



UNITED STATES
DEPARTMENT OF
AGRICULTURE

FOREST SERVICE

PACIFIC NORTHWEST
REGION

MARCH 2013



OREGON WHITE OAK RESTORATION STRATEGY FOR NATIONAL FOREST SYSTEM LANDS EAST OF THE CASCADE RANGE



ABSTRACT

Significant work has been undertaken to conserve and restore Pacific Northwest Oregon white oak habitats, but this work has almost entirely focused on lands west of the Cascade Range. Much of the historical eastside Oregon white oak savanna and woodland habitat has been lost, and the combined effects of fire suppression, invasive species, grazing, and development threaten significant portions of the remaining extent. This restoration strategy focuses on conservation and preservation of stands that are still structurally and functionally intact, and restoration of degraded stands, to ensure the longevity of this habitat and the species that rely on it. The target audience is managers at the Mt. Hood, Gifford Pinchot, and Okanogan-Wenatchee National Forests and the Columbia River Gorge National Scenic Area. The strategy includes a review of the relevant biological and ecological literature, a discussion of restoration issues, tools for prioritizing restoration sites and choosing management actions, and discussion of management activities. Also included are maps, restoration case studies, recommendations for planning and research, and an annotated bibliography of relevant literature.

KEYWORDS

Oregon white oak, *Quercus garryana*, restoration, release, thinning, fuels reduction

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

COVER PHOTO

Provided by Columbia River Gorge National Scenic Area

EDITORIAL SUPPORT AND DOCUMENT DESIGN

Provided by Publishing Arts, USDA Forest Service. http://fsweb.wo.fs.fed.us/em/nfs_bass/

SUGGESTED CITATION

Devine, W.; Bower, A.; Miller, J.; Aubry, C. 2013. Oregon white oak restoration strategy for National Forest System lands east of the Cascade Range. Olympia, WA: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 97 p.

OREGON WHITE OAK RESTORATION STRATEGY FOR NATIONAL FOREST SYSTEM LANDS EAST OF THE CASCADE RANGE

MARCH 2013

Prepared by:

Warren Devine, Andrew Bower, Jeanne Miller, and Carol Aubry

Contributors:

Kristen Chadwick, Forest Service Forest Health Protection

Lindsay Cornelius, Columbia Land Trust

Whitney Olsker, Mt. Hood National Forest

Roland Rose, Columbia River Gorge National Scenic Area

Mark Williams, Bureau of Land Management

Authors

Warren Devine is a biological scientist, 1835 Black Lake Blvd. SW, Suite A, Olympia, WA 98512; **Andrew Bower and Carol Aubry** are geneticists, U.S. Department of Agriculture, Forest Service, Olympic National Forest, 1835 Black Lake Blvd. SW, Suite A, Olympia, WA 98512; and **Jeanne Miller** is a GIS specialist, 1835 Black Lake Blvd. SW, Suite A, Olympia, WA 98512.

Table of Contents

Executive Summary.....	1
Chapter 1. Introduction.....	2
Chapter 2. Literature Review	3
Distribution.....	3
Physical Description.....	3
Genetics	5
Reproduction	6
Growth and Development.....	7
Successional Role.....	8
Adaptations to Fire	8
Wildlife Habitat.....	9
Eastside Oregon White Oak Community Types.....	9
Soils	11
Insect Threats.....	12
Disease Threats.....	12
Other Threats to Eastside Oregon White Oak Habitat.....	14
Classification Systems.....	14
Growth and Mortality Modeling.....	15
Chapter 3. Restoration Issues	17
Restoration Targets.....	17
Distribution of Oak Habitats	17
Public Outreach and Collaboration.....	18
Sensitive Species	19
Gene Conservation	19
Climate Change	20
Chapter 4. Development of a Landscape-Scale Restoration Strategy	23
Phase 1: Mapping	23
Phase 2: Ecological Prioritization of Sites	24
Phase 3: Site Selection.....	26
Chapter 5. Stand-Level Restoration.....	27
Flowchart A - Location	28
Flowchart B - Conifer Competition.....	30
Flowchart C - Habitat	32
Flowchart D - Density	34
Flowchart E - Regeneration.....	36

Flowchart F - Understory	38
Chapter 6. Management Actions	40
1. Map and Inventory at the Stand Level.....	40
2. Release from Conifer Encroachment.....	41
3. Planting Oak	44
4. Thinning Oak Stands	47
5. Prescribed Burning	50
6. Monitoring.....	53
7. Managing Understory Plant Species.....	55
Chapter 7. Recommendations.....	58
Landscape-Scale Planning.....	58
Individual Restoration Projects	58
Research Needs	58
Chapter 8. Case Studies.....	60
Case Study 1: Goldendale Fuels Reduction and Oak Woodland Restoration	60
Case Study 2: Columbia Land Trust Oak Restoration: Dillacort Creek, Logging Camp Creek, Bowman Creek, and Little White Salmon – Wind Rim	62
Case Study 3: Rock Thin.....	70
Case Study 4: Burdoin Mountain	73
Case Study 5: Collins Slide	74
Case Study 6: Catherine Creek.....	76
Case Study 7: Hazardous Fuel and Oak Restoration work (CRGNSA-WDNR Agreement).....	79
Case Study 8: Rowena 2007 Oak Restoration.....	79
Case Study 9: Seven Mile Fuels Treatment Restoration Project.....	80
Case Study 10: D10 Underburn.....	81
Chapter 9. Additional Resources	82
Working Groups	82
Key Publications.....	82
Acknowledgments	84
Metric Equivalents.....	85
Literature Cited.....	86
Appendix	87

List of Figures

Figure 1. Range of Oregon white oak.....	3
Figure 2. Documented occurrences of Oregon white oak (<i>Quercus garryana</i>) in southcentral Washington and northcentral Oregon	4

Figure 3. Occurrences of Oregon white oak (<i>Quercus garryana</i>) in the northeastern Mt. Hood National Forest area	94
Figure 4. Occurrences of Oregon white oak (<i>Quercus garryana</i>) in the eastern Mt. Hood National Forest area.....	95
Figure 5. Occurrences of Oregon white oak (<i>Quercus garryana</i>) stands in southcentral Washington and northcentral Oregon, as mapped in the Washington Department of Fish and Wildlife Klickitat Study	96
Figure 6. Locations of all FIA annual inventory plots, regardless of which tree species were recorded	97

List of Tables

Table 1. Species composition of overstory and understory layers of eastside Oregon white oak communities.....	10
Table 2. Eastside plant associations containing Oregon white oak	16
Table 3. Example of a system developed to calculate a prioritization score for each site considered for potential restoration activities	25

EXECUTIVE SUMMARY

Significant work has been undertaken to conserve and restore Pacific Northwest Oregon white oak habitats, but this work has almost entirely focused on lands west of the Cascade Range. Much of the historical eastside Oregon white oak savanna and woodland habitat has been lost, and the combined effects of fire suppression, invasive species, grazing, and development threaten significant portions of the remaining extent.

The goal of this strategy is to provide a framework to restore and conserve Oregon white oak habitats on eastside National Forest System lands. The strategy focuses on conservation and preservation of stands that are still structurally and functionally intact, and restoration of degraded stands, to ensure the longevity of this habitat and the species that rely on it. The target audience is managers at the Mt. Hood, Gifford Pinchot, and Okanogan-Wenatchee National Forests and the Columbia River Gorge National Scenic Area.

This strategy includes:

Literature Review—A review of what is currently known about eastside oak and oak habitats.

Important Restoration Issues—An overview of relevant issues such as habitat distribution, gene conservation, and climate change.

Development of a Landscape-Scale Restoration Strategy—A proposed approach for planning restoration at the landscape level.

Stand-Level Restoration—A section including flow diagrams to assist managers with the planning process, as well as descriptions of specific management actions with annotated lists of references.

Recommendations—Key components of restoration planning and a list of research needs.

Case Studies—Ten case studies to provide insight on oak habitat restoration based on the experiences of regional forest managers.

Recommendations

Landscape-Scale Planning

- **Map oak habitat**—Compile existing spatial data and determine data needs so that a comprehensive map of eastside oak habitat can be created.
- **Prioritize sites**—Develop a protocol to assess the priority of potential restoration sites based on ecological habitat value and likelihood of habitat loss without treatment.
- **Strategize at the landscape level**—Combine mapped habitat and site prioritization data with landscape-level considerations such as habitat connectivity and occurrences of sensitive species.

Individual Restoration Projects

- **Set restoration targets**—Base restoration projects on defined targets that are measureable and attainable.
- **Conduct outreach and collaborate**—Conduct proactive public outreach as an initial step in restoration projects. Collaborate with other agencies and groups to share knowledge, experience, and resources.
- **Monitor**—Restoration projects should include a monitoring component to measure if restoration targets have been met.

Research Needs

Key areas of research include:

- Genetic structure of eastside oak populations
- Understory management, including effects of fire
- Density management in oak-pine stands
- Oak regeneration
- Historical and potential extent of eastside oak habitat

CHAPTER 1. INTRODUCTION

During the past 2 decades, conservation, management, and research have progressed rapidly for the Oregon white oak (*Quercus garryana*) and prairie ecosystems west of the Cascade Range in the Willamette Valley – Puget Trough – Georgia Basin ecoregion of Oregon, Washington, and British Columbia (Dunwiddie and Bakker 2011). However, Oregon white oak habitat east of the Cascade Range crest (i.e., “eastside”) and in the Columbia River Gorge has so far received less attention, particularly from researchers.

Oregon white oak is capable of growing on a wide variety of sites; however, it is relatively slow-growing and on moister sites is often outcompeted by other tree species such as Douglas-fir (*Pseudotsuga menziesii*).

Historically, the regular occurrence of fire favored Oregon white oak over less fire-tolerant tree species. Without fire, Oregon white oak is limited to sites that are too exposed or droughty for other species during at least part of the year (Stein 1990). East of the Cascades, Oregon white oak occupies the transition zone between conifer forest and shrub-steppe, where low soil moisture reduces or precludes the occurrence of other tree species (Silen 1958, Voeks 1981).

