullman, WA: Washington Agricultural Experiment Station, Washington State University. 104 p.

Davis, K.M., B.D. Clayton, and W.C. Fischer. 1980. Fire ecology of Lolo National Forest habitat types. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT.

Desimone, S.M., and D.W. Hays. 2004. Northern Goshawk (*Accipiter gentilis*). Pages 6-1 to 6-17 *in* E. Larsen, J.M. Azerrad, and N. Nordstrom, editors. Management recommendations for Washington's priority species. Volume IV: birds. Washington Department of Fish and Wildlife, Olympia, WA.

Dixon, R.D. 1995. Ecology of White-headed Woodpeckers in the central Oregon Cascades. Masters thesis. University of Idaho, Moscow, ID.

Everett, R.L., P.F. Hessburg, M.E. Jensen, and B.Bormann. 1994. Eastside forest ecosystem health assessment. General Technical Report PNW-GTR-317, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Everett, R.L., R. Schellhaas, D. Keenum, D. Spurbeck, and P. Ohlson. 2000. Fire history in the ponderosa pine/Douglas fir forests on the east slope of the Washington Cascades. Forest Ecology and Management **129**:207-225.

Falk, D.A. 2006. Process-centred restoration in a fire-adapted ponderosa pine forest. Journal for Nature Conservation **14**:140-151.

Finch, R.B. 1984. Fire history of selected sites on the Okanogan National Forest. Unpublished. Page 22. USDA Forest Service, Okanogan National Forest, Okanogan, WA.

Finney, M.A. 2004. Landscape fire simulation and fuel treatment optimization. Pages 117-131 *in* J.L. Hayes, A. Ager, and R.J. Barbour, editors. Methods for integrated modeling of landscape change: interior northwest landscape analysis system. Gen. Tech. Rep. PNW-GTR-610. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. Forman, R. T.T., and M. Godron. 1986. Landscape Ecology. John Wiley and Sons, New York, NY.

Forsman, E.D., R.G. Anthony, J.A. Reid, P.J. Loschl, S.G. Sovern, M. Taylor, B.L. Biswell, A. Ellingson, E.C. Meslow, G.S. Miller, K.A. Swindle, J.A. Thrailkill, F.F. Wagner, and D.E. Seaman. 2002. Natal and breeding dispersal of Northern Spotted Owls. Wildlife Monographs **149**:1-35.

Forsman, E.D., I.A. Otto, S.G. Sovern, M. Taylor, D.W. Hays, H. Allen, S.L. Roberts, and D.E. Seaman. 2001. Spatial and temporal variation in diets of Spotted Owls in Washington. Journal of Raptor Research **35**:141-150.

Foster, S.A. 1992. Studies of ecological factors that affect the population and distribution of the western gray squirrel in north central Oregon. Ph.D. dissertation. Portland State University, Portland, OR.

Franklin, J.F., D.R. Berg, D.A. Thornburgh, and J.C. Tappeiner. 1997. Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. Pages 111-139 *in* K. A. Kohm and J. F. Franklin, editors. Creating a forestry for the 21st century: the science of ecosystem management. Island Press, Covelo, CA.

Franklin, J.F., K.J. Cromack, W. Dennison, A. McKee, C. Maser, J. Sedell, F.J. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas- fir forests. General Technical Report PNW-GTR-118, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Franklin, J.F., M.A. Hemstrom, R. Van Pelt, S. Hull, R. Crawford, S. Curry, W. Obermeyer, and J. Buchanan. 2007. Extent and distribution of old forest conditions on Washington Department of Natural Resources-managed forest lands in eastern Washington. Washington Department of Natural Resources, Olympia, WA.

Franklin, J.F., T. Spies, and R. Van Pelt. 2005. Section 1. Report by the old growth definition committee. Pages i-A22 *in* anonymous, editor. Definition and inventory of old growth forests on DNR-managed state lands. Washington State Department of Natural Resources, Olympia, WA.

Franklin, J. F., F. J. Swanson, M. E. Harmon, D. A. Perry, T. A. Spies, V. H. Dale, A. McKee, W. K. Ferrell, J. E. Means, S. V. Gregory, J. D. Lattin, T. D. Schowalter, and D. Larsen. 1991. Effects of Global Climatic Change on Forests in Northwestern North America. The Northwest Environmental Journal **7**:233-254.

Franklin, J.F., and R. Van Pelt. 2004. Spatial aspects of structural complexity in old-growth forests. Journal of Forestry **102**:22-28.

Frasier, M.W. 1997. Roost site characteristics of the long-legged myotis (*Myotis volans*) in the Teanaway River Valley of Washington. Masters thesis. University of Washington, Seattle, WA.

Frenzel, R.W. 2000. Nest-sites, nesting success, and turnover-rates of White-headed Woodpeckers on the Deschutes and Winema national forests, Oregon in 2000. Oregon Natural Heritage Program, The Nature Conservancy, Portland, OR.

Fretwell, S.D., and H.L. Lucas. 1969. On territorial behavior and other factors influencing habitat distribution in birds. Acta Biotheoretica **19**:16-36.

Fule, P.Z., W.W. Covington, and M.M. Moore. 1997. Determining reference conditions for ecosystem management of southwestern ponderosa pine forests. Ecological Applications **7**:895-908.

Goggans, R. 1985. Habitat use by Flammulated Owls in northeastern Oregon. Masters thesis. Oregon State University, Corvallis, OR.

Gregory, S. 2005. Seasonal movements and nest site selection of the western gray squirrel (*Sciurus griseus*) in the Methow River watershed. Masters thesis. University of Washington, Seattle, WA.

Gutiérrez, R.J., A.B. Franklin, and W.S. LaHaye. 1995. Spotted Owl (*Strix occidentalis*). The Birds of North America **179**:1-28.

Gutiérrez, R.J., M. Cody, S. Courtney, and A.B. Franklin. 2007. The invasion of Barred Owls and its potential effect on the Spotted Owl: a conservation conundrum. Biological Invasions **9**:181-196.

Hall, F.C. 1976. Fire and vegetation in the Blue Mountains—implications for land managers. Tall Timbers Fire Ecology Conference **15**:155-170.

Hann, W.J., J.L. Jones, M.G. Karl, P.F. Hessburg, R.E. Keane, D.G. Long, J.P. Menakis, C.H. McNicoll, S.G. Leonard, R.A. Gravenmier, and B.G. Smith. 1997. Landscape dynamics of the basin. Pages 337-1055 *in* T. M. Quigley and S. J. Arbelbide, editors. An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great basins. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Hanson, E., D. Hays, L. Hicks, L. Young, and J. Buchanan. 1993. Spotted Owl habitat in Washington. Washington Forest Practices Board, Olympia, WA.

Harrington, M.G., and S.S. Sackett. 1992. Past and present fire influences on southwestern ponderosa pine old growth. General Technical Report RM-GTR-213, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO.

Harrod, R.J., B.H. McRae, and W.E. Hartl. 1999. Historical stand reconstruction in ponderosa pine forests to guide silvicultural prescriptions. Forest Ecology and Management **114**:433-446.

Hayes, G.E. In Preparation. Washington State bat conservation and management plan. Washington Department of Fish and Wildlife, Olympia, WA.

Hemstrom, M.A. 2003. Forests and woodlands of western North America. Pages 9-40 *in* C.J. Zabel, R.G. Anthony, editors. Mammal Community Dynamics. Cambridge University Press, Cambridge, UK.

Hemstrom, M.A., J.J. Korol, and W.J. Hann. 2001. Trends in terrestrial plant communities and landscape health indicate the effects of alternative management strategies in the interior Columbia River basin. Forest Ecology and Management **153**:105-126.

Hemstrom, M.A., S.E. Logan, and W. Pavlat. 1987. Plant association and management guide Willamette National Forest. R6-Ecol-257-b-86, USDA Forest Service, Portland, OR.

Hemstrom, M.A., J. Merzenich, A. Reger, and B. Wales. 2007. Integrated analysis of landscape management scenarios using state and transition models in the upper Grande Ronde River Subbasin, Oregon, USA. Landscape and Urban Planning **80**:198-211.

Hessburg, P.F., and J.K. Agee. 2003. An environmental narrative of Inland Northwest United States forests, 1800-2000. Forest Ecology and Management **178**:23-59.

Hessburg, P.F., J.K. Agee, and J.F. Franklin. 2005. Dry mixed conifer forests and wildland fires of the inland Northwest USA: contrasting the landscape ecology of the pre-settlement and modern eras. Forest Ecology and Management **211**:117-139.

Hessburg, P.F., R.B. Salter, and K.M. James. 2007. Re-examining fire severity relations in pre-management era mixed conifer forests: inferences from landscape patterns of forest structure. Landscape Ecology **22**:5-24.

Hessburg, P.F., B.G. Smith, S.D. Kreiter, C.A. Miller, R.B. Salter, C.H. McNicoll, and W.J. Hann. 1999a. Historical and current forest and range landscapes in the Interior Columbia River Basin and portions of the Klamath and Great basins, Part I: Linking vegetation patterns and landscape vulnerability to potential insect and pathogen disturbances. General Technical Report PNW-GTR-458, USDA Forest Service, Pacific Northwest Research Station, Portland, OR

Hessburg, P.F., B.G. Smith, and R.B. Salter. 1999b. Using estimates of natural variation to detect ecologically important change in forest spatial patterns: a case study, Cascade Range, eastern Oregon. Research Paper PNW-RP-514, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Hessburg, P.F., B.G. Smith, R.B. Salter, R.D. Ottmar, and E. Alvarado. 2000. Recent changes (1930s-1990s) in spatial patterns of interior northwest forests, USA. Forest Ecology and Management **136**:53-83.

Heyerdahl, E., L.B. Brubaker, and J.K. Agee. 2001. Factors controlling spatial variation in historical fire regimes: a multiscale example from the interior west, USA. Ecology **82**:660-678.