Eastside Oregon white oak can be found in dense, pure stands, in open woodlands and savannas, and as a component of mixed oak-conifer stands (Larsen and Morgan 1998). On xeric eastside sites, ponderosa pine (*Pinus ponderosa*) is Oregon white oak’s most frequent conifer associate, although where soil moisture is slightly greater, Douglas-fir becomes increasingly common. Competition from Douglas-fir is substantial in the transitional zone between the west and east sides of the Cascades, particularly in the Columbia River Gorge.

Much of the historical eastside Oregon white oak savanna and woodland habitat has been lost, and the combined effects of fire suppression, invasive species, grazing, and development threaten significant portions of the remaining extent. Conservation and preservation of stands that are still structurally and functionally intact, and restoration of degraded stands, are needed to ensure the longevity of this habitat and the species that rely on it.

This strategy frequently discusses “oak stands” and “oak communities,” but our focus is not on the restoration of a single tree species; rather, the goal of the strategy is to restore functioning ecosystems, of which Oregon white oak is a vital structural component. This includes restoration of healthy, reproducing oak trees, as well as ponderosa pine, native understory vegetation, and associated wildlife species.

The Goal ***Restore and*** ***conserve Oregon*** ***white oak habitats*** ***on eastside*** ***National Forest*** ***System lands***

This strategy was written for managers on the Mt. Hood, Gifford Pinchot, and Okanogan-Wenatchee National Forests and the Columbia River Gorge National Scenic Area; however, much of its contents may also be useful to managers in other agencies, conservation organizations, and landowners. Although the focus of the strategy is eastside oak ecosystems, some sections provide information that is also relevant to

ecosystems west of the Cascades.

The strategy begins by summarizing the literature on the biology of Oregon white oak and eastside oak communities. The subsequent chapters provide information, examples, and tools to help land managers select restoration sites and plan restoration treatments. It includes a scoring system that may be used to assist in prioritizing potential restoration sites based on habitat value, threats, and dependent species. Also included is a series of flow diagrams designed to assist managers in selecting the most appropriate management activities for a particular site.

CHAPTER 2. LITERATURE REVIEW

Distribution

The native range of Oregon white oak (*Quercus garryana*, also known as Garry oak) is an inland region along the Pacific Coast from southwestern British Columbia to southern California (fig. 1). In the Pacific Northwest, defined here as Washington and Oregon, Oregon white oak occurs west of the Cascade Crest from the Puget Trough through the Willamette Valley and southward throughout southwestern Oregon into California. East of the Cascade Crest, Oregon white oak occurs as far north as Swauk Creek (Kittitas Co., WA) and as far south as Warm Springs Indian Reservation (OR), although its occurrences become sporadic near the northern and southern extremes of this eastside range (fig. 2). Oregon white oak is common in the area north of the Columbia River Gorge as far east as eastern Klickitat Co., WA. It is common south of the Gorge as far east as the vicinity of The Dalles, OR. Additional maps showing documented occurrences of eastside oak appear in the Appendix.

Physical Description

Oregon white oak is a broadleaf, deciduous tree with a maximum size that varies widely depending on site. Heights may reach 100 ft (30 m) on a moist, productive site or only 20 ft (5 m) on the driest sites, where it exhibits a stunted growth form. It is often multi-stemmed, and commonly occurs in clumps, where multiple trees have originated as sprouts from a single rootstock. Whereas access to water strongly influences maximum height, competition from other trees determines crown shape, which also is quite variable. Savanna and open-grown woodland trees may have a broad, mushroom-shaped crown with large, spreading limbs. In higher-density stands, oak trees typically have a crown shaped like a vase: limbs are ascending, and crowns are much narrower than those of open-grown trees. These narrow-crowned

trees growing in dense woodlands or forests have a more slender stem than open-grown trees (Gould et al. 2011). Often, multi-stemmed trees or clumps of trees will have crowns that, in aggregate, resemble a broad, mushroom shape. Oregon white oak may live 300 to 400 or more years (Gedalof et al. 2006, Gilligan and Muir 2011).

Oregon white oak has a prominent and fast-growing taproot that forms soon after germination, presumably as an adaptation for reaching soil moisture to survive the dry summer conditions typical of the species' native range (Hibbs and Yoder 1993). Seedlings invest much of their early growth below ground; this, combined with their capacity to re-sprout, makes them well-adapted to surviving top-kill. As it reaches the sapling stage, Oregon white oak produces an increasing number of lateral roots.

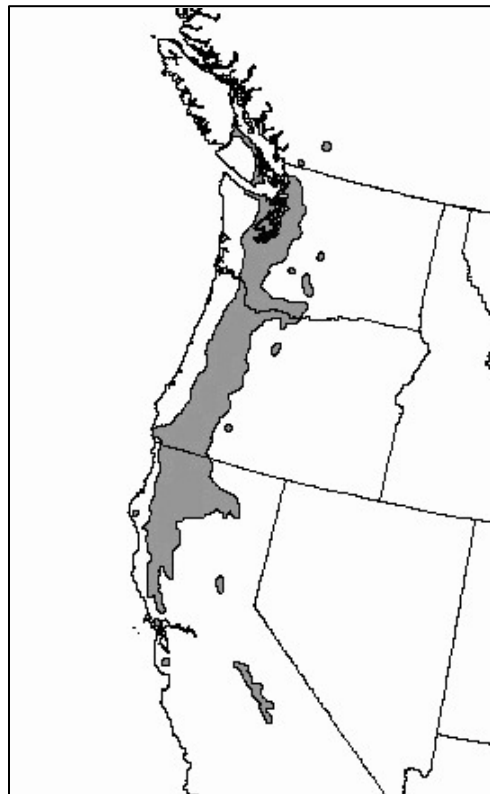
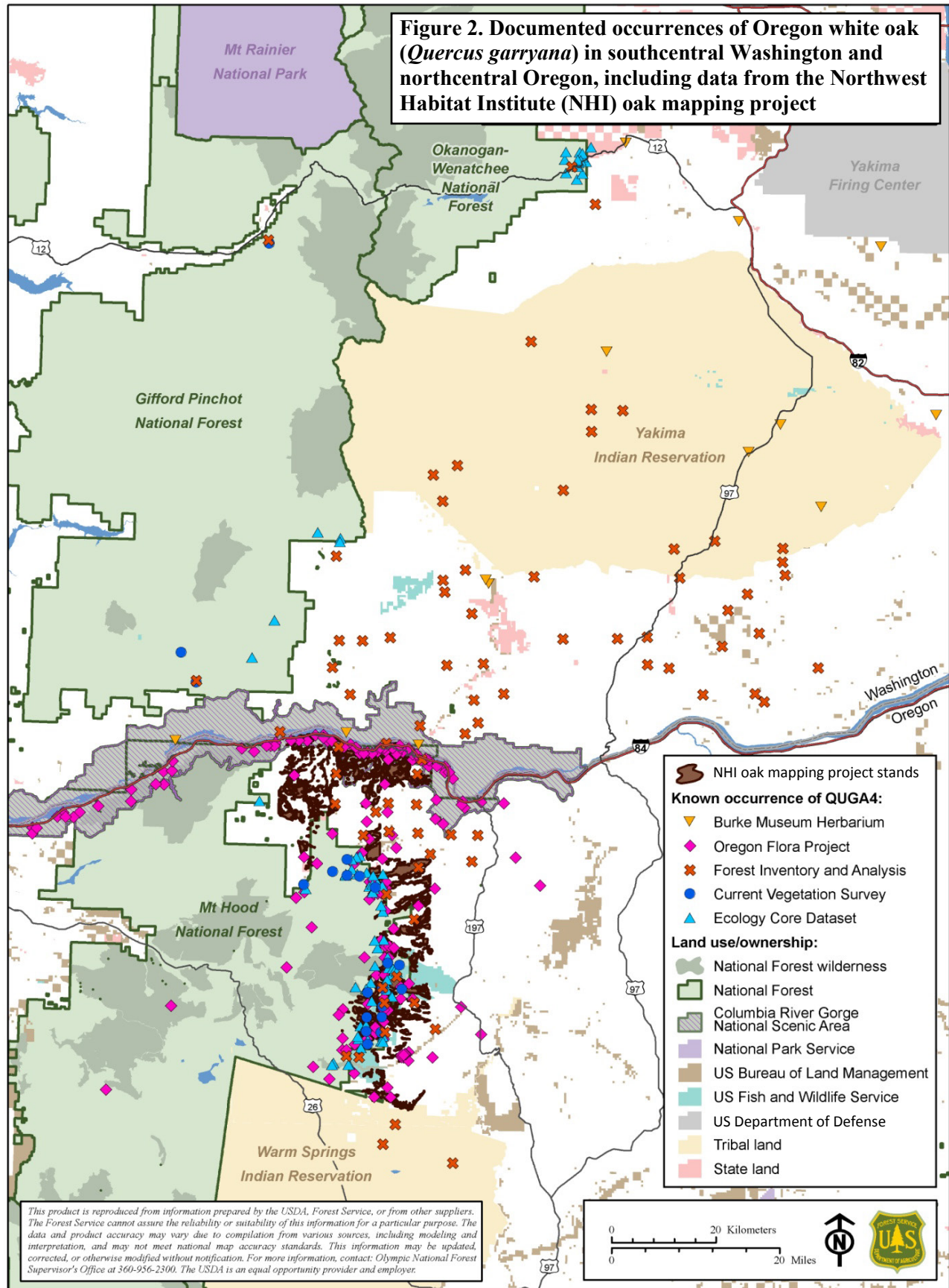


Figure 1. Range of Oregon white oak.
From: USGS (1999).





Andrew Bower, U.S. Forest Service (both photos)

Oregon white oak crown shapes vary dramatically, depending on competition. Narrow crowns in dense stands have been described as “vase shaped” (left), whereas spreading, open-grown trees have “mushroom shaped” crowns (right).

At maturity, trees exhibit a well-developed lateral root system in surface soils, in addition to a taproot (Krygier 1971, Devine and Harrington 2005). Oregon white oak root systems are capable of adapting to very rocky soils and horizons that severely limit taproot growth (Devine and Harrington 2005). Oregon white oak's mycorrhizal associations have been documented on several sites (Moser et al. 2005, Southworth et al. 2009, Valentine et al. 2002); the presence of these mycorrhizal associations has been correlated with an increased seedling growth rate (Devine et al. 2010b).