Hopkins, W.E. 1979a. Plant associations of the Fremont National Forest. R6 Ecol 79-004, USDA Forest Service, Pacific Northwest Region, Portland, OR.

Hopkins, W.E. 1979b. Plant associations of the south Chiloquin and Klamath Ranger Districts, Winema National Forest. R6 Ecol 79-005, USDA Forest Service, Pacific Northwest Region, Portland, OR.

Huffman, D.W., M.M. Moore, W.W. Covington, J.E. Crouse, and P.Z. Fule. 2001. Ponderosa pine forest reconstruction: comparisons with historical data. Pages 3-8 *in* R.E. Vance, B. Carleton, W.W. Covington, and J.A. Blake, editors. Ponderosa pine ecosystems restoration and conservation: steps toward stewardship. RMRS-P-22. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT.

Irwin, L.L., T.L. Fleming, S.M. Speich, and J.B. Buchanan. 1991. Spotted owl presence in managed forests of southwestern Washington. Technical Bulletin No. 601. National Council for Air and Stream Improvement, Inc., Corvallis, OR.

John, T., D. Tart, and R. Clausnitzer. 1988. Forest plant associations of the Yakima Indian Reservation. Draft Field Guide Yakima Indian Nation, Soil and Vegetation Survey. Yakama Nation, Toppenish, WA.

Johnson, C.G., Jr., and R.R. Clausnitzer. 1992. Plant associations of the Blue and Ochoco Mountains. R6 ERW-TP-036-92, USDA Forest Service, Pacific Northwest Region, Portland, OR.

Johnson, C.G., Jr., and S.A. Simon. 1987. Plant associations of the Wallowa-Snake Province. R6 Ecol TP 255a-86, USDA Forest Service, Pacific Northwest Region, Portland, OR.

Johnson, D. H., and T. A. O'Neil, editors. 2001. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR.

Johnson, K.N., J.F. Franklin, and D.L. Johnson. 2007. A plan for the Klamath Tribes' management of the Klamath Reservation forest. Corvallis, OR.

Kaufmann, M.R. 1996. To live fast or not: growth, vigor and longevity of old-growth ponderosa pine and lodgepole pine trees. Tree Physiology **16**:139-144.

Keeton, W.S., J.F. Franklin, and P.W. Mote. In Press. Climate variability, climate change, and forest ecosystems in the Pacific Northwest. Ch.13 *in* E.L. Miles, A.K. Snover, and T.C.I. Group, editors. Rhythms of Change: An Integrated Assessment of Climate Impacts on the Pacific Northwest. MIT Press, Boston, MA.

Keeton, W.S., P.W. Mote, J.F. Franklin, T. Austin, and G.K. Roger. 2007. Climate variability, climate change, and western wildfire with implications for the urban-wildland interface. Advances in the Economics of Environmental Resources **6**:225-253.

Koehler, G.M. 1990a. Population and habitat characteristics of lynx and showshoe hares in northcentral Washington. Canadian Journal of Zoology **68**:845-851.

Koehler, G.M. 1990b. Snowshoe hare, *Lepus americanus*, use of forest successional stages and population changes during 1985-1989 in north-central Washington. Canadian Field-Naturalist **105**:291-293.

Kolb, T.E., J.K. Agee, P.Z. Fule, N.G. McDowell, K. Pearson, A. Sala, and R.H. Waring. 2007. Perpetuating old ponderosa pine. Forest Ecology and Management **249**:141-157.

Krannitz, P.G. and T.E. Duralia. 2004. Cone and seed production in *Pinus ponderosa*: a review. Western North American Naturalist **64**:208-218.

Lehmkuhl, J.F., K.D. Kistler, J.S. Begley, and J. Boulander. 2006. Demography of northern flying squirrels informs ecosystem management of western interior forests. Ecological Applications 16:584-600. Li, H., and J.F. Reynolds. 1995. On definition and quantification of heterogeneity. Oikos **73**:280-284.

Lillybridge, T.R., B.L. Kovalchik, C.K. Williams, and B.G. Smith. 1995. Field Guide for forested plant association of the Wenatchee National Forest. General Technical Report PNW-GTR-359. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Linders, M.J. 2000. Spatial ecology of the western gray squirrel (*Sciurus griseus*) in Washington: the interaction of season, habitat and home range. Masters thesis. University of Washington, Seattle, WA.

Linders, M.J. and D.W. Stinson. 2006. Draft Washington State recovery plan for the western gray squirrel. Washington Department of Fish and Wildlife, Olympia, WA.

Maletzke, B.T. 2004. Winter habitat selection of lynx (*Lynx canadensis*) in northern Washington. Master's thesis. Washington State University, Pullman, WA.

Marshall, D.B. 2003. White-headed Woodpecker (*Picoides albolarvatus*). Pages 364-367 *in* D.B. Marshall, M.G. Hunter, and A.L. Contreras, editors. Birds of Oregon: a general reference. Oregon State University Press, Corvallis, OR.

McCallum, D.A. 1994a. Flammulated Owl (*Otus flammeolus*). The Birds of North America **93**:1-24.

McCallum, D.A. 1994b. Conservation status of Flammulated Owls in the United States. Pages 74-79 *in* Hayward, G.D. and J. Verner, editors. Flammulated, Boreal, and Great Gray owls in the United States: a technical conservation assessment. USDA Forest Service General Technical Report GTR RM-253.

McCallum, D.A. 1994c. Review of technical knowledge: Flammulated Owls. Pages 14-46 *in* Hayward, G.D. and J. Verner, editors. Flammulated, Boreal, and Great Gray owls in the United States: a technical conservation assessment. USDA Forest Service General Technical Report GTR RM-253.

McKelvey, K.S., S.W. Buskirk, and C.J. Krebs. 2000. Theoretical insights into the population viability of lynx. Pages 21-37 *in* L.F. Ruggiero, K.B. Aubry, S.W. Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey, and J.R. Squires, editors. Ecology and conservation of lynx in the United States. USDA Forest Service, RMRS-GTR-30WWW and University of Colorado Press.

McKenzie, D., Z.E. Gedalof, D.L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. Conservation Biology **18**:890-902.

Morrison, M.L., B.G. Marcot, and R.W. Mannan. 1992. Wildlife-habitat relationships: concepts and applications. University of Wisconsin Press, Madison, WI.

Mote, P.W., E.A. Parson, A.F. Hamlet, W.S. Keeton, D. Lettenmaier, N. Mantua, E.L. Miles, D.W. Peterson, D.L. Peterson, R. Slaughter, and A.K. Snover. 2003. Preparing for climatic change: the water, salmon, and forests of the Pacific Northwest. Climatic Change **61**:45-88.

Mueller, R.C., C.M. Scudder, M.E. Porter, R. Talbot Trotter, C.A. Gehring, and T.G. Whitham. 2005. Differential tree mortality in response to severe drought: evidence for long-term vegetation shifts. Journal of Ecology **93**:1085-1093.

Munger 1917. Munger, T.T. 1917. Western yellow pine in Oregon. Bulletin 418. Washington, D.C.: U.S. Department of Agriculture; 48 p.

Noss, R.F., P. Beier, W.W. Covington, R.E. Grumbine, D.B. Lindenmayer, J.W. Prather, F. Schmiegelow, T.D. Sisk, and D.J. Vosick. 2006. Recommendations for integrating restoration ecology and conservation biology in ponderosa pine forests of the Southwestern United States. Restoration Ecology **14**:4-10.

O'Connell, M.A., J.G. Hallett, S.D. West, K.A. Kelsey, D.A. Manuwal, and S.F. Pearson. 2000. Effectiveness of riparian management zones in providing habitat for wildlife. Timber, Fish and Wildlife Program report No. TFW-LWAG1-00-001, Olympia, WA.

O'Neil, T.A., K.A. Bettinger, M. Vander Heyden, B.G. Marcot, T.K. Mellen, W.M. Vander Haegen, D.H. Johnson, P.J. Doran, L. Wunder, and K.M. Boula. 2001. Structural conditions and habitat elements of Oregon and Washington. Pages 115-139 *in* D.H. Johnson and T.A. O'Neil, editors. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR.

Peter, D. and C. Harrington. 2002. Site and tree factors in Oregon white oak acorn production in western Washington and Oregon. Northwest Science **76**:189-201.

Peterson, D.L., M.C. Johnson, J.K. Agee, T.B. Jain, D. MacKenzie, and E.D. Reinhardt. 2005. Forest structure and fire hazard in dry forests of the western United States. Gen. Tech. Rep. PNW-GTR-628. USDA Forest Service, Pacific Northwest Research Station, Seattle, WA. Peterson, D.L., and V.T. Parker, editors. 1998. Ecological scale: theory and applications. Columbia University Press, New York, NY.

Poole, K.G. 1994. Characteristics of an unharvested lynx population during a snowshoe hare decline. Journal of Wildlife Management **58**:608-618.

Poole, K.G. 1997. Dispersal patterns of lynx in the Northwest Territories. Journal of Wildlife Management **61**:497-505.

Riggs, R.A., A.R. Tiedemann, J.G. Cook, T.M. Ballard, P.J. Edgerton, M. Vavra, W.C. Krueger, F.C. Hall, L.D. Bryant, L.L. Irwin, and T. Delcurto. 2000. Modification of mixed-conifer forests by ruminant herbivores in the Blue Mountains ecological province. Research Paper. PNW-RP-527, USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Ruediger, B., J. Claar, S. Gniadek, L. Lewis, B. Holt, S. Mighton, B. Naney, G. Patton, T. Rinaldi, J. Trick, A. Vandehey, F. Wahl, N. Warren, D. Wenger, and A. Williamson. 2000. Canada lynx conservation assessment and strategy. Second edition. USDA Forest Service, USDI Fish and Wildlife Service, Bureau of Land Management, and National Park Service. Forest Service Publication R1-00-53. Missoula, MT.