Genetics

There are three varieties of Oregon white oak, although only *Q. garryana* var. *garryana* occurs in the region discussed in this strategy. The other two varieties occur in southwestern Oregon (var. *breweri*) and California (var. *semota*). Based on genetic markers, Oregon white oak has lower levels of genetic diversity relative to other species but experiences very little inbreeding. Populations west of the Cascade mountains fall into two main groups north and south of the Strait of Juan de Fuca. However, populations within these groups are generally not strongly

differentiated genetically. Populations in the northern part of the species' range, and those that are geographically isolated, have the lowest genetic diversity (Ritland et al. 2005, Marisco et al. 2009). A study of seedling traits also found relatively weak population differentiation, but significant genetic differences for height growth, date of germinant

emergence, and cold hardiness were related to climate variables. Height and date of germinant emergence were both related to summer aridity, whereas cold hardiness was related to temperature (Huebert 2009). Research on the genetic structure of both eastside and westside oak populations is ongoing (Andrew Bower, study lead).

Huebert (2009) provided guidelines for Oregon white oak seed movement based on results from a common garden study. He suggested that seed can be moved between areas differing by as much as 0.75 in. of summer precipitation or as much as 1.8 °F in mean temperature of the warmest month, with minimal risk of being poorly adapted to the new environment. These climatic differences equate to approximately 2 degrees latitude, 1 degree longitude, or 500 ft in elevation. Temperature and precipitation information for a specific location (latitude/longitude/elevation) can be obtained from the ClimateWNA program online at http://www.genetics.forestry.ubc.ca/cfcg/ClimateWNA_web/. It should be noted, however, that no eastside oak populations were included in Huebert's (2009) study.

Current genetic investigations of Oregon white oak have not included sources from east of the Cascades. A study is under way to assess the level of genetic diversity in eastside populations and to determine how closely they are related to westside populations.

Reproduction

Oregon white oak flowers in the spring around the time its leaves are expanding. It is a wind-pollinated monoecious species, with separate male and female flowers on the same individuals. Oregon white oak acorns develop over a single growing season, and reach maturity between late August and October, depending on region and annual climate patterns. At maturity, acorn length averages 0.8 to 1.2 in., and weight averages 0.18 ounces (85/lb) (Bonner and Karrfalt 2008). Acorn production begins around age 20, and trees reach maximum production around age 80, after which production levels off (Peter and Harrington 2002).

Individual-, population-, and regional-scale factors influence individual tree acorn production (Peter and Harrington 2002, 2009). At the individual-tree level, crown competition is negatively associated with acorn production: as the percentage of a tree's crown perimeter that is in contact with adjacent crowns increases, a tree's probability of acorn production decreases. Similarly, crown shape, which is related to the level of competition a tree receives, is also associated with acorn production. Production is greatest for mushroom-shaped crowns, associated with open-grown trees, and least for vase-shaped crowns, which are associated with crowded, forest-grown trees. Within the range of soils on Oregon white oak westside sites, acorn production is highest for trees with high available water capacity (Peter and Harrington 2002). In an analysis of Oregon white oak acorn production throughout the Pacific Northwest, the highest level of production was associated with eastside oak populations on riparian sites (Peter and Harrington 2009).



Paul Slichter

Newly emerged leaves and highly visible male flowers of Oregon white oak.

Most populations of Oregon white oak exhibit a high level of inter-annual variation in acorn production, with large acorn crops occurring two to three years apart (Peter and Harrington 2009). Levels of acorn production are generally synchronous within a region (the Columbia Gorge-eastside Cascades is a single region), but range-wide synchrony is observed only in years of very high or very low production. The level of acorn production in a given year is influenced by climatic factors (Peter and Harrington 2009). For example, for eastside oak, June precipitation is positively correlated with the level of acorn production in that year. However, June precipitation is also negatively correlated with acorn production in the *following* year, suggesting that resources are usually not sufficient to produce large crops in consecutive years. An exception to this pattern occurs among eastside riparian populations; many of these trees are

capable of producing large acorn crops in most years (Peter and Harrington 2009).

Acorns are dispersed by mammals, birds, and gravity, although potential dispersal distances are greatest for acorns dispersed by birds (more than 1,000 ft). In central Oregon, acorns were dispersed by a variety of species including Douglas squirrels (*Tamiasciurus douglasii*), western gray squirrels (*Sciurus griseus*), Steller's jays (*Cyanocitta stelleri*), and Lewis's woodpeckers (*Melanerpes lewis*) (Voeks 1981). Overall, cumulative Oregon white oak acorn predation—predation by mammals, birds, and insects—is very high (Coblentz 1980, Voeks 1981).

Oregon white oak acorns may be stored under refrigeration at temperatures just above freezing for up to 2 years without significant loss of viability (Devine et al. 2010a). However, acorns are highly prone to germination during storage, with most germinating between 6 and 12 months after being placed in refrigerators. Storage has been shown to be most successful when acorns with a healthy appearance are washed and placed in freezer bags or specialized gas-permeable bags prior to being placed in refrigerators (Devine et al. 2010a).

Oregon white oak reproduces vegetatively by sprouting from the root crown (i.e., the base of the stem around the point where it enters the ground) or, less often, from roots. The sprouts are typically triggered by top-kill from harvest or fire, but they may

also occur when a tree is damaged or stressed.

Sprouting is very common but does not occur on all trees, even among young trees, which are more prone to sprouting than older trees.

Growth and Development

Oregon white oak acorns germinate in the fall, not long after they are dropped or cached by animals. Acorns do not persist in the seed bank from one year to the next. Factors reducing germination rates are predation, desiccation, and fire. Unless acorns are buried under soil or litter, the likelihood of loss to predation or desiccation is very high (Fuchs et al. 2000).

Assuming sufficient moisture availability, germination percentages are high for Oregon white oak (Bonner and Karrfalt 2008). After germinating, Oregon white oak produces a rapidly growing taproot, and later, a comparatively small shoot. The primary source of germinant mortality is desiccation. Alternatively, desiccation sometimes results in shoot mortality (i.e., top-kill), after which the rootstock subsequently re-sprouts. Growth of Oregon white oak trees varies by site, but growth rates generally increase to a maximum when trees are around 40 cm (16 in.) diameter and then decline after that (Gould et al. 2011). Growth rates also decline as stand density increases.

At the seedling and sapling stages, Oregon white oak commonly experiences top-kill as a result of fire, mechanical damage, or drought, but it is highly adapted to sprouting. Individuals may suffer top-kill multiple times before attaining a size sufficient to withstand surface fires, browse or other types of damage.

Oregon white oak is a prolific producer of epicormic branches (i.e., branches that originate from dormant buds on a tree's stem or major limbs) (Devine and Harrington 2006). Sprouting of new epicormic branches is most commonly triggered by an increase in sunlight or by damage to the tree. Trees that have undergone severe crown damage, or crown dieback as a result of shading from competitors, often initiate



Andrew Bower, US Forest Service

Oregon white oak acorns.

epicormic branches, some of which persist and continue to develop over time (Devine and Harrington 2006).

Successional Role

Although Oregon white oak is shade-tolerant as a seedling, its shade tolerance decreases with age, and mature trees are intolerant of shade from other oak trees and from other species. When overtopped by Douglas-fir (*Pseudotsuga menziesii*), oak suffers crown dieback, declining vigor, and eventual mortality (Devine and Harrington 2006).

On most sites historically occupied by Oregon white oak, it has the capacity to establish as a pioneer species and then persist as a disturbance climax species, given recurring fire. On these sites, oak depends on fire at an interval sufficient to prevent regeneration and eventual dominance of conifers. On sites that support Douglas-fir, it is the primary competitor of Oregon white oak. On dry sites where ponderosa pine (*Pinus ponderosa*) is the primary conifer species, it provides competition, albeit often at a lower intensity than Douglas-fir. Oak and ponderosa pine co-exist as a climax forest type in some areas (Lillybridge et al. 1995).

In the absence of fire, the rate at which early seral Oregon white oak succeeds to conifers is largely determined by the amount of available growing-season moisture; with greater moisture, conifers establish and grow more rapidly. Westside oak savannas may have been burned by Native Americans as often as every year (Gedalof et al. 2006); this frequent anthropogenic ignition was vital in preventing rapid conifer encroachment on most westside sites. On eastside sites, the historical fire frequencies were lower because plant production and accumulation of fuels is slower; the fire return interval was probably around 5 to 30 years on eastside Washington oak sites (Lillybridge et al. 1995). Although lightning ignition is much more common on the eastside than on the westside, oak woodlands may also have been burned by Native Americans (Agee 1994). Thus, the

distribution of oak on the eastside has been influenced to a large extent by the fire regime that was present prior to European settlement. Without the same fire regime, successional pathways and the composition and structure of eastside seral forest stands will certainly differ from pre-settlement conditions.

Oregon white oak also may exist as a climax species—in the absence of disturbance—on very dry eastside sites that are unsuitable for Douglas-fir and, at best, marginal for ponderosa pine (Lillybridge et al. 1995). Such sites include dry uplands, shallow rocky soils, and steep slopes near the eastern edge of Oregon white oak's distribution.

Adaptations to Fire

Oregon white oak is highly adapted to fire (Gucker 2007). Trees resist fire damage or mortality owing to protective bark, the capacity to sprout following top-kill, and relatively low flammability of foliage. Oregon white oak is infrequently killed by fire, although saplings, seedlings, and sometimes mature trees, may incur top-kill. Trees that have been top-killed or damaged by fire usually sprout from the root crown or from roots. These sprouts are typically numerous and grow rapidly. Oak stands that are scrubby, such as those originating from sprouts after logging or other activities, have greater susceptibility to stand-replacing fire (Lillybridge et al. 1995). In general, the historical fire interval in Oregon white oak stands is not evident in fire scars because fires were typically of low intensity and thus did not produce scarring in oak trees (Agee 1993).

Oregon white oak's two primary competitors, Douglas-fir and ponderosa pine, are also resistant to fire at maturity. Young ponderosa pine is relatively resistant to low-intensity fire (Habeck 1992). Douglas-fir is susceptible to fire-induced mortality at the seedling, sapling, and pole stages, but becomes resistant to fire at about 40 years of age (Steinberg 2002).

Wildlife Habitat

Oregon white oak woodland and savanna stands provide important food and cover for a wide range of wildlife species (Gucker 2007, Manuwal 2003). Key food sources associated with Oregon white oak include acorns, leaves, and invertebrates living in the vicinity of trees. Acorns are consumed by small mammals (including the western gray squirrel), birds, deer, and insects. Foliage provides a source of browse for deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), and livestock. Insects associated with oak communities provide food for birds including Lewis's woodpecker, a species that also consumes acorns produced by Oregon white oak. Lewis's woodpecker is one of many species listed by the Interagency Special Status / Sensitive Species Program (ISSSSP), an interagency program established by the Forest Service and Bureau of Land Management for the conservation and management of rare species.

Oak trees provide nesting cavities, perches, and shade for a variety of wildlife species (Gucker 2007). In a south-central Washington study of six oak habitat types, bird abundance and species richness were

greatest in habitats containing small oak and pine trees, and in nearly pure stands of small oak (Manuwal 2003). Some species, including the wild turkey (*Meleagris gallopavo*) and western gray squirrel, require mixed oak/conifer habitat (Larsen and Morgan 1998). The western gray squirrel's habitat requirements include large oak and pine trees with a contiguous canopy structure in the vicinity of nest sites; its diet includes both acorns and pine seeds. Habitat for Merriam's turkey includes mature oak-conifer or oak stands, dense conifer forests, and early seral stands. Lewis's woodpecker uses large oak and ponderosa pine trees, particularly dying trees and snags.

Eastside Oregon White Oak Community Types

Oregon white oak woodland stands

Oak occurs as a climax tree species in these stands because drought conditions are too severe for Douglas-fir and ponderosa pine species to consistently regenerate (Lillybridge et al. 1995). These conifers may regenerate episodically but overstory specimens are sparse and often limited to microsites with slightly greater growing-season moisture. Common understory species are listed in table 1.

Ponderosa pine – Oregon white oak stands

Pine-oak stands represent the warmest and driest sites supporting ponderosa pine (Simpson 2007). Tree canopy cover averages 40 to 50 percent, and shrub and herbaceous cover each average 5 to 10 percent. Species composition of the herbaceous layer is variable. Historically, low-intensity fire was frequent on these sites (Simpson 2007).

Mixed conifer stands containing seral oak

Oak may occur as a seral species in mixed Douglas-fir-ponderosa pine stands (Simpson 2007). In these stands, fire suppression or long fire-return intervals favor Douglas-fir, whereas more frequent fire favors



Steller's jay.

Vern Wilkins, Indiana University

Table 1. Species composition of overstory and understory layers of eastside Oregon white oak communities.

Stand type	Tree canopy	Understory		Notes
		Common shrubs	Common herbaceous plants	
Oregon white oak woodland (climax)	Primarily oak with scattered ponderosa pine and Douglas-fir; typically less than 40 percent total cover on upland sites; total cover often 65 percent or greater on river terraces	Bitterbrush (<i>Purshia tridentata</i>) Serviceberry (<i>Amelanchier</i> spp.) Shinyleaf spirea (<i>Spiraea betulifolia</i> var. <i>lucida</i>) California hazel (<i>Corylus cornuta</i>) Common snowberry (<i>Symphoricarpos albus</i>)	Bluebunch wheatgrass (<i>Pseudoroegneria spicata</i>) Pinegrass (<i>Calamagrostis rubescens</i>) Elk sedge (<i>Carex garberi</i>) Sulfur lupine (<i>Lupinus sulphureus</i>) Carey's balsamroot (<i>Balsamorhiza careyana</i>) Showy phlox (<i>Phlox speciosa</i>) Common yarrow (<i>Achillea millefolium</i>) Sandberg bluegrass (<i>Poa secunda</i>) <i>Lomatium</i> spp.	Described by Lillybridge et al. (1995) for Washington
Ponderosa pine – Oregon white oak (climax)	40 to 50 percent cover typically dominated by ponderosa pine with oak somewhat less frequent; western juniper (<i>Juniperus occidentalis</i>) also occurs (Simpson 2007)	Bitterbrush (<i>Purshia tridentata</i>) <i>Artemisia</i> spp. Yellow rabbitbrush (<i>Chrysothamnus viscidiflorus</i>) Snowberry (<i>Symphoricarpos</i> spp.) Serviceberry (<i>Amelanchier</i> spp.) Prostrate ceanothus (<i>Ceanothus prostratus</i>)	Idaho fescue (<i>Festuca idahoensis</i>) Western fescue (<i>Festuca occidentalis</i>) Bluebunch wheatgrass (<i>Pseudoroegneria spicata</i>) Squirreltail (<i>Sitanion hystrix</i>) Ross's sedge (<i>Carex rossii</i>) Cheatgrass (<i>Bromus tectorum</i>) Bristly dogstail grass (<i>Cynosurus echinatus</i>) Bulbous bluegrass (<i>Poa bulbosa</i>) Arrowleaf balsamroot (<i>Balsamorhiza sagittata</i>)	Described as PIPO-QUGA climax associations in Oregon by Simpson (2007) and as oak-pine forests and woodlands in Washington by Rocchio (2011)
Mixed conifer, including seral oak	Forest overstory dominated by Douglas-fir and ponderosa pine; Oregon white oak occurs as a seral species	Bitterbrush (<i>Purshia tridentata</i>) Oceanspray (<i>Holodiscus discolor</i>) Serviceberry (<i>Amelanchier</i> spp.) Wax currant (<i>Ribes cereum</i>) Common snowberry (<i>Symphoricarpos albus</i>)	Arrowleaf balsamroot (<i>Balsamorhiza sagittata</i>) Idaho fescue (<i>Festuca idahoensis</i>) Western fescue (<i>Festuca occidentalis</i>) Elk sedge (<i>Carex garberi</i>) Sweetcicely (<i>Osmorhiza berteroi</i>) Strawberry (<i>Fragaria virginiana</i>)	Described for Oregon by Simpson (2007)

ponderosa pine and Oregon white oak. With increasing overstory cover of Douglas-fir, shrub layer cover and herbaceous layer diversity decline.

Soils

Oregon white oak occurs on a wide range of soil types east of the Cascade Crest. Soils of native Oregon white oak sites may be formed from a variety of materials

including igneous and sedimentary rock, alluvium and volcanic ash. On many eastside oak sites, soils are formed in basalt colluvium and are commonly gravelly and stony (Rocchio 2011). Soil moisture regimes in the area range from moist, well-drained alluvial soils of riparian areas to shallow, dry, rocky soils.



David Patte, US Fish and Wildlife Service



Andrew Bower, US Forest Service



Columbia River Gorge National Scenic Area

Eastside and Columbia River Gorge oak communities; overstory composition is largely influenced by moisture availability, including the soil's capacity to retain moisture during summer. The upper photo of the Klickitat River Canyon shows the influence of slope position and aspect on tree species, with fewer conifers and more oak on the harshest soils. In the lower left is dry eastside site supporting scattered ponderosa pine and oak trees. The lower right photo is a seral oak stand on a moister site that is succeeding to Douglas-fir.

Insect Threats

Many insects are known to damage Oregon white oak; however, the damage is usually not severe enough to result in mortality (Stein 1990). The western oak looper (*Lambdina fiscellaria somnaria*) defoliates trees but this does not result in permanent damage (Niemiec et al. 1995). Temporary crown damage also results from tent caterpillars (*Malacosoma californicum* and *M. constrictum*) and gall wasps (e.g., *Andricus californicus* and *Bassettia ligni*), which create highly visible galls in some trees (Niemiec et al. 1995). Occasionally, Douglas squirrels and western gray squirrels strip the bark from branches when feeding on gall wasp larvae.

Oregon white oak acorns are prone to damage from larvae of the filbertworm (*Melissopus latiferreanus*) and the filbert weevil (*Curculio occidentalis*) (Stein 1990).



Jerald E. Dewey, US Forest Service

Western oak looper.

Disease Threats

Prepared by Kristen Chadwick, Forest Service Forest Health Protection

There are numerous pathogens that have been found on leaves, branches, trunks, and roots of Oregon white oak (Sinclair et al. 1987, Stein 1990). However, most are of minor consequence, and few cause severe dieback or mortality. Unfortunately, little effort has

been made to collect and isolate pathogens in eastside oak; more is known about the occurrence of pathogens on Oregon white oak in California and in the Willamette Valley.

Diseases affecting leaves and twigs

Foliar diseases are common in oaks (Swiecki and Bernhardt 2006). Leaf-spot, mildew, and anthracnose fungi sometimes attack foliage. However, these are more common in moister environments; the dry climate of the eastside region is generally less conducive to foliar pathogens.

Oak anthracnose—*Apiognomania errabunda* (asexual stage = *Discula umbrinella*) affects oaks and several other hardwoods; it occurs throughout California, Oregon, and Washington. Typically, anthracnose is of minor importance to Oregon white oak. However, years with frequent rainfall continuing through the spring are conducive to disease development, and in those years it can cause substantial defoliation and dieback. Impacts on oak east of the Cascade Crest would likely be minor owing to the dry environment; in general the leaf spots would be incidental.

Powdery mildews—There are several species of powdery mildews that can be found on oaks in Oregon and Washington. In general, levels of infection are not normally severe enough to be detrimental to plant health.

Diseases affecting branches and trunks

Inonotus dryophilus—*I. dryophilus* is a canker rotting fungi found throughout North America on several hardwoods. It is common on Oregon white oak and is thought to be one of the most damaging agents of the species. *I. dryophilus* decays heartwood, strips sapwood, and kills the cambium. In areas where the cambium is killed this causes an externally visible canker, which is elongate and may be callused at the edges. Conks are hoof-shaped and usually solitary; the upper surface is buff to reddish-brown and the lower surface is covered with a layer of tubes. *I. dryophilus*

is typically associated with oak decline, failure, and mortality. New infections are thought to be caused by spores invading wounds. Although many other decay fungi are found throughout the range of Oregon white oak, they are generally not as important as *I. dryophilus*.



Joseph O'Brien, US Forest Service

Inonotus dryophilus conk.

***Phellinus igniarius* (L.:Fr.) Quel.**—“False tinder fungus” occurs on both sides of the Cascade Range and is found most frequently on living cottonwoods, birches, oaks, maples, madrone, and willows. Both heartwood and sapwood are damaged; conks generally indicate the presence of extensive stem decay. *P. igniarius* conks are similar and the decay is identical to that caused by *Phellinus tremulae*. Conks are hoof-shaped, perennial, hard, and woody, with the upper surface gray-black, roughened, and cracked. The underside is brown with small regular pores.