Sackett, S., S. Haase, and M.G. Harrington. 1993. Restoration of southwestern ponderosa pine ecosystems with fire. Pages 115-121 in W.W. Covington and L.E. DeBano, editors. Sustainable ecological systems: implementing an ecological approach to land management. General Technical Report RM-247. USDA Forest Service, Fort Collins, CO.

Sallabanks, R., B.G. Marcot, R.A. Riggs, C.A. Mehl, and E.B. Arnett. 2001. Wildlife of eastside (interior) forests and woodlands. Pages 213-238 *in* D.H. Johnson and T.A. O'Neil, editors. Wildlife-habitat relationships in Oregon and Washington. Oregon State University Press, Corvallis, OR.

Savage, M. 1991. Structural dynamics of a southwestern pine forest under chronic human influence. Annals of the Association of American Geographers **81**:271-289.

Shaw, J.D. 2006. Population-wide changes in pinyon-juniper woodlands caused by drought in the American Southwest: effects on structure, composition, and distribution. Pages 117-124 *in* R. Lafortezza and G. Sanesi, editors. Patterns and processes in forest landscapes. Consequences of Human Management. Proceedings of the 4th Meeting of IUFRO Working Party 8.01.03, Locorotondo, Bari, Italy. USDA Forest Service Rocky Mountain Research Station, Ogden, UT.

Soeriaatmadja, R.E. 1966. Fire history of the ponderosa pine forests of the Warm Springs Indian Reservation, Oregon. Oregon State University, Corvallis, OR.

Spies, T.A., M.A. Hemstrom, A. Youngblood, and S. Hummel. 2006. Conserving old-growth forest diversity in disturbance-prone landscapes. Conservation Biology **20**:351-362.

Spies, T.A., G.H. Reeves, K.M. Burnett, W.C. McComb, K.N. Johnson, G. Grant, J.L. Ohmann, S.L. Garman, and P. Bettinger. 2002. Assessing the ecological consequences of forest policies in a multi-ownership province in Oregon. Pages 179-207 *in* J. Liu and W.W. Taylor, editors. Integrating landscape ecology into natural resource management. Cambridge University Press, New York, NY.

Stamps, J.A. 1988. Conspecific attraction and aggregation in territorial species. American Naturalist **131**:329-347.

Stephens, S.L. 1998. Evaluation of the effects of silvicultural and fuels treatments on potential fire behaviour in Sierra Nevada mixed-conifer forests. Forest Ecology and Management **105**:21-35.

Stephens, S.L., and J.J. Moghaddas. 2005a. Experimental fuel treatment impacts on forest structure, potential fire behavior, and predicted tree mortality in a California mixed conifer forest. Forest Ecology and Management **215**:21-36.

Stephens, S.L., and J.J. Moghaddas. 2005b. Fuel treatment effects on snags and coarse woody debris in a Sierra Nevada mixed conifer forest. Forest Ecology and Management **214**:53-64.

Stephens, S.L., and J.J. Moghaddas. 2005c. Silvicultural and reserve impacts on potential fire behavior and forest conservation: twenty-five years of experience from Sierra Nevada mixed conifer forests. Biological Conservation **125**:369-379.

Stinson, D.W. 2001. Washington State recovery plan for the lynx. Washington Department of Fish and Wildlife. Olympia, WA.

Stuart, J.D. 1984. Hazard rating of lodgepole pine stands to mountain pine beetle outbreaks in southcentral Oregon. Forest Ecology and Management **5**:207-214.

Taylor, J.A. 1999. Roost-site and habitat selection of the long-legged myotis (*Myotis volans*) in a managed landscape of the eastern Cascade Range. Masters thesis. Michigan State University, East Lansing, MI.

Topik, C. 1989. Plant Association and Management Guide for the Grand Fir Zone, Gifford Pinchot National Forest. R6-ECOL-TP-006-88. USDA Forest Service, Pacific Northwest Region, Portland, OR.

Topik, C., N.M. Halverson, and D.G. Brockway. 1986. Plant association and management Guide for the Western Hemlock Zone, Gifford Pinchot National Forest. R6-ECOL-30A-1986. USDA Forest Service, Pacific Northwest Region, Portland, OR.

Topik, C., N.M. Halverson, and T. High. 1988. Plant Association and Management guide for the Ponderosa Pine, Douglas fir, and Grand Fir Zones, Mount Hood National Forest. R6-ECOL-TP-004-88. USDA Forest Service, Pacific Northwest Region, Portland, OR.

U.S. Department of Agriculture, and U.S. Department of the Interior. 1994. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the Northern Spotted owl. Standards and guidelines for management of habitats for late-successional and old-growth forest related species within the range of the Northern Spotted Owl. U.S. Government Printing Office, Washington, D.C.

U.S. Fish and Wildlife Service. 2000. Endangered and threatened wildlife and plants: determination of threatened status for the contiguous U.S. distinct population segment of the Canada lynx and related; final rule. Federal Register **65**:16052-16086.

Van Pelt, R. 2008. Identifying old trees and forests in eastern Washington. Washington State Department of Natural Resources, Olympia, WA.

Vavra, M., M.A. Hemstrom, and M. Wisdom. 2007. Modeling the effects of herbivores on the abundance of forest overstory states using a state-transition approach in the upper Grande Ronde River Basin, Oregon, USA. Landscape and Urban Planning **80**:212-222.

Volland, L.A. 1985. Plant associations of the central Oregon pumice zone. R6 Ecol 104-1985, USDA Forest Service, Pacific Northwest Region, Portland, OR.

von Kienast, J.A. 2003. Winter habitat selection and food habits of lynx on the Okanogan Plateau, Washington. Master's thesis. University of Washington, Seattle, WA.

Wahl, T.R., B. Tweit, and S.G. Mlodinow, editors. 2005. Birds of Washington: status and distribution. Oregon State University Press, Corvallis, OR.

Walker, C.J. 2005. Influences of landscape structure on snowshoe hare populations in fragmented forests. Master's thesis. University of Montana, Missoula, MT.

Washington Department of Fish and Wildlife. 1999. Priority habitats and species list. Washington Department of Fish and Wildlife, Olympia, WA.

Washington Department of Fish and Wildlife. 2005. Washington's comprehensive wildlife conservation strategy. Washington Department of Fish and Wildlife, Olympia, WA.

Washington State Department of Natural Resources. 1996. Lynx habitat management plan for DNR-managed lands. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 1997. Final habitat conservation plan. Washington State Department of Natural Resources, Olympia, WA.

Washington State Department of Natural Resources. 2006. Lynx habitat management plan for DNR-managed lands. Washington State Department of Natural Resources, Olympia, WA.

Weaver, H. 1959. Ecological changes in the ponderosa pine forest of the Warm Springs Indian Reservation in Oregon. Journal of Forestry **57**:15-20.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. Science **313**:940-943.

White, A.S. 1985. Presettlement regeneration patterns in a southwestern ponderosa pine stand. Ecology **66**:589-594.

Williams, C.K., B.F. Kelley, B.G. Smith, and T.R. Lillybridge. 1995. Forested plant association of the Colville National Forest. General Technical Report PNW-GTR-360. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Williams, C.K., and T.R. Lillybridge. 1983a. Forested plant association of the Okanogan National Forest. R6-Ecol-132b. USDA Forest Service, Pacific Northwest Region, Portland, OR.

Williams, C.K., and T.R. Lillybridge. 1983b. Forested plant associations of the Okanogan National Forest. R6 Ecol 132-1983, USDA Forest Service, Pacific Northwest Region, Portland, OR.

Wischnofske, M.G., and D.W. Anderson. 1983. The natural role of fire in the Wenatchee Valley. USDA Forest Service, Pacific Northwest Region, Wenatchee National Forest, Wenatchee, WA.

Youngblood, A., T. Max, and K. Coe. 2004. Stand structure in eastside old-growth ponderosa pine forests of Oregon and northern California. Forest Ecology and Management **199**:191-217.

Appendix A

Plant Associations, Potential Vegetation Types, and Historic and Current Fire Regime for DNR-Managed Lands East of the Cascade Crest

Appendix A

Plant Associations, Potential Vegetation Types (PVT), and Historic and Current Fire Regime for DNR-Managed Lands East of the Cascade Crest

Plant association - location - citation [1]	PVT	Historical fire regime	Current fire regime
PIPO/QUGA4/CAGE-YAKIMA-JOHN-88	Ponderosa pine-oak	low	mixed
PIPO/QUGA4/PUTR2-YAKIMA-JOHN-88	Ponderosa pine-oak	low	mixed
PIPO/QUGA4/SYAL-YAKIMA-JOHN-88	Ponderosa pine-oak	low	mixed
QUGA/AGSP-WEN-LILLYBRIDGE-95	Ponderosa pine-oak	low	mixed
QUGA4/PUTR2-YAKIMA-JOHN-88	Ponderosa pine-oak	low	mixed
QUGA4/SYAL-YAKIMA-JOHN-88	Ponderosa pine-oak	low	mixed
PIPO/AGSP/ASDE-WEN-LILLYBRIDGE-95	Dry ponderosa pine	low	mixed
PIPO/AGSP-IDAHO-COOPER-87	Dry ponderosa pine	low	mixed
PIPO/AGSP-WEN-LILLYBRIDGE-95	Dry ponderosa pine	low	mixed
PIPO/CAQU2-YAKIMA-JOHN-88	Dry ponderosa pine	low	mixed
PIPO/CARU/AGSP-WEN-LILLYBRIDGE-95	Dry ponderosa pine	low	mixed
PIPO/FEID-IDAHO-COOPER-87	Dry ponderosa pine	low	mixed
PIPO/LONU2-YAKIMA-JOHN-88	Dry ponderosa pine	low	mixed
PIPO/PUTR/AGSP-WEN-LILLYBRIDGE-95	Dry ponderosa pine	low	mixed
PIPO/PUTR/AGSP-WEN-LILLYBRIDGE-95	Dry ponderosa pine	low	mixed
PIPO/PUTR2/FEID-YAKIMA-JOHN-88	Dry ponderosa pine	low	mixed
PIPO/PUTR2-YAKIMA-JOHN-88	Dry ponderosa pine	low	mixed
PIPO/SYAL-IDAHO-COOPER-87	Dry ponderosa pine	low	mixed
PIPO/SYAL-YAKIMA-JOHN-88	Dry ponderosa pine	low	mixed
PSME/AGSP/ASDE-WEN-LILLYBRIDGE-95	Dry ponderosa pine	low	mixed
PSME/AGSP-IDAHO-COOPER-87	Dry ponderosa pine	low	mixed
PSME/AGSP-WEN-LILLYBRIDGE-95	Dry ponderosa pine	low	mixed
PSME/FEID-IDAHO-COOPER-87	Dry ponderosa pine	low	mixed
PSME/PIPO/AGIN-OKAN-WILL-LILLY-83	Dry ponderosa pine	low	mixed
PSME/PUTR/AGSP-WEN-LILLYBRIDGE-95	Dry ponderosa pine	low	mixed
ABGR/ARCO-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
ABGR/ARNE-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
ABGR/CAGE-GP-TOPIK-89	Dry mixed conifer	low	mixed
ABGR/CAGE-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
ABGR/CARU/LUPIN-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
ABGR/CARU-GP-TOPIK-89	Dry mixed conifer	low	mixed

[1] COOPER-91 = Cooper et al. (1987), YAKIMA-JOHN-88 = John et al. (1988), WEN-LILLYBRIDGE-95 = Lillybridge et al. (1995), GP-TOPIK-89 = Topic (1989), GP-TOPIK-86 = Topic et al. (1986), GP-TOPIK-88 = Topic et al. (1988), OKAN-WILL-LILLY-83 = Williams and Lillybridge (1983a) WILLIAMS-95 = Williams et al. (1995)

Plant association - location - citation	PVT	Historical fire regime	Current fire regime
ABGR/CARU-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
ABGR/CARU-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
ABGR/COCOC-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
ABGR/HODI/CARU-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
ABGR/HODI-GP-TOPIK-89	Dry mixed conifer	low	mixed
ABGR/LIBO3/TRLA6-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
ABGR/PAMY-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
ABGR/PHMA-COLVILLE-WILLIAMS-95	Dry mixed conifer	low	mixed
ABGR/POPU3-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
ABGR/SPBE2-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
ABGR/SPBEL/PTAQ-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
ABGR/SYAL/CARU-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
ABGR/SYAL-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
ABGR/SYMOH-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
ABGR/SYOR-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
ABGR/VAMY2/LIBO3-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
ABGR/VAMY2-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
PIPO/PHMA-IDAHO-COOPER-87	Dry mixed conifer	low	mixed
PSME/ACCI/FEOC-GP-TOPIK-89	Dry mixed conifer	low	mixed
PSME/ARNE-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
PSME/ARUV/CARU-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/ARUV/PUTR-OKAN-WILL-LILLY-83	Dry mixed conifer	low	mixed
PSME/ARUV/PUTR-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/ARUV-OKAN-WILL-LILLY-83	Dry mixed conifer	low	mixed
PSME/ARUV-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/CAGE-HOOD-TOPIK-88	Dry mixed conifer	low	mixed
PSME/CAGE-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/CARU/AGSP-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/CARU-OKAN-WILL-LILLY-83	Dry mixed conifer	low	mixed
PSME/CARU-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
PSME/COCO-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
PSME/FEOC-HOOD-TOPIK-88	Dry mixed conifer	low	mixed
PSME/HODI/CAGE-HOOD-TOPIK-88	Dry mixed conifer	low	mixed
PSME/HODI-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
PSME/PAMY/CARU-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/PAMY-OKAN-WILL-LILLY-83	Dry mixed conifer	low	mixed
PSME/PHMA-COLVILLE-WILLIAMS-95	Dry mixed conifer	low	mixed
PSME/PHMA-OKAN-WILL-LILLY-83	Dry mixed conifer	low	mixed
PSME/PUTR/CARU-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/PUTR-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed

Plant association - location - citation	PVT	Historical fire regime	Current fire regime
PSME/SPBE2-YAKIMA-JOHN-88	Dry mixed conifer	low	mixed
PSME/SPBEL/CARU-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/SPBEL-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/SYAL/AGSP-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/SYAL/CARU-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/SYAL-OKAN-WILL-LILLY-83	Dry mixed conifer	low	mixed
PSME/SYAL-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/SYOR-OKAN-WILL-LILLY-83	Dry mixed conifer	low	mixed
PSME/SYOR-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/VACA-COLVILLE-WILLIAMS-95	Dry mixed conifer	low	mixed
PSME/VACA-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/VACCI-OKAN-WILL-LILLY-83	Dry mixed conifer	low	mixed
PSME/VAME-COLVILLE-WILLIAMS-95	Dry mixed conifer	low	mixed
PSME/VAMYCARU-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
PSME/VAMY-WEN-LILLYBRIDGE-95	Dry mixed conifer	low	mixed
POTR/CARU-OKAN-WILL-LILLY-83	Aspen	mixed	mixed
POTR/SYAL-OKAN-WILL-LILLY-83	Aspen	mixed	mixed
ABLA/LUHI2-YAKIMA-JOHN-88	Subalpine Parklands	mixed	mixed
ABLA/LUHI-IDAHO-COOPER-87	Subalpine Parklands	mixed	mixed
ABLA2/LUHI-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
ABLA2/PHEM-OKAN-WILL-LILLY-83	Subalpine Parklands	mixed	mixed
ABLA2/VADE-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
LALY/CAME/LUPE-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
LALY/DROC-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
LALY/JUCO4-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
LALY/VADE/CAME-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
LALY/VASC/LUHI-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
PIAL/CAME/LUPE-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
PIAL/CARU-OKAN-WILL-LILLY-83	Subalpine Parklands	mixed	mixed
PIAL/CARU-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
PIAL/FEVI-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
PIAL/JUCO4-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
PIAL/VASC/LUHI-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
TSME/LUHI4-YAKIMA-JOHN-88	Subalpine Parklands	mixed	mixed
TSME/LUHI-IDAHO-COOPER-87	Subalpine Parklands	mixed	mixed
TSME/LUHI-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
TSME/PHEM/VADE-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
TSME/VASC/LUHI-WEN-LILLYBRIDGE-95	Subalpine Parklands	mixed	mixed
ABGR/ACCI/BEAQ/TRLA2-GP-TOPIK-89	Moist mixed conifer	mixed	high
ABGR/ACCI/CHUM-WEN-LILLYBRIDGE-95	Moist mixed conifer	mixed	high

Plant association - location - citation	PVT	Historical fire regime	Current fire regime
ABGR/ACCI/CLUN-WEN-LILLYBRIDGE-95	Moist mixed conifer	mixed	high
ABGR/ACCI-WEN-LILLYBRIDGE-95	Moist mixed conifer	mixed	high
ABGR/ACCI-YAKIMA-JOHN-88	Moist mixed conifer	mixed	high
ABGR/ACTR-WEN-LILLYBRIDGE-95	Moist mixed conifer	mixed	high
ABGR/BENE/ACTR-GP-TOPIK-89	Moist mixed conifer	mixed	high
ABGR/BENE/CARU-WEN-LILLYBRIDGE-95	Moist mixed conifer	mixed	high
ABGR/BENE-WEN-LILLYBRIDGE-95	Moist mixed conifer	mixed	high
ABGR/COCO2/ACTR-GP-TOPIK-89	Moist mixed conifer	mixed	high
ABGR/CONU/ACTR-GP-TOPIK-89	Moist mixed conifer	mixed	high
ABGR/PIEN/ATFI-YAKIMA-JOHN-88	Moist mixed conifer	mixed	high
ABGR/PIEN/CLUN2-YAKIMA-JOHN-88	Moist mixed conifer	mixed	high
ABGR/RUPA/DIHO-GP-TOPIK-89	Moist mixed conifer	mixed	high
ABGR/SYMO/ACTR-GP-TOPIK-89	Moist mixed conifer	mixed	high
ABGR/VAME/CLUN-GP-TOPIK-89	Moist mixed conifer	mixed	high
ABGR/VAME/LIBO2-GP-TOPIK-89	Moist mixed conifer	mixed	high
ABLA/CAGE-YAKIMA-JOHN-88	Douglas fir-subalpine fir	mixed	high
ABLA/CARU-IDAHO-COOPER-87	Douglas fir-subalpine fir	mixed	high
ABLA/CARU-YAKIMA-JOHN-88	Douglas fir-subalpine fir	mixed	high
ABLA/PAMY2-YAKIMA-JOHN-88	Douglas fir-subalpine fir	mixed	high
ABLA2/CARU-OKAN-WILL-LILLY-83	Douglas fir-subalpine fir	mixed	high
ABLA2/CARU-WEN-LILLYBRIDGE-95	Douglas fir-subalpine fir	mixed	high
ABLA2/PAMY/CARU-WEN-LILLYBRIDGE-95	Douglas fir-subalpine fir	mixed	high
ABLA2/PAMY-OKAN-WILL-LILLY-83	Douglas fir-subalpine fir	mixed	high
ABLA2/PAMY-WEN-LILLYBRIDGE-95	Douglas fir-subalpine fir	mixed	high
ABLA2/RULA-WEN-LILLYBRIDGE-95	Douglas fir-subalpine fir	mixed	high
ABLA2/VACCI-OKAN-WILL-LILLY-83	Douglas fir-subalpine fir	mixed	high
ABLA2/VASC/CARU-WEN-LILLYBRIDGE-95	Douglas fir-subalpine fir	mixed	high
THPL/ACTR-GP-TOPIK-89	Western redcedar-western hemlock	mixed	high
THPL/ASCA2-YAKIMA-JOHN-88	Western redcedar-western hemlock	mixed	high
THPL/CLUN-WEN-LILLYBRIDGE-95	Western redcedar-western hemlock	mixed	high
THPL/COCA-YAKIMA-JOHN-88	Western redcedar-western hemlock	mixed	high
TSHE/ACCI/ACTR-WEN-LILLYBRIDGE-95	Western redcedar-western hemlock	mixed	high
TSHE/ACCI/ASCA3-WEN-LILLYBRIDGE-95	Western redcedar-western hemlock	mixed	high
TSHE/ACCI/CLUN-WEN-LILLYBRIDGE-95	Western redcedar-western hemlock	mixed	high
TSHE/ACTR-GP-TOPIK-86	Western redcedar-western hemlock	mixed	high
TSHE/ACTR-WEN-LILLYBRIDGE-95	Western redcedar-western hemlock	mixed	high
TSHE/ACTR-YAKIMA-JOHN-88	Western redcedar-western hemlock	mixed	high
TSHE/ARNE-WEN-LILLYBRIDGE-95	Western redcedar-western hemlock	mixed	high
TSHE/ASCA3-WEN-LILLYBRIDGE-95	Western redcedar-western hemlock	mixed	high