***Phaeolus schweinitzii* (Fr.:Fr.) Pat.**—“Velvet-top fungus” or “cow-pie fungus” is most commonly found infecting conifers, although deciduous hosts occasionally include Oregon white oak, *Betula* spp., and *Prunus* spp. *P. schweinitzii* is believed to occur in Oregon white oak throughout its range on the west side of the Cascades and probably occurs in the Columbia River Gorge and in central Oregon and Washington. The *P. schweinitzii* fruiting body is annual, but it will dry to a dark brown and persist for several years around the base of infected trees. Conks

will fruit from the ground above infected roots, or shelf from the bole, usually at sites of wounds. When fresh, they are brown with a yellow edge, multi-layered, spongy, and of a soft velvet texture that is easily bruised.

Wetwood—Also called slime flux or wetwood slime, it is caused by various microorganisms and is common on oaks and many other hardwoods. Wet wood is identified by a dark wet area around cracks or wounds that oozes a sour, rancid-smelling liquid that is typically slimy. The liquid is initially clear but darkens over time. Typically wetwood does not have much impact on tree health but is common in occurrence and sometimes mistaken as a damaging agent.

Root Diseases

Armillaria root disease (*Armillaria* spp.)—

Armillaria root disease is common in oak ecosystems. There are three potential *Armillaria* species of concern in the Columbia River Gorge area (*A. mellea*, *A. gallica*, *A. ostoyae*); the *A. gallica* complex has been isolated from the east side of the Mt. Hood National Forest in Oregon white oak. Distinguishing between



Joseph O'Brien, US Forest Service

Armillaria gallica rhizomorphs.

species of *Armillaria* is less critical than determining if it is acting as a pathogen. Hardwoods with *Armillaria* root disease tend to have crown dieback and thinning as the root system is stressed. Trees with extensive root decay are prone to failure at the root collar. When found acting pathogenically, *Armillaria* kills the cambium and bark as it moves up the roots, causing a white rot of the wood. The bark of diseased root crown areas may ooze a thick, dark fluid. Mycelial fans are typically found taking the place of the cambium and can sometimes be found throughout the bark. Thick white mycelial fans are indicative of *Armillaria* acting as a pathogen. Rhizomorphs are dark, thin shoestring like structures that are commonly found on roots or at the base of windthrown trees, although rhizomorphs alone are not indicative of pathogenic *Armillaria* root disease.

Ganoderma root rot—There are two species of *Ganoderma* found in oaks. *G. applanatum*, “Artist’s conk,” is widely distributed throughout North America on living conifers and hardwoods. *G. brownii* has been found throughout the Pacific Northwest and California. *G. brownii* sporocarps have been collected throughout Oregon and Washington, but little is known about its impact on living trees. *G. applanatum* is known to be an important cause of root disease in hardwoods. It forms a white mottled rot in the roots and lower bole. Conks generally indicate the presence of extensive root, butt, and lower trunk rot. Trees with extensive decay are prone to failure at the roots and root crown. The conk is hard, woody and shelf-like, with a smooth, concentrically ridged top, tan-colored, and often with a dusting of tannish-brown spores. The margin and underside are white.

Pacific mistletoe (also called oak mistletoe or hairy mistletoe)

Pacific mistletoe (*Phoradendron villosum* (Nutt.) Nutt.) is common in Oregon white oak from western Oregon southward through California into Mexico (Scharpf and Hawksworth 1974). It has not been documented in the Columbia River Gorge or on the eastside, but it is a species to be aware of and to watch

for. *Phoradendron* spp. are flowering, parasitic plants that depend on their host for water and mineral nutrients; they consist of spherical clusters of evergreen foliage on host branches.

Wind and snow damage

South-central Washington and north-central Oregon along the Columbia River are infamous for high winds, wet snow, and freezing rain that can cause damage to Oregon white oak. However, breakage, dieback, and damage to Oregon white oak are generally less than that which occurs in associated hardwoods during severe weather events.

Other Threats to Eastside Oregon White Oak Habitat

Several factors threaten to reduce or degrade existing eastside Oregon white oak habitat. On moist sites, particularly locations in the Columbia River Gorge west of Hood River, Douglas-fir is a strong competitor and has invaded many former oak stands. In those stands, the absence of the historical fire regime is a significant threat to the oak woodland stand structure. Throughout its Pacific Northwest range, fire suppression in oak woodlands has led to greater accumulations of fuels and shifts in both understory and overstory species composition. In many areas, stand structure has shifted in the absence of fire from large, widely spaced trees, to denser stands of smaller trees. Conversion of lands to range or agricultural uses represents another threat. For example, heavy grazing favors regeneration of shrubs and conifers over grasses and oak trees (Chappell et al. 2001). Non-native species, particularly grasses associated with livestock grazing, represent a shift in species composition from that which existed in pre-settlement times.

Classification Systems

The Washington Natural Heritage Program has classified one ecological system containing Oregon white oak east of the Cascade Crest in Washington: East Cascades Oak-Ponderosa Pine Forest and

Woodland (Rocchio and Crawford 2008). This ecological system can be identified by “the presence of *Quercus garryana* generally mixed with *Pinus ponderosa* or *Pseudotsuga menziesii*... These woodlands occur at the lower treeline/ecotone between *Artemisia* spp. or *Purshia tridentata* steppe or shrubland and *Pinus ponderosa* and/or *Pseudotsuga menziesii* forests or woodlands” (Rocchio and Crawford 2008). The classification of this ecological system was adapted for the State of Washington, based on the NatureServe ecological system of the same name (number CES204.085) (NatureServe 2011). This is the same ecological system that is used in LANDFIRE mapping (LANDFIRE 2012).

Plant associations including Oregon white oak have most recently been described for the Mt. Hood National Forest by Simpson (2007), the Wenatchee National Forest by Lillybridge et al. (1995), and the Gifford-Pinchot National Forest by Topik (1989) (table 2). In *Forested Plant Associations of the Oregon East Cascades* (Simpson 2007), which includes the Mt. Hood National Forest, Oregon white oak is listed as a seral species in the PSME Dry and PSME Moist plant association groups (PAG) and as a climax species in the PIPO-QUGA Moist and PIPO-QUGA

Dry PAG (Simpson 2007). On the Gifford Pinchot National Forest, Oregon white oak occurs in two plant association groups: Hot, Dry Grassy and Hot, Dry Brushy within the Douglas-fir and grand fir series (Topik 1989). On the Wenatchee National Forest, the Oregon white oak series occurs in the lower Naches and Tieton watersheds, at an elevational band below conifer forests and above shrublands (Lillybridge et al. 1995).

Growth and Mortality Modeling

Recently, the Oregon white oak component of the Forest Vegetation Simulator (FVS) model underwent a major revision to improve its accuracy in predicting growth and mortality of the species (Gould et al. 2011). The East Cascades variant of FVS has incorporated the Oregon white oak revision and is the appropriate variant for modeling in the region covered by this strategy. The Southern Oregon/Northern California variant of FVS has *not* incorporated the Oregon white oak revision as of July 2012. The accuracy of any modeling efforts with an emphasis on Oregon white oak is much improved by the revision. Oregon white oak growth and mortality have also been modeled using ORGANON (Gould et al. 2008).



Warren Devine

Riparian oak habitat, Swauk Valley Ranch, WA. The area represents the northernmost population of Oregon white oak on the eastside.

Table 2. Eastside plant associations containing Oregon white oak.

National Forest	Series	Plant association group	Plant association	Canopy oak component	Source
Mt. Hood	Douglas-fir	PSME Moist	PSME/SYMO	Minor seral	Simpson (2007)
			PSME/HODI	Minor seral	
		PSME Dry	PSME/SYAL	Minor seral	
			PSME/CAGE	Minor seral	
			PSME/ARPA	Minor seral	
	Ponderosa pine	PIPO-QUGA Moist	PIPO-QUGA/SYAL	Minor climax	
		PIPO-QUGA Dry	PIPO-QUGA/PUTR	Major climax	
Gifford Pinchot	Douglas-fir	Hot Dry Grassy	PSME/ACCI/FEOC	None; occurs in understory only	Topik (1989)
	Grand fir	Hot Dry Grassy	ABGR/CARU	None; occurs in understory only	
		Hot Dry Brushy	ABGR/HODI-GP	Minor seral	
Wenatchee	Oregon white oak	Hot Dry Grass	QUGA/AGSP	Major climax	Lillybridge et al. (1995)
			QUGA/CARU-CAGE	Major climax	
		Hot Mesic Shrub/Herb	QUGA/COCO2-SYAL	Major climax	

CHAPTER 3. RESTORATION ISSUES

This section outlines several key issues that should be considered in the development of plans for restoring and conserving eastside Oregon white oak. Topics include: defining restoration targets, historical and present distribution of oak habitats, public outreach and collaboration, sensitive species, gene conservation, and climate change.

Restoration Targets

Different approaches may be used to define restoration targets (i.e., goals). For example, one approach is to set a target of a restored ecosystem that is functionally comparable to that which existed historically (i.e., in presettlement times). This approach is based on the assumption that long-term viability of the species associated with that ecosystem depend on the sustainability of that ecosystem function (Ehrenfeld 2000). However, this requires that both the ecosystem and its function are clearly defined in a way that is quantifiable. If parameters quantifying historical function cannot be defined, then it cannot be an attainable goal. An alternative approach, applied to westside restoration projects by The Nature Conservancy, is to set restoration target conditions based on the specific requirements of individual priority species (Hanna and Dunn 1997). This approach can be very effective in restoring habitat for individual species, but it requires an understanding of the ecosystem-level interactions and processes that influence that species' habitat (Ehrenfeld 2000). Another disadvantage of the species-based target is that may divert resources from other species.

Limited information exists on the presettlement condition and function of eastside oak ecosystems. Additionally, these ecosystems have been substantially changed by factors including nonnative species, an altered disturbance regime, and habitat fragmentation. They will also be influenced by a future climate that differs from that during recent history (Thorpe and

Stanley 2011). Thus, it is unclear if it will be possible to restore presettlement ecosystem function.

Based on experience with westside oak savanna and prairie, Thorpe and Stanley (2011) suggest using a realistic approach in defining restoration targets. The authors recommend setting clear and quantifiable goals such as percentage of native species, diversity metrics, or abundance of rare or keystone species. They also recommend restoration targets that incorporate a level of resiliency; for example, stand structure with increased resilience to wildfire.