Plant association - location - citation	PVT	Historical fire regime	Current fire regime
TSHE/BENE-WEN-LILLYBRIDGE-95	Western redcedar-western hemlock	mixed	high
TSHE/CONU4-YAKIMA-JOHN-88	Western redcedar-western hemlock	mixed	high
TSHE/PAMY/CLUN-WEN-LILLYBRIDGE-95	Western redcedar-western hemlock	mixed	high
TSHE/VAME-YAKIMA-JOHN-88	Western redcedar-western hemlock	mixed	high
ABGR/ACGLD/CLUN-COLVILLE-WILLIAMS-95	Western redcedar-western hemlock	high	high
ABGR/ASCA-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
ABGR/CLUN-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
ABGR/VACA-COLVILLE-WILLIAMS-95	Western redcedar-western hemlock	high	high
ABGR/VAME/CLUN-COLVILLE-WILLIAMS-95	Western redcedar-western hemlock	high	high
ABGR-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
THPL/ADPE-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
THPL/ARNU3-COLVILLE-WILLIAMS-95	Western redcedar-western hemlock	high	high
THPL/ASCA-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
THPL/CLUN-COLVILLE-WILLIAMS-95	Western redcedar-western hemlock	high	high
THPL/CLUN-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
THPL/GYDR-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
THPL/OPHO-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
TSHE/ARNU3-COLVILLE-WILLIAMS-95	Western redcedar-western hemlock	high	high
TSHE/ASCA-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
TSHE/CLUN-COLVILLE-WILLIAMS-95	Western redcedar-western hemlock	high	high
TSHE/CLUN-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
TSHE/GYDR-COLVILLE-WILLIAMS-95	Western redcedar-western hemlock	high	high
TSHE/GYDR-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
TSHE/MEFE-COLVILLE-WILLIAMS-95	Western redcedar-western hemlock	high	high
TSHE/MEFE-IDAHO-COOPER-87	Western redcedar-western hemlock	high	high
TSHE/RUPE-COLVILLE-WILLIAMS-95	Western redcedar-western hemlock	high	high
ABAM/ACCI-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
ABAM/ACTR-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
ABAM/MEFE-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
ABAM/RHAL/VAME-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
ABAM/RHAL2/CLUN2-YAKIMA-JOHN-88	Pacific silver fir	high	high
ABAM/RHAL2-YAKIMA-JOHN-88	Pacific silver fir	high	high
ABAM/RULA/VAME-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
ABAM/TITRU-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
ABAM/VAME/CLUN-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
ABAM/VAME/CLUN-YAKIMA-JOHN-88	Pacific silver fir	high	high
ABAM/VAME/PYSE-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
ABAM/VAME/XETE-YAKIMA-JOHN-88	Pacific silver fir	high	high
TSME/MEFE/VAAL-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
TSME/MEFE/VAME-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high

Plant association - location - citation	PVT	Historical fire regime	Current fire regime
TSME/RHAL/VAAL-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
TSME/RHAL/VAME-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
TSME/RULA-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
TSME/VAAL-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
TSME/VAME-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
TSME/VAME-YAKIMA-JOHN-88	Pacific silver fir	high	high
TSME/XETE/VAMY-WEN-LILLYBRIDGE-95	Pacific silver fir	high	high
ABGR/VAGL-IDAHO-COOPER-87	Engelmann spruce-subalpine fir	high	high
ABGR/XETE-IDAHO-COOPER-87	Engelmann spruce-subalpine fir	high	high
ABLA/CLUN2-YAKIMA-JOHN-88	Engelmann spruce-subalpine fir	high	high
ABLA/CLUN-IDAHO-COOPER-87	Engelmann spruce-subalpine fir	high	high
ABLA/MEFE-IDAHO-COOPER-87	Engelmann spruce-subalpine fir	high	high
ABLA/STAM-IDAHO-COOPER-87	Engelmann spruce-subalpine fir	high	high
ABLA/VACA-IDAHO-COOPER-87	Engelmann spruce-subalpine fir	high	high
ABLA/VAGL-IDAHO-COOPER-87	Engelmann spruce-subalpine fir	high	high
ABLA/VASC-IDAHO-COOPER-87	Engelmann spruce-subalpine fir	high	high
ABLA/VASI-YAKIMA-JOHN-88	Engelmann spruce-subalpine fir	high	high
ABLA/XETE/CLUN2-YAKIMA-JOHN-88	Engelmann spruce-subalpine fir	high	high
ABLA/XETE/LUHI4-YAKIMA-JOHN-88	Engelmann spruce-subalpine fir	high	high
ABLA/XETE-IDAHO-COOPER-87	Engelmann spruce-subalpine fir	high	high
ABLA/XETE-YAKIMA-JOHN-88	Engelmann spruce-subalpine fir	high	high
ABLA2/ARLA/POPU-WEN-LILLYBRIDGE-95	Engelmann spruce-subalpine fir	high	high
ABLA2/CLUN-COLVILLE-WILLIAMS-95	Engelmann spruce-subalpine fir	high	high
ABLA2/COCO-COLVILLE-WILLIAMS-95	Engelmann spruce-subalpine fir	high	high
ABLA2/LIBO2-OKAN-WILL-LILLY-83	Engelmann spruce-subalpine fir	high	high
ABLA2/RHAL/LUHI-WEN-LILLYBRIDGE-95	Engelmann spruce-subalpine fir	high	high
ABLA2/RHAL/XETE-COLVILLE-WILLIAMS-95	Engelmann spruce-subalpine fir	high	high
ABLA2/RHAL-OKAN-WILL-LILLY-83	Engelmann spruce-subalpine fir	high	high
ABLA2/RHAL-WEN-LILLYBRIDGE-95	Engelmann spruce-subalpine fir	high	high
ABLA2/VACA-WEN-LILLYBRIDGE-95	Engelmann spruce-subalpine fir	high	high
ABLA2/VAME-COLVILLE-WILLIAMS-95	Engelmann spruce-subalpine fir	high	high
ABLA2/VAME-WEN-LILLYBRIDGE-95	Engelmann spruce-subalpine fir	high	high
ABLA2/VASC/ARLA-WEN-LILLYBRIDGE-95	Engelmann spruce-subalpine fir	high	high
ABLA2/VASC/LUHI-WEN-LILLYBRIDGE-95	Engelmann spruce-subalpine fir	high	high
ABLA2/VASC-OKAN-WILL-LILLY-83	Engelmann spruce-subalpine fir	high	high
ABLA2/VASC-WEN-LILLYBRIDGE-95	Engelmann spruce-subalpine fir	high	high
ABLA2/XETE-COLVILLE-WILLIAMS-95	Engelmann spruce-subalpine fir	high	high
CHNO/RHAL2-YAKIMA-JOHN-88	Engelmann spruce-subalpine fir	high	high

Appendix B

Habitat Relationships for Species Dependent on or Strongly Associated With Old Forest Characteristics in Dry Environments in Eastern Washington

Appendix B

Habitat Relationships for Species Dependent on or Strongly Associated With Old Forest Characteristics in Dry Environments in Eastern Washington

In this section we describe ecological relationships between several vertebrate species and the forests managed by the Washington State Department of Natural Resources (DNR) east of the Cascade Mountains crest. An emphasis is placed on the Northern Spotted Owl and lynx because of their regulatory and conservation significance. Other species addressed more briefly below are associated with older dry-site forests and include long-legged myotis, western gray squirrel, Flammulated Owl and White-headed Woodpecker.

Spotted Owl

The Northern Spotted Owl, a federally threatened subspecies, has been the focus of substantial conservation and management activity designed to protect its habitat in the Pacific Northwest for over two decades. In Washington the Spotted Owl is found, in appropriate habitat, throughout western Washington and in all but the far eastern portion of the east slope of the Cascade Mountains. Ongoing demography research in the Pacific Northwest indicates that Spotted Owl populations are declining in many areas, and declines are more pronounced in Washington than in Oregon or California (Anthony et al. 2006). The reasons for these declines are thought to include past and ongoing habitat loss and the effects of suspected competition with the Barred Owl (*Strix varia*), a species that expanded its range into and through the Pacific Northwest in the last 40 years (Gutiérrez et al. 2007). Habitat loss is related to a number of disturbance factors including timber harvest, stand-replacement fire, windthrow, and insect outbreaks (Courtney et al. 2004).

Spotted Owls in the eastern Cascade Mountains use a variety of forest associations and age classes to meet their life needs. Throughout most of their range Spotted Owls are associated with older coniferous forests. In the eastern Cascades the owl uses old forest habitat but also uses comparatively younger forests. The median age of dominant and co-dominant trees in vegetation plots at a sample of over 80 nest sites in and near the Wenatchee National Forest (i.e., on federal and nonfederal lands) was about 130 years, and some sites were only about 60 years old (Buchanan et al. 1995). Forests used for nesting in Klickitat County were occasionally as young as 45 years old, but were characterized by the presence of residual trees from the previous stand (Buchanan 1996). Forests used by Spotted Owls range from western hemlock – Douglas fir stands near the Cascade crest and in moist areas throughout the region to mixed conifer Douglas fir – ponderosa pine forests in lower elevations and drier settings.

Structural features at Spotted Owl nest sites vary across the eastern Cascade Mountains province. Forests used by Spotted Owls near the Cascade crest are typical of conditions used by owls in western Washington, and are older, have a greater stand basal area and fewer stems than are found at sites further east in the Cascade Mountain foothills (Buchanan and Irwin 1998). Within four zones of the drier portion of the owl's range in and near the Wenatchee National Forest, Spotted Owl nest sites are characterized by an abundance of Douglas fir and/or grand fir, mean values of approximately 162 to 182 conifers per acre (400 to 450 conifers per hectare), 118 to 200 square feet per acre of basal area of live conifers (27 to 46 square meters per hectare), generally >70 percent canopy closure and presence of dwarf mistletoe, typically *Arceuthobium douglasii* (Buchanan and Irwin 1998) which is an important nest structure for owls in this region (Buchanan et al. 1995). Presence of large-diameter ponderosa pines was an important variable in a model that correctly differentiated 70 percent of Spotted Owl nest sites from random locations (Buchanan 1991). Snags and downed wood, normally associated with Spotted Owl habitat in other regions (Gutiérrez et al. 1995), tend to be found in low amounts except in older forests and in comparatively younger stands undergoing suppression mortality (Buchanan et al. 1995). Spotted Owl nesting habitat in Klickitat County and vicinity is generally similar to the description above although mistletoe is not as prevalent and there is a much greater representation of very large residual Douglas fir and ponderosa pine trees and/or snags (Buchanan 1996) than in areas farther north (Buchanan et al. 1995). Most nests in the Wenatchee National Forest study area are open platform structures (i.e., nests originally built by Northern Goshawks [*Accipiter gentilis*] or accumulations of debris atop clumps of branches infected by mistletoe; Buchanan et al. 1993), whereas most nests in the Klickitat County study area were in cavities or broken tops of large residual snags or trees (Buchanan 1996).

The home range areas used by Northern Spotted Owls in Washington are the largest documented for the subspecies (Gutiérrez et al. 1995). It is generally assumed that home range size is dictated to some extent by the availability of suitable prey (Courtney et al. 2004). Radio telemetry data from four Spotted Owl home ranges in the eastern Cascades indicate home ranges of between 3,687 and 9,111 acres (1,492 and 6,305 hectares) in size (based on the minimum convex polygon); within these home ranges the amount of habitat used by Spotted Owls ranged between about 2,100 and 9,501 acres (850 and 3,845 hectares) (Hanson et al. 1993). The primary prey found in these home ranges is the northern flying squirrel (*Glaucomys sabrinus*); among other prey species of the Spotted Owl, the most important, based on biomass or frequency in diet, include bushy-tailed woodrat (*Neotoma cinerea*), snowshoe hare (*Lepus americanus*), mice (*Peromyscus* spp.), and red-backed vole (*Clethrionomys gapperi*) (Forsman et al. 2001).

In addition to having large home ranges, juvenile Spotted Owls move substantial distances during natal dispersal. Median dispersal distances, based on radio-telemetry, were 8.4 and 14.2 miles (13.5 and 22.9 kilometers) for males and females, respectively (Forsman et al. 2002). The direction of dispersal movements is random, as juveniles have no prior knowledge of the landscape conditions around them (Forsman et al. 2002). The stand- and landscape-level patterns of habitat use by dispersing juveniles have not been intensively studied anywhere in the species' range and there are no published empirical data on habitat use by dispersing Spotted Owls in Washington (Buchanan 2005). Perhaps due to general inexperience that results in inefficient foraging and use of inadequate habitats, the mortality rate of juveniles is high; most mortality during dispersal is due to starvation or predation (Forsman et al. 2002). Although data associating dispersal success with habitat conditions are lacking it seems likely that dispersal success is related to the amount, quality and distribution of suitable habitat in landscapes through which juveniles disperse.

Implemented management actions to conserve Spotted Owl populations in the eastern Cascade Mountains include the Northwest Forest Plan (USDA and USDI 1994), two habitat conservation plans negotiated between landowners and the U.S. Fish and Wildlife Service, and Washington forest practices rules. DNR has one of two major habitat conservation plans in the eastern Cascades. That plan (Washington State Department of Natural Resources 1997) and the forest practices rules (Buchanan and Swedeen 2005) are designed to augment ongoing management strategies for Spotted Owls on federal lands. The majority of Spotted Owl habitat, and thus the majority of conservation emphasis for the species, occurs on federal lands. Under the Northwest Forest Plan most federal lands will be managed according to one of three principal management designations:

1. Late-successional reserves are landscapes within which all suitable Spotted Owl habitat is protected with the exception of certain silvicultural treatments that are allowed in younger stands to accelerate development of habitat.
2. Adaptive management areas are landscapes where a combination of owl conservation and experimental harvest activities will occur.
3. Matrix areas are landscapes in which the primary emphasis is timber harvest.

The DNR habitat conservation plan augments the Northwest Forest Plan by designating one of three management functions to portions of its ownership depending in part on the distance to federal lands and the conservation function of those federal lands. Areas of DNR land adjacent to late-successional reserves on federal lands (and some other DNR lands in large blocks) are designated as having a function to provide nesting, roosting and foraging habitat at a target of 50 percent of watershed analysis units within DNR ownership blocks. Some DNR lands are designated as dispersal landscapes for Spotted Owls, providing habitat connectivity between population clusters of owls, while other lands have no designated conservation function for owls (Washington State Department of Natural Resources 1997).

Lynx

The Lynx is an uncommon feline, numbering perhaps fewer than 100 individuals in Washington, that was designated a threatened species at the state and federal levels in 1993 and 2000, respectively (Stinson 2001). The species was listed because of concerns about its small population size, the effects of forest management, fire and fire suppression, and the consequences of insect epidemics (U.S. Fish and Wildlife Service 2000). The Lynx is known to occur in the northeastern Cascade Mountains, and in several other mountainous areas in Okanogan, Ferry, Stevens, and Pend Oreille counties; it formerly occurred in the southeastern Cascade Mountains (Stinson 2001). Lynx populations are characterized in many areas by their well-known cyclic responses — at approximately ten-year intervals — to population fluctuations of their most important prey, the Snowshoe Hare (*Lepus americanus*). Cyclic population fluctuations have not been well documented in Washington, but moderate cycles are believed to occur (Stinson 2001). Formerly a game species, the lynx is no longer trapped in Washington (Stinson 2001).

Lynx in Washington predominantly use lodgepole pine and Engelmann spruce–subalpine fir forests for den sites and foraging areas (Brittell et al. 1989, Koehler 1990a), but the successional stages they use differ according to life stage. Den and rearing areas in Washington, for example, are generally in older forests (> 200 years old) where disturbance events or succession dynamics have created an abundance of downed logs that provide protective cover (Koehler 1990b). Studies in other regions, however, indicate use of younger forest age classes with high amounts of horizontal and vertical cover in all seasons (see Washington State Department of Natural Resources 2006). Foraging occurs in forests that support high densities of Snowshoe Hares. These forests are generally young (e.g. <20 to 40 years old) and may have stem densities of over 6,070 per acre (15,000 per hectare) (Koehler 1990a). Winter use of early seral forests is limited to those areas where the vegetation with forage value (e.g. deciduous shrubs, saplings) protrudes above deep snowfall (von Kienast 2003), indicating that some very young forests may not provide winter foraging opportunities for Snowshoe Hares or Lynx. In northern Washington, Lynx in winter used small forest gaps in mid- to late-successional forests (von Kienast 2003) and used forests with 11 to 39 percent canopy and understory cover more than expected by chance (Maletzke 2004). A habitat use study involving Snowshoe Hares in northern Washington found that hare density was positively associated with increasing amounts of boreal forest within 980 feet (300 meters) of a patch of dense forest cover (Walker 2005).

The mean annual home range of the Lynx in northern Washington is generally smaller than has been documented from other regions; nonetheless, home ranges are quite large. Mean home range size varied from about 14 to 27 square miles (37 to 69 square kilometers) for females and males, respectively, in Okanogan County (see Stinson 2001). Home ranges may overlap among females and males (e.g. 31to 44 percent in Washington; Brittell et al. 1989), but rarely do they overlap among males (Koehler 1990a), suggesting the occurrence of mutual avoidance by territorial animals. Home ranges in Okanogan County were comprised of several cover types: lodgepole pine (56 percent), Engelmann spruce–subalpine fir (26 percent), Douglas fir and western larch (13 percent) and open meadow and ponderosa pine (Brittell et al. 1989, Koehler 1990b). Travel within the home range usually occurs in habitats with substantial overhead (canopy) and ground cover, and also includes some areas otherwise unsuitable for denning or foraging that are used simply for travel among suitable patches (Stinson 2001).

As is true for many predators, Lynx are capable of, and regularly engage in, substantial dispersal movements. All age classes of animals are known to disperse depending on a variety of conditions. Dispersal events may involve movements by juveniles away from the natal area for the purpose of territory establishment, or the movement of animals, including adults, seeking better prey resources, particularly in periods of low hare abundance (Poole 1994; see McKelvey et al. 2000). Dispersing lynx may travel over 62 miles (100 kilometers (median distance in the Northwest Territories = 55 miles (88 kilometers); Poole 1997), and an animal from northern Washington dispersed to British Columbia, traveling at least 283 miles (616 kilometers) (Brittell et al. 1989). Dispersal is thought to be a particularly important life function in poorly distributed (i.e., potentially isolated) populations, as movements from “source” populations may be necessary to support “sink” populations (McKelvey et al. 2000b). Habitat used during dispersal is apparently similar to that described above.