This strategy sets a goal of restoring and conserving Oregon white oak habitats on National Forest System lands east of the Cascade Range crest. This goal is intentionally broad because it is designed to encompass a variety of restoration goals set for individual projects implemented at a range of scales. Rather than prescribing site-specific restoration targets, this strategy is designed to provide a framework that facilitates effective restoration planning as well as collaboration among managers.

Distribution of Oak Habitats

Historical Distribution

Although it may not be practical or possible to restore oak habitats to a condition identical to that of presettlement times, information on the historical extent and condition of those ecosystems will be useful in planning restoration projects. Presently, the best source for data on historical forest coverage in Oregon and Washington is Portland State University's School of the Environment Pacific Northwest Landscape Assessment and Mapping Program (<http://www.pdx.edu/pnwlamp/historical-vegetation-in-the-pacific-northwest>). This program has compiled spatially explicit historical vegetation data from a variety of sources. Data compiled on the website include:

- Oregon Statewide Composite Historical Vegetation Map (Tobalske 2002). This map

was developed as part of the Oregon Gap Analysis Program and can be downloaded as a shapefile from: http://navigator.state.or.us/sdl/data/shapefile/k100/historic_vegetation.zip. The map contains data from sources including the 1930s Forest Service timber survey maps (Harrington 2003) and GLO maps.

- 1930s Forest Service forest resources maps of Oregon and Washington (Harrington 2003). These forest cover data include the earliest Forest Service surveys (scale = 1:253,440) and county-level maps (scale = 1:63,360). They do not include areas lacking forest cover. The digitized maps are available at: http://www.fs.fed.us/pnw/publications/pnw_gtr584/. Other historical Forest Service maps are available through USFS Pacific Northwest Research Station Forest Inventory and Analysis (Corvallis, OR) and at university libraries (e.g., University of Washington).
- GLO-based cover maps (<http://www.pdx.edu/pnwlamp/glo-historical-mapping-in-oregon>). These currently provide partial coverage of the state of Oregon. The maps most relevant to eastside oak are those of the eastern Columbia River Gorge and the east slope of Mount Hood (1859-1939; scale = 1:24,000), available at: http://www.pdx.edu/sites/www.pdx.edu.pnwlamp/files/glo_gorge_hood_2010_12_OR.zip (Christy 2010).

Modeled Present Distribution

Although not based on historical data, modeled distributions of oak ecosystems may be useful in describing the extent of potential oak habitat. Two sources of such information, which include spatially explicit data, are:

- The modeled potential vegetation zones of Washington and Oregon (Henderson 2009). This classification system is based on climax vegetation type: the plant community that would establish through succession after an extended period without disturbance (typically

hundreds of years). Because oak is not a climax species on many of the sites that it historically occupied in the region (though it is often classified as a disturbance climax species), classification based on climax species is not well-suited to defining the historical extent of the species, which was heavily influenced by frequent disturbance.

- NatureServe's Ecological Systems concept (NatureServe 2011), used in the LANDFIRE Existing Vegetation Type dataset (Comer et al. 2003). This system uses ecosystem classification units that include seral as well as climax vegetation (Comer et al. 2003).

Public Outreach and Collaboration

Outreach and collaboration are particularly important for oak ecosystems because the majority of oak habitat in the Pacific Northwest occurs on non-Federal land, including private land, tribal land, and land managed by State and local government agencies. Thus, the future of oak ecosystems at a landscape scale depends upon decisions made by a variety of agencies and numerous landowners and managers. Even if these individuals are not participating in a common strategy, their support for restoration work may provide many benefits. A successful oak habitat restoration project performed on Federal land may serve as an important educational tool, in part because federally managed oak habitat often occurs in close proximity to oak habitat under other ownerships.

Restoration of public lands usually benefits substantially from public support. Proactive outreach should be planned as an initial step in a restoration project, to be implemented as early as possible. The outreach activities should convey to local landowners, landowner groups, conservation organizations, and the general public the specific and tangible benefits of the restoration work. If these groups and individuals understand the need for the restoration work, they will have ownership in a project well in advance of its implementation.

Sensitive Species

As part of the National Environmental Policy Act (NEPA) process, Forest Service personnel conduct a biological evaluation to determine potential effects of management activities on sensitive species. According to the Forest Service Manual, management actions “must not result in a loss of species viability or create significant trends toward Federal listing” (FSM 2670.32). There are more than 700 sensitive plants, animals, and fungi in the Forest Service Pacific Northwest Region. In this strategy, the presence of sensitive species is considered during the site prioritization phase (phase 2) of strategy development, which is discussed in the next chapter.

Gene Conservation

A study of the genetic structure of Oregon white oak showed a separation between populations north and south of the Strait of Juan de Fuca, but only minor genetic differences within these groups (Ritland et al. 2005). Unfortunately, no eastside populations were included in this study to assess the presence and extent

of any genetic differences between eastside and westside populations. Taylor and Boss (1975) hypothesized that oak in Washington originated from Oregon populations that migrated northward through the Willamette Valley with the drying and cooling of the late Tertiary period. They further hypothesized that the migrating oak was split by the Washington Cascade Range, with one arm following the Puget Sound lowlands into British Columbia and the other migrating through the Columbia River Gorge to eastern Washington and Oregon. If this is the case, then it might be expected that eastside populations are more closely related to Willamette Valley populations than to Puget Sound lowland populations.

A study is currently underway to determine the genetic structure of both eastside and westside populations (Andrew Bower, study lead). However, identifying genetic resources is only part of the issue. Once the population structure is quantified, the next question is how to conserve the genetic resources. Gene conservation efforts are usually classified as *in situ*, meaning done in place, or *ex situ*, meaning done



David Patte, US Fish and Wildlife Service

An example of *in situ* gene conservation: Oregon white oak in Tom McCall Preserve near Rowena, Oregon.

outside the natural position of the species.

Ex situ gene conservation is accomplished by preserving genetic material at a location other than where the species is naturally found. One of the most common methods of *ex situ* conservation is the storage of seed in freezers. Oak seeds (acorns) are recalcitrant and cannot tolerate desiccation below approximately 25 to 30 percent; therefore, they are difficult to store (Bonner and Karrfalt 2008). When stored properly at high moisture conditions just above freezing, Oregon white oak acorns can maintain viability for only 2 years (Devine et al. 2010a). For this reason, *ex situ* gene conservation of Oregon white oak will not be feasible by seed storage.

In situ gene conservation is accomplished by protecting trees in natural stands. Often this type of gene conservation can be comparatively inexpensive, as it entails the maintenance of existing stands. However, for *in situ* gene conservation to be effective, entire biological communities should be preserved (Ledig 1988). Some examples of land classifications that function as *in situ* preserves include congressionally designated wilderness areas, parks, research natural areas (RNA), and botanical areas. However, preserving Oregon white oak communities often requires some type of restoration treatment (e.g., reducing tree density, conifer removal, prescribed burning) to maintain full ecosystem function; therefore, it is not advisable that Oregon white oak habitat be set aside or given a special management status that would preclude or further complicate the application of such treatments.

A potential concern with *in situ* preserves is that they are still vulnerable to catastrophic disturbance such as fire or an insect or disease outbreak. But because Oregon white oak is a prolific sprouter following

disturbance, loss of an entire stand owing to disturbance is unlikely. Given these considerations, the best way to conserve the genetic diversity of Oregon white oak is to restore degraded habitats and to maintain ecosystem function through periodic fire.

Climate Change

Predicted impacts of climate change on Oregon white oak habitats are varied and could be positive or negative, depending on the site. Air temperatures are likely to increase, especially minimum temperatures in winter, but changes in precipitation are less certain (D. Bachelet, pers. comm.). Although Oregon white oak is highly drought tolerant, areas that are already at the lower limit of its tolerated precipitation range may become too dry for successful regeneration. However, if summer drought stress increases in the future as

expected, oak may become more competitive in areas that are currently conifer-dominated.

Oregon white oak scored relatively high in climate change vulnerability in the recent vulnerability assessment of forest trees in the Pacific Northwest (Devine et al. 2012). However, this high score was driven primarily by high vulnerability in the areas of reproductive capacity and adaptive genetic variation. In other areas,

including habitat affinity and insect and disease threats, Oregon white oak ranked less vulnerable to climate change impacts than most other regional tree species. Owing to its drought-tolerance and other factors, Oregon white oak is likely less susceptible to habitat loss than the most at-risk tree species: mid- to high-elevation conifers (Devine et al. 2012).

Although Oregon white oak is likely less susceptible to climate-related threats than many other regional tree species, potential effects of climate change on the plant and animal species associated with oak habitats should be addressed when planning restoration work. The Yale Framework, developed by the Yale School

The best way to conserve the genetic diversity of Oregon white oak is to restore degraded habitats and to maintain ecosystem function through periodic fire.

of Forestry and Environmental Studies (<http://yale.databasin.org/pages/documents>) provides six broad questions that should be considered when integrating climate adaptation into restoration planning (see box below).

A key component of “climate-smart” restoration and conservation is maintaining or improving resiliency of ecosystems so that they are buffered against potential future changes. The National Wildlife Federation

outlined a series of concepts and approaches to planning climate-smart restoration (see box on next page). While more general than those of the Yale Framework, these concepts are designed to promote sound conservation planning and are applicable to Oregon white oak restoration activities.

Strategies for Integrating Climate Adaptation into Resource Planning

From: http://databasin2-filestore.s3.amazonaws.com/%40page_images/Yale_Framework_Brochure.pdf

1. What are the current patterns of biodiversity and how can they be conserved?

This constitutes the baseline of current assets that will help ensure the highest-possible resilience to change.

2. What will the future patterns of biodiversity look like across a varied landscape?

Models can be used to predict the manner in which climate change fundamentally influences the distribution of species, interactions among species and the underlying ecological processes that support them.

3. What is the best way to maintain ecological processes?

Changes in an ecosystem's processes can influence its ability to withstand and/or adapt to environmental change. Understanding these potential impacts is necessary for finding the right strategies to preserve ecological function.

4. How can ecological connectivity be best maintained or restored?

Species may respond to changes in their habitats by shifting their geographic ranges, either longitudinally or by elevation. Maintaining and restoring landscape connectivity can help species adapt to a changing climate.