The Lynx occurs on federal and nonfederal lands in Washington, and a number of efforts to manage Lynx habitat have been implemented. It has been estimated that 4,857 square miles (12,579 square kilometers) of Lynx habitat exists in six Lynx management zones (LMZ) in Washington. The largest LMZ, the Okanogan, contains over 70 percent of suitable known occupied Lynx habitat in the state. The vast majority of Lynx habitat (88 percent) is found on federal lands, and about 40 percent of this occurs on lands with reserve designation (e.g. wilderness areas, national parks; Stinson 2001). The federal government has developed guidelines for management of the Lynx on federal lands (Ruediger et al. 2000, U.S. Fish and Wildlife Service 2000, Stinson 2001).

Lynx management plans have also been developed for nonfederal lands by two private landowners and DNR (Stinson 2001). The management plan developed by DNR is briefly described here. The current plan covers an area of 125, 980 acres (50,982 hectares). The original goal of the plan was to minimize, based on current understanding of Lynx habitat needs and the landbase's potential to provide Lynx habitat, the probability of a long-term negative effect on the Lynx while integrating other forest management concerns (Washington State Department of Natural Resources 1996). One of the primary management goals is to maintain at least 70 percent forest on the landscape (Washington State Department of Natural Resources 2006). Within that area, specific conservation measures involve maintenance of at least 20 percent foraging habitat and 10 percent denning habitat, including habitat suitable for at least two den sites per mi^2 (5.2 per km^2); the additional 40 percent of the forested land area would be managed as travel habitat (Washington State Department of Natural Resources 2006). The remaining 30 percent of the landscape is considered temporarily unsuitable for Lynx, meaning that in the future it will serve one of the functions described above (Washington State Department of Natural Resources 2006).

Long-legged Myotis

At least 14 bat species are associated with forest environments in Washington (Hayes, in preparation). Habitat relationships for most species have been linked to moist forest conditions, often in or near riparian areas (O'Connell et al. 2000). However, Long-legged Myotis are known to use grand fir snags as day roost locations in forests of the eastern Cascades dominated by ponderosa pine, Douglas fir and grand fir (Frasier 1997, Taylor 1999), and this species appears to have the strongest association with xeric forest conditions in Washington. A recent study of day roosts in the eastern Cascade Mountains found that both large (≥50 bats) and small (<50 bats) flyout roosts used by Long-legged Myotis were in larger-diameter (mean 32.8 and 24 inches or 82.3 and 60.9 cm dbh) and taller snags (103.3 and 87.6 feet or 31.5 and 26.7 meter) with greater amounts of total bark (256 and 200 square inches or 1,649 and 1,291 square centimeters) and exfoliating bark cover (87 and 56 square inches or 561 and 361 square centimeters) than random snags in the landscape. In addition, large and small flyout roosts were characterized by low canopy cover (22 and 31 percent), live tree density of 101 and 118 per acre (249.7 and 291.7 per hectare), respectively, and high snag densities of 16.7 and 17.2 per acre (41.2 and 42.7 per hectare, respectively). Although slightly over one-half (52.8 percent) of the roosts (both large and small) were in ponderosa pines and 37.9 percent were in white and grand firs, 26 of 28 large-flyout roosts were under large plates of bark on ponderosa pines; all roosts in ponderosa pines were under exfoliating bark. Four large flyout roosts supported ≥345 bats (Baker and Lacki 2006).

Western Gray Squirrel

The Western Gray Squirrel, designated a threatened species in Washington by the Washington Fish and Wildlife Commission in 1993 (Linders and Stinson 2006), is found in three discrete areas in the state. Two of these areas are in eastern Washington: an area of southwestern Okanogan County and northeastern Chelan County, and an area that includes much of the western two-thirds of Klickitat County, extreme eastern Skamania County, and a narrow corridor in southcentral Yakima County (see Figure 4 *in* Linders and Stinson 2006). Mean annual home range size was 121 acres (49 hectares) and 694 acres (281 hectares) for females and males, respectively, in Okanogan County, and 44 acres (18 hectares) and 183 acres (74 hectares) for females and males, respectively, in Klictitat County (Linders and Stinson 2006). Squirrels in the northern area are associated with stands of ponderosa pine and Douglas fir and adjacent riparian areas dominated by black cottonwood (Gregory 2005), whereas squirrels in the southern area occur in the zone where ponderosa pine and oak woodlands (each with their associated species) converge (Linders 2000). In Klickitat County, these squirrels used forest with an overstory dominated by ponderosa pine, an understory of oak, and very low shrub cover. Mean canopy cover at the home range scale varied between 25 and 75 percent, and generally exceeded 75 percent in the core use area; forest areas with estimates of canopy cover <25 percent were much less frequently used by squirrels (Linders 2000). Data from plots within the core area of home ranges in Klickitat County indicated high densities of trees (mean = 235.9 per acre or 583 per hectare) of which most were ponderosa pine (406) or oak (144). The mean diameter (at breast height) of ponderosa pines was 9.6 inches (24.3 centimeters) and stand basal area was 103.7 square feet per acre or 23.8 square meters per hectare (Linders 2000). In the northern study area, mean basal area was 118 square feet per acre or 27 square meters per hectare, and mean canopy cover was 45 percent (Gregory 2005). Most nests are in dominant or codominant trees that are >16 inches dbh (>40 centimeters dbh), and are typically larger than other trees in the vicinity; between 72 and 81 percent of nests were in ponderosa pines in the two regions (Linders 2000, Gregory 2005), although another recent survey in the northern area found only 31 percent of nests in ponderosa pine. Nest trees often have crowns that interlock with crowns of multiple adjacent trees (Foster 1992, Linders 2000, Gregory 2005). One-half of nest trees in the northern study area had brooms associated with mistletoe infection (Gregory 2005). Western Gray Squirrel food supply includes acorns from oaks (no production until trees are ≥20 years, maximum production ≥80 years; Peter and Harrington 2002). Ponderosa pine seed is also important, and seed production is strongly associated with tree size (Krannitz and Duralia 2004).

Flammulated Owl

The only North American neotropical migrant owl (McCallum 1994a), the diminutive and insectivorous Flammulated Owl nests in ponderosa pine and mixed pine-fir forests in eastern Washington (Wahl et al. 2005). Mixed pine-fir stands are dominated by ponderosa pine and include Douglas fir, grand fir or western larch (Wahl et al. 2005). Although perhaps more common in western North America than previously thought (McCallum 1994b), this owl is generally uncommon in Washington (Wahl et al. 2005). It tends to nest in open forest on south or east-facing slopes or on ridges (Bull et al. 1990) and has a mean breeding season home range of about 40 acres (16 hectares) (Goggans 1985). Forests used for nesting in Oregon had a mean canopy closure of 55 percent (Bull et al. 1990), and an open understory (Bull and Anderson 1978, McCallum 1994c) with areas of dense vegetation that owls use as roost locations (Goggans 1985). Cavities excavated in snags and occasionally in live trees by Pileated Woodpeckers (*Dryocopus pileatus*), and to a lesser extent by Northern Flickers (*Colaptes auratus*), are used as nests (Bull and Anderson 1978, Bull et al. 1990). Seventy percent of nests in northeastern Oregon were in ponderosa pines and 27 percent were in western larches (Bull et al. 1990). Mean diameter of nest snags / trees was 22 inches (56 centimeters) and 28 inches (72 centimeters) dbh in two studies (Goggans 1985, Bull et al. 1990). It is likely that fire suppression eliminates the open understory believed to be important for this species (McCallum 1994b). Flammulated Owl abundance, population status and specific habitat associations in Washington have not been investigated (Wahl et al. 2005).

White-headed Woodpecker

White-headed Woodpeckers are strongly associated with ponderosa pine and mixed pine-fir forests in Washington (Wahl et al. 2005), where they are a candidate for listing and a "species of greatest conservation concern" (Washington Department of Fish and Wildlife 1999, 2005). Seventeen of 21 known nests in Washington occurred in the ponderosa pine vegetation zone (Buchanan et al. 2003) as defined by Cassidy (1997). White-headed Woodpeckers have surprisingly large annual home ranges for a species of their size (e.g., mean in contiguous habitats = 257 acres [range = 166-403 acres], mean in fragmented habitats = 793 acres [range = 141-11,000 acres] or, in hectares, mean in contiguous habitats = 104 hectares [range = 67-163 hectares], mean in fragmented habitats = 321 hectares [range = 57-445 hectares]; Dixon 1995). Population densities in Oregon were higher in landscapes with higher volumes of old-growth ponderosa pine (Dixon 1995). These woodpeckers forage on ponderosa pine seeds (Dixon 1995) and such seeds are generally more abundant in larger, open-grown trees (Krannitz and Duralia 2004); the mean number of ponderosa pines greater than about 20 inches dbh (>50 centimeters dbh) at nest sites in eastern Washington was 4 per acre (10.4 per hectare) (Buchanan et al. 2003). Snags (n = 17) and trees (n = 4) used for nesting are generally large (mean = about 20 inches dbh or 51.5 centimeters dbh) and range from 6.2 to 118 feet or 1.9 to 36 meters in height (mean = 41.3 feet or 12.6 meters). Canopy closure at nests sites averaged only 7 percent (Buchanan et al. 2003), slightly lower than values reported from Oregon (Frenzel 2000 in Marshall 2003). Although only 4 of the sites in Washington exhibited any evidence of silvicultural activity (Buchanan et al. 2003), 86 percent of 66 sites in eastern Oregon had been harvested in some manner (Frenzel 2000 in Marshall 2003). White-headed Woodpeckers in sites that had been harvested in Oregon (partial cut = 9, clearcut = 9, shelterwood or seedtree = 11, overstory removal = 7, commercial thin = 2, precommercial thin = 3) had substantially lower nesting success (35.6 percent) compared to that in uncut stands (62 percent; Frenzel 2000 in Marshall 2003). Sixteen of 17 nests that were found in the ponderosa pine vegetation zone in eastern Washington (as defined by Cassidy 1997) occurred below 3,999 feet elevation (1,219 meters) and on slopes <20 percent; these combined attributes comprise only 33.6 percent of the vegetation zone in the eastern Cascade Mountains (Buchanan et al. 2003).