5. What areas are predicted to have relatively stable climate over the long term?

When climate-related stressors change species' habitats so quickly that migration is impossible, those species may benefit from the availability of uniquely situated areas within a specific habitat that offer relatively stable environmental conditions. It is important to identify these safe havens—also known as refugia.

6. What are the on-the-ground environmental conditions best suited to provide habitats for the native plant and animal species of a region to persist in a climate-change era?

Recent research suggests that conserving the underlying “ecological stage” of a region (its geological, soil and topographic features) is a solid approach for maintaining biodiversity under different climate-impact scenarios.

Key Characteristics of Climate-Smart Conservation

From: National Wildlife Federation <http://www.nwf.org/What-We-Do/Energy-and-Climate/Climate-Smart-Conservation/Adaptation-Principles.aspx>

1. Actions Linked to Climate Impacts

Conservation strategies and actions are designed specifically to address the impact of climate change in concert with existing threats; actions are supported by an explicit scientific rationale.

2. Forward-Looking Goals

Conservation goals focus on future, rather than past, climatic and ecological conditions; strategies take a long view (decades to centuries) but account for near-term conservation challenges and needed transition strategies.

3. Broader Landscape Context

On-the-ground actions are designed in the context of broader geographic scales to account for likely shifts in species distributions, to sustain ecological processes, and to promote collaboration.

4. Robust in an Uncertain Future

Strategies and actions provide benefit across a range of possible future conditions to account for uncertainties in future climatic conditions, and in ecological and human responses to climate shifts.

5. Agile and Informed Management

Conservation planning and resource management is capable of continuous learning and dynamic adjustment to accommodate uncertainty, take advantage of new knowledge, and cope with rapid shifts in climatic, ecological, and socio-economic conditions.

6. Minimizes Carbon Footprint

Strategies and projects minimize energy use and greenhouse gas emissions, and sustain the natural ability of ecosystems to cycle and sequester carbon and other greenhouse gases.

7. Climate Influence on Project Success

Considers how foreseeable climate impacts may compromise project success; generally avoids investing in efforts likely to be undermined by climate-related changes unless part of an intentional strategy.

8. Safeguards People and Wildlife

Strategies and actions enhance the capacity of ecosystems to protect human communities from climate change impacts in ways that also sustain and benefit fish, wildlife, and plants.

9. Avoids Maladaptation

Actions taken to address climate change impacts on human communities or natural systems do not exacerbate other climate-related vulnerabilities or undermine conservation goals and broader ecosystem sustainability.

CHAPTER 4. DEVELOPMENT OF A LANDSCAPE-SCALE RESTORATION STRATEGY

Although the locations of restoration activities are often influenced by agency policies, cooperators, or availability of funding, it is important to consider long-term, landscape-scale effects in restoration planning. This section presents a three-phase approach to developing a landscape-level strategy for prioritizing eastside oak stands for restoration. This approach is intended to be used as a guide in planning restoration across large areas with many individual stands.

The first phase involves identifying and mapping all potential restoration sites within the scope of the project. The scope may be a single national forest or it may encompass sites across multiple cooperating agencies or landowners. The second phase of the process is calculating a numeric prioritization score for each of the potential restoration sites based on ecological habitat value and likelihood of habitat loss without treatment. The third phase—the site selection process—combines data from phases 1 and 2 with other management considerations to assist managers in prioritizing individual sites for restoration.

Phase 1: Mapping

Restoration planning at the landscape scale requires current information on the distribution of oak and oak-pine woodlands and associated habitats. Phase 1 involves acquiring and compiling spatial data on potential oak restoration sites within the scope of the project using GIS. Although an exhaustive inventory of oak habitat within each national forest is unlikely to be feasible, an inventory such as that conducted by Northwest Habitat Institute for the Northwest Oregon Ecology Group (see below) would provide a sufficient level of detail for prioritizing stands for restoration.

Data should describe the extent of each stand and also include associated information on stand condition. At

a minimum, condition data should describe the stand type (e.g., pure oak, oak-pine, Douglas-fir-oak); ideally, it should also include information on tree size, overstory density, and presence of remnant trees. The extent to which oak habitat on each national forest has been mapped varies; current mapping status is summarized in the box on the next page. The major sources of existing spatial data that document occurrences of eastside Oregon white oak are:

- Oak habitat maps created by Northwest Habitat Institute (NHI) via a contract with the Northwest Oregon Ecology Group—**These maps of oak and associated habitat types consist of polygons ($n = 2,538$) mapped in the field using GPS between 2006 and 2010. The extent of the mapped area is the 7.5' USGS Quadrangles that included a portion of the Mt. Hood National Forest (fig. 2; figs. 3 and 4 in appendix). Oak habitats in some portions of the Columbia River Gorge National Scenic Area (Oregon only) were also mapped. Associated with the polygons are data on canopy type (30 classes, most with some oak component), canopy cover percentage class (four classes), tree size (six classes), number of canopy layers (either single or multi-story), and presence of old, remnant trees (nine classes, based on species).
- Washington Department of Fish and Wildlife (WDFW)—**The WDFW Priority Habitats and Species Spatial View database contains numerous polygons identified as oak woodland. Polygons occur across multiple land ownerships, including the Columbia River Gorge National Scenic Area and the Okanogan-Wenatchee National Forest. There are no polygons mapped on the other regional national forests. A second WDFW dataset titled “Oak Forest Stands in Klickitat County, Washington” contains polygons of all oak and oak-pine mixed stands in the county, identified from aerial photos taken between 1975 and 1993 (fig. 5 in appendix). For each

polygon of the oak forest type or the oak-pine mixed forest type, canopy cover is classified into one of three categories (0 to 25, 25 to 75, and 75 to 100 percent cover).

- **Herbarium specimen collection locations**—Two major sources of online, spatially explicit species occurrence data are Oregon Flora Project (data for OR only) and the Burke Museum Herbarium (data primarily for WA). Both include searchable online databases with data on the locations of specimen collections or species observations. These data can be used to identify locations of oak habitat.
- **Plot-based inventories**—There are three major sources of data collected in Forest Service inventories: Forest Inventory and Analysis (FIA) annual inventory data (USDA Forest Service 2010b) (fig. 6 in appendix), Current Vegetation Survey (CVS) inventory data (USDA Forest Service 2008), and the U.S. Forest Service Pacific Northwest Region Ecology Program Core Dataset (USDA Forest Service 2010a). However, the spatial data in the publically accessible versions of the FIA and CVS datasets have been “fuzzed” to conceal plot locations; thus, they are not useful in locating specific plots on which oak has been recorded. The Ecology Program Core Dataset, however, contains accurate plot locations and can thus be used to identify specific locations on the national forests where oak habitat occurs. The Ecology Core Dataset contains data on overstory and understory species, and thus it may be searched for occurrences of individual species of interest. Furthermore, it contains percentage canopy cover by species, thus providing an indication of the relative importance of various species.

Phase 2: Ecological Prioritization of Sites

After mapping all potential oak restoration sites in phase 1, the next step is to rate the sites by using a

Current Oak Habitat Mapping Status

Mt. Hood National Forest

Oak habitat was mapped by NHI between 2006 and 2010 (see text). However, Forest Service Ecology Program plots and herbarium collections indicate oak in locations outside NHI's mapped polygons; thus, it is likely that additional oak habitat could be mapped on the forest, guided by inventory data and aerial photos.

Gifford Pinchot National Forest

There is no comprehensive map of oak habitat at present. Some stands were mapped during the Bear Creek restoration project, and there are a few Ecology Program plots indicating oak.

Okanogan-Wenatchee National Forest

Regional Ecology Program plots indicate locations of some oak habitat. The WDFW Priority Habitats and Species database shows three mapped oak stands on the forest.

Columbia River Gorge National Scenic Area

Stands with oak and oak-pine canopy are mapped on the Washington side of the river in the WDFW Priority Habitats and Species database and by an earlier inventory that was limited to Klickitat County (see text). The NHI oak habitat maps include portions of the National Scenic Area on the Oregon side of the river. Herbarium collections mark additional occurrences. Roland Rose (CRGNSA) is working on a grassroots effort to compile an interagency map of all regional oak restoration projects.

simple model to produce an overall “prioritization score” for each site (table 2). For a given site, each of three factors is scored as 0, 1, or 2, based on the site's habitat value and its likelihood of losing that habitat without active restoration. The site's prioritization score is calculated by adding the three factor scores.

Thus, the highest possible score is 6 ($2 + 2 + 2$) and the lowest possible score is 0 ($0 + 0 + 0$).

The first factor is potential overstory habitat value. Because overstory structure of high-quality oak woodland habitat takes many decades or even centuries to develop, preserving and managing for this structure is a priority, as is preventing its loss. The lowest score (0) is assigned to stands where no mature oak trees are present, or where there are only infrequent mature oak trees in poor condition. The highest score (2) is assigned to stands that contain large, remnant oak trees that provide important habitat features.

The second factor is threats. Three key threats are identified: (i) invasive species, (ii) destructive wildfire,

and (iii) encroachment of overtopping conifers.

Presence of one or more of these threats indicates potential for habitat degradation. A score of 0 is assigned to stands where these threats are low, whereas the highest score of 2 is assigned where at least one of these threats is likely to cause significant habitat degradation.

The third factor is rare or sensitive species. If the stand contains one or more sensitive, threatened, or endangered species endemic to oak or oak-pine habitat, then it is assigned the highest score of 2.

The factors and score definitions shown in table 3 are not definitive; they may be modified as desired for a given area or set of objectives.

Table 3. Example of a system developed to calculate a prioritization score for each site considered for potential restoration activities.