Appendix C

Washington State Department of Natural Resources Policies, Procedures, and Strategies as a Management Framework for DNR lands in Eastern Washington

by Tami Miketa

Appendix C

Washington State Department of Natural Resources Policies, Procedures, and Strategies as a Management Framework for DNR lands in Eastern Washington

by Tami Miketa

The Washington State Department of Natural Resources (DNR) manages approximately 700,000 acres (283,280 hectares) of forested state trust lands in eastern Washington. Except for the State Natural Area Preserves and the Natural Resources Conservation Areas, these forestlands are managed in trust. Under the short- and the long-term, DNR's fiduciary responsibility is to maintain and generate revenue from those forested trust lands to benefit the designated beneficiaries. In addition to trust obligations, DNR is subject to a number of federal and state statutes that protect public resources and provide public benefits. To fulfill these mandates, there are governing regulations, policies, procedures, and strategies for management of forested state trust lands.

DNR Policy for Sustainable Forests

The Board of Natural Resources set the major policies for DNR-managed state lands through the *Policy for Sustainable Forests* (December 2006). This document is intended to conserve and enhance natural systems and resources of forested state trust lands managed by DNR to produce long-term, sustainable trust income, and environmental and other benefits for the people of Washington. The *Policy for Sustainable Forests* contains four policies, described below, that are pertinent to management of eastside forests.

General Silvicultural Strategy Policy

The *General Silvicultural Strategy* (PO14-019) encourages the use of innovative silviculture to create, develop, enhance, or maintain forest biodiversity, health and revenue potential. The policy states that DNR will:

- Provide professional management of forested state trust lands through active management and stewardship of the greatest possible portion on these lands;
- Carry out active management as an integral part of the department's fiduciary responsibilities to achieve, on a landscape basis, a combination of forest structures that, over time, provide for broad and balanced economic, ecological and social benefits; and
- Use intensive and innovative silviculture to guide the desired progression of stand development to simultaneously produce trust revenue and create structural diversity across the landscape.

Forest Health Policy

The *Forest Health Policy* (PO14-006) identifies two major components of maintaining forest health, which are: 1) prevention of damage by maintaining ecologically appropriate species composition/age and stocking levels; and 2) treatment of insects, noxious weeds, disease, and animal damage when their impacts are excessive. The DNR forest health priority in this policy is to develop landscape strategies at an appropriate scale to address the forest health issues of overstocking and/or inappropriate species composition. Using vegetative series or other appropriate guidelines, the goal is to adjust stand composition to favor species best adapted to the site.

Catastrophic Loss Prevention Policy

The *Catastrophic Loss Prevention Policy* (PR14-007) recognizes that one of DNR's primary fiduciary responsibilities is to protect trust assets from catastrophic loss due to wildfire, or other factors such as wind, insects, and disease. This policy commits DNR to: 1) incorporate strategies, including development of fire-resistant stands, to prevent catastrophic loss into its management of forested state trust lands; and 2) coordinate with local, state, and federal fire prevention programs; the scientific community; other agencies; and other landowners to reduce the risk of forest resource loss from catastrophic events.

Wildlife Habitat Policy

An additional policy that is pertinent to management of eastside old forest conditions is the *Wildlife Habitat Policy* (PO14-009). This policy states that an important trust objective is the conservation of upland, riparian, and aquatic wildlife species, including fish and their habitats, species listed as threatened and endangered, and non-listed species. DNR has adopted a number of land management strategies that incorporate the importance of biodiversity to ecosystem integrity. In essence, the *Wildlife Habitat Policy* states that the department's conservation efforts will focus on biodiversity, which is recognized as the fundamental guiding principle for sustainable forest management. Specifically, the department will meet the requirements of federal and state laws that protect endangered, threatened, and sensitive species and their habitats; and when consistent with trust objectives, the department intends to voluntarily participate with federal and state agencies and other organization or governments, in additional efforts to protect state and federal listed threatened and endangered species, recover and restore their habitat, and participate in initiatives related to non-listed species and habitats.

DNR State Trust Lands Habitat Conservation Plan

In 1997, DNR implemented a long-term multi-species Habitat Conservation Plan (HCP), authorized under the Endangered Species Act, with U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration Fisheries Service. This HCP, which covers 1.8 million acres (728,435.3 hectares) within the range of the Northern Spotted Owl, allows DNR to harvest timber and engage in other management activities, while emphasizing wildlife species conservation and ecosystem health as the basis for prudent trust management.

In eastern Washington, the HCP provides specific conservation strategies for the Northern Spotted Owl along the eastern slopes of the Cascade Mountains. The objective of this conservation plan is to provide habitat that makes a significant contribution to demographic support, maintenance of species distribution, and facilitation of dispersal. The Northern Spotted Owl strategy is intended to provide nesting, roosting, and foraging (NRF) habitat and dispersal habitat in strategic areas to achieve the conservation objectives. In areas designated to provide habitat, the strategy is intended to create a landscape in which active forest management plays a role in the development and maintenance of structural characteristics that constitute such habitat. The HCP conservation strategies for the Northern Spotted Owl consist of four main components: 1) identification of DNR-managed lands most important to Northern Spotted Owl conservation; 2) determination of habitat goals for areas established to provide NRF habitat; 3) guidelines for management activities allowed in NRF management areas; and 4) guidelines for the provision of dispersal habitat.

Approximately 230,000 acres (93,078 hectares) of DNR-managed lands are covered by the HCP in three eastside landscapes: the Chelan, Yakima, and Klickitat planning units (for a map of these planning units, refer to the maps located in the last section of the 1997 DNR state lands Habitat Conservation Plan). In areas designated to provide NRF habitat, DNR shall provide a target condition of at least 50 percent of its managed lands measured within each Watershed Administrative Unit as NRF habitat.

Nesting, roosting, and foraging functions are provided by sub-mature, mature, and old-growth forest types in eastern Washington. Both Type A and sub-mature habitat provide nesting habitat. The Type A habitat definition is included as a reference point for the range of habitat qualities that exist in eastern Washington. The management standards use the sub-mature definition as the minimum standard for spotted owl nesting habitat to be met within NRF management areas.

Type 'A' Spotted Owl Habitat

Nesting, roosting, and foraging habitat in eastern Washington generally occurs in grand fir, Douglas fir, and ponderosa pine forest zones. Forest stands of Type A habitat are mature habitat that has naturally regenerated following wind throw or fire. These stands have the following characteristics:

- Multi-layered, multispecies canopy dominated by overstory trees that exceed 20 inches (51 centimeters) DBH (typically 35-100 trees per acre, or 86 to 247 per hectare);
- At least 75 percent canopy closure;
- Some dominant trees have mistletoe brooms, cavities, or broken tops;

- Three snags per acre (or 7.4 per hectare) greater than or equal to 20 inches (50.8 centimeters) DBH; and
- Down woody debris that is greater than or equal to 20 inches (50.8 centimeters) DBH and accumulations of other woody debris.

Submature Spotted Owl Habitat

This definition is applied as average conditions over a stand. Submature habitat has the following characteristics:

- Forest community composed of at least 40 percent Douglas fir or grand fir;
- Canopy closure of at least 70 percent;
- Tree density of between 110 and 260 trees per acre (or 271.8 to 642.4 per hectare);
- Either tree height or vertical diversity (one characteristic but not both needs to be present):
  - o Dominant and co-dominant trees at least 90 feet (27 meters) tall; and
  - o Two or more canopy layers with numerous intermediate trees and low perches;
- Either snags/cavity trees or mistletoe infection (one characteristic but not both needs to be present):
  - o If mistletoe is not present, three or more snags or cavity trees per acre (7.4 or more per hectare) equal to or greater than 20 inches (51 centimeters) DBH must be present.

Spotted Owl Dispersal Habitat

In areas designated to provide dispersal habitat, DNR shall provide a target condition of at least 50 percent of its managed lands measured within each quarter township be maintained as dispersal habitat. The definition of dispersal habitat is applied as average conditions over a stand. Dispersal habitat has the following characteristics:

- At least 50 percent canopy closure;
- Overstory tree density of at least 40 trees per acre (98.8 per hectare) that are at least 11 inches (27.9 centimeters) DBH;
- Top height of at least 60 feet (18 meters); and
- Retention of 4 green trees per acre (or 9.8 per hectare) from the largest size class present for recruitment of snags and cavity trees.

Administrative Amendment

In 2004, DNR implemented an *Administrative Amendment to the Northern Spotted Owl conservation strategy for the Klickitat Planning Unit*. The primary reason for a modified approach to Northern Spotted Owl conservation in this planning unit is that some forests on the east slopes of the Cascade Range in Washington are experiencing serious forest health problems. In some areas, disease is degrading or eliminating habitat for the Northern Spotted Owl. This problem is compromising the effectiveness of the original HCP conservation strategy in the Klickitat Planning Unit.

A requirement of this modified approach was that it must allow DNR to manage forestlands as long-term, sustainable forest ecosystems. This modified approach to Northern Spotted Owl conservation delineated four sub-landscapes, each assessed by vegetative series, forest health conditions, and use by Northern Spotted Owls. Management approaches were developed for each sub-landscape based on this information.

The Administrative Amendment also identifies forest health concerns that may arise in the future. Specifically, the modified approach results in:

- Moving forests toward historic cover types more resistant to fire and insects;
- Improving DNR's ability to meet its HCP commitments by focusing development of Northern Spotted Owl habitat where it can be sustained for the long-term;
- Managing habitat by vegetative series, forest health conditions, and historic Northern Spotted Owl use within sub-landscapes;
- Eliminating requirements to create and protect Northern Spotted Owl habitat where it may not be sustainable; and
- Promoting active management of the entire landscape over time to meet both Northern Spotted Owl conservation and sustainable forest objectives.