Factor	Score	Description
Potential overstory habitat value	0	No mature oak trees present, or infrequent mature trees that are in poor condition. Oak reproduction may be present. Conifers may be present.
	1	Stand contains mature oak trees, but crown form is not ideal for wildlife; for example, the stand may be too dense, or crowns may be narrow. Large, remnant oak trees are very rare or absent. Conifers may be present.
	2	Stand includes large, remnant oak trees, at least some of which have broad crowns, spreading limbs, and cavities. The stand may also include mature pines. Douglas-fir and younger oaks and pines may be present.
Threats	0	No urgent concerns regarding susceptibility to wildfire or invasive species. No significant presence of Douglas-fir.
	1	Contains at least one of the following: (i) an invasive species causing moderate habitat degradation that could likely be alleviated through management; (ii) high fuel loads present but ladder fuels are not significant; or (iii) overtopping conifers are causing crown dieback of mature oaks, but large, remnant oak trees are either not present in the stand or not threatened by overtopping.
	2	Contains at least one of the following: (i) an invasive species causing substantial habitat degradation that could likely be alleviated through management; (ii) presence of fuels highly conducive to stand-replacing wildfire; or (iii) overtopping conifers that are causing significant crown dieback of large, remnant oak trees.
Rare/ sensitive species	0	Stand is not known to contain any sensitive, threatened, or endangered species and does not currently provide high-quality habitat for any such species.
	1	Stand is not known to contain any sensitive, threatened, or endangered species but does represent high-quality habitat for at least one such species.
	2	Stand contains at least one sensitive, threatened, or endangered species.

After a score is assigned for each factor, the three scores are added to determine the site's prioritization score; prioritization scores are then compared across sites, with higher scores indicating higher priority for restoration.

Phase 3: Site Selection

In phase 3, the spatial data from phase 1 and the prioritization data from phase 2 are combined in a manner that will be useful to managers for prioritizing and selecting individual sites for restoration activities. The most efficient way of doing this may be to create a GIS map that includes all potential restoration sites, with symbology indicating the phase-2 prioritization score for each site. After this map is created, several other important factors must be considered when selecting specific sites for restoration work:

- **Habitat connectivity**—Regional populations of some oak-obligate species may require an increased level of habitat connectivity; thus, it may be necessary to prioritize restoration in areas that increase this connectivity. Habitat connectivity requirements are species-dependent and therefore must be evaluated by experts on an individual-species basis. Habitat connectivity can be evaluated quantitatively, by using spatial analysis in GIS.
- **Social factors**—Partnerships with specific groups may limit restoration work to sites within certain target areas. In such cases, these areas should be included as a layer on the same map as the oak habitat mapped in phase 1 of this process. Thus, sites outside of partnership target areas can be eliminated from consideration under that partnership.
- **Economic and regulatory constraints**—As with social considerations, various funding sources for restoration work may be available

only for specific areas or forest types. For example, funding for a fuels reduction thinning may be limited to specific, designated areas. In such cases, the areas should be included as a map layer and handled the same as target areas based on social factors.

- **Climate change**—Though specific effects on oak habitat are not certain, numerous studies have projected increased summer drought and increases in the annual area burned by wildfire (summarized in Devine et al. 2012). The factors should be integrated into the restoration planning process using the key concepts outlined in the previous chapter.
- **Adjacent lands**—Adjacent habitats that differ from that of a targeted site may be beneficial to wildlife species that require multiple stand types (e.g., Merriam's turkey); alternatively, contrasting habitats may limit dispersal of other species (Hanna and Dunn 1997). A quantitative analysis of adjacent habitats would require a map of not only oak habitats, but of other habitat types as well.

During the site selection process, the prioritization scores from phase 2 should not be regarded as a definitive ranking; they are only intended as a guide. For example, if a stand with a prioritization score of 5 provides important habitat connectivity than a stand with a score of 6 does not provide, then it may be of greater benefit to plan restoration activities in the former stand first.



David Patte, US Fish and Wildlife Service

CHAPTER 5. STAND-LEVEL RESTORATION

There are several common eastside oak stand types (see box to the right) and many variations on each of these; each stand type requires a different set of restoration objectives and management activities. Several management activities, such as treatment of invasive species and prescribed fire, are recommended in all of these stand types, whereas others are only recommended in certain scenarios.

This chapter provides a template for the decision-making process involved in planning restoration at the stand level. It is based on the assumption that the stand has already been selected as a priority for restoration. This chapter provides a framework that is broad enough to apply to most eastside oak stands.

Once a site has been identified for potential restoration, the flow diagram in this chapter will help to determine what may be the most appropriate sequence of actions. The flow diagram includes factors such as habitat suitability, conifer competition, stand density, and regeneration. Beginning with chart A, users assess an individual site using a series of yes/no questions to arrive at recommended management activities, which are described in detail in chapter 6.

Common Eastside Oak Stand Types

Pristine or semi-pristine oak stands

These are existing, functioning oak stands, of high value to wildlife. Restoration should include management of areas outside these stands to expand habitat. Management actions include

- invasive species treatments (if needed);
- prescribed fire; and
- planting of oak seedlings (if needed).

Stands containing remnant or large-diameter oaks

Restoration should focus on oak regeneration and the understory. Management actions include

- treatment of invasive species;
- fuels reduction, including removal/thinning of smaller oaks and/or conifers;
- prescribed fire; and
- planting of oak seedlings (if needed).

Small-diameter, high-density oak stands

Restoration should focus on thinning and fuels reduction followed by understory restoration.

Management actions include

- thinning of oak;
- treatment of invasive species;
- fuels reduction;
- prescribed fire; and
- seeding or planting of understory plants.

Mixed oak-conifer stands

Restoration should focus on preserving the larger oak and ponderosa pine trees (if present), release from encroaching Douglas-fir, and the understory.

Management actions include

- removal or girdling of Douglas-fir;
- treatment of invasive species;
- fuels reduction, including removal/thinning of smaller oaks and/or conifers;
- prescribed fire; and
- seeding or planting understory plants.



Flowchart A - Location

Is this area/stand on the west side of the Cascades?

This restoration strategy is intended for areas on the east side of the Cascade Range.

Has this area/stand been mapped?

Restoration of oak stands will require that the extent of the habitat be mapped as a GIS layer. This allows integration with other geospatial data such as land allocation, soils, and hydrology.

Is the area/stand in wilderness?

Due to wilderness management regulations, a Minimum Requirements Decision Guide analysis is likely to be required to justify any potential treatments within wilderness.

Is the area/stand in late successional reserve (LSR) or a riparian zone?

Restoration activities in these land allocations may need additional justification to implement restoration treatments. This is likely to be addressed in a NEPA analysis.

Can management actions be justified?

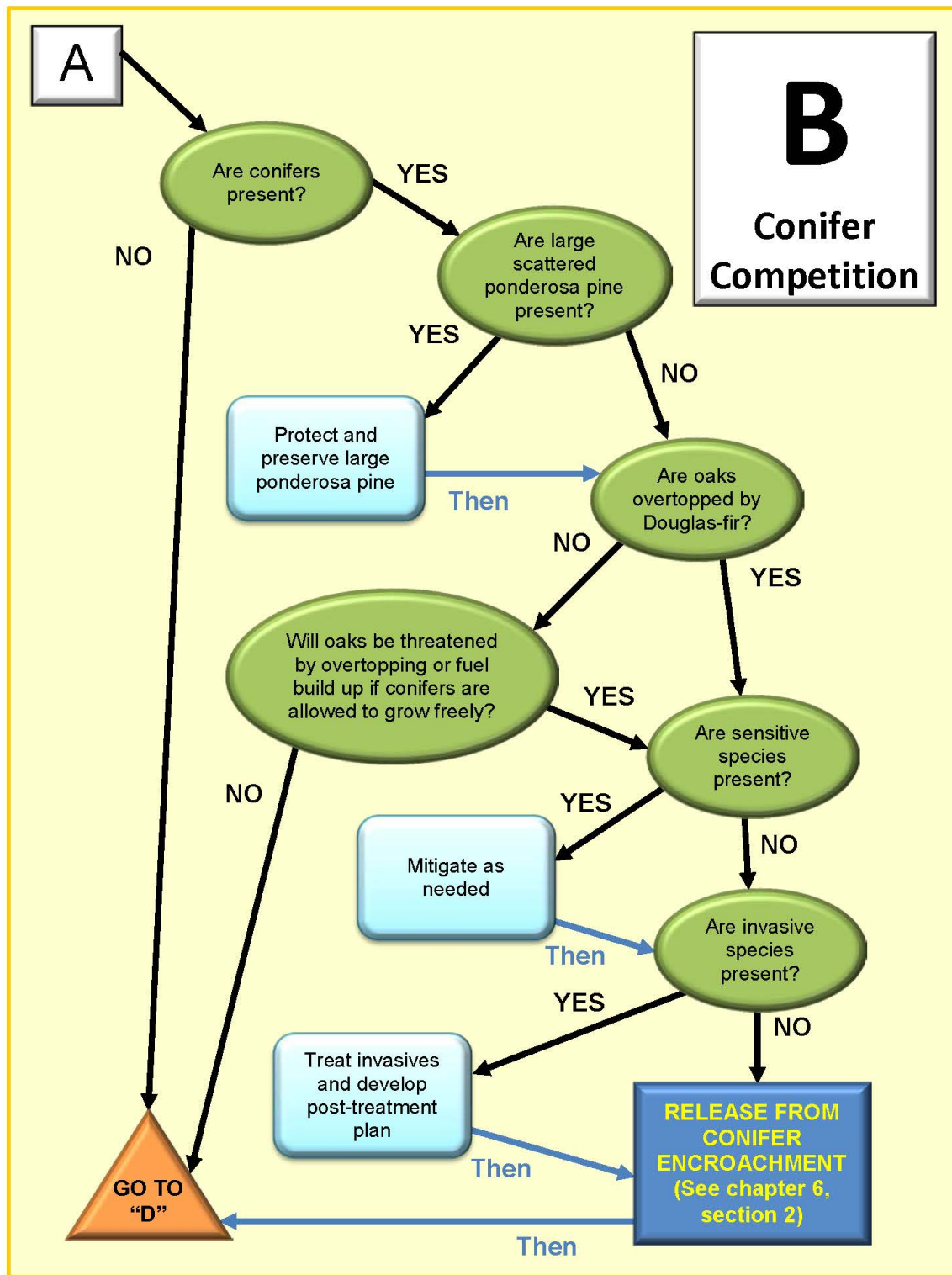
Late successional reserves and riparian zones likely have more stringent restrictions on permissible management actions, and additional justification may be necessary to implement restoration treatments.

Has the area/stand been inventoried?

Overstory density, species composition, diameter/age class distribution, and health/condition should be assessed to determine whether and what type of restoration activities may be appropriate.

Are oaks present?

The absence of oaks does not necessarily mean that they were not present historically; however, their absence will influence recommended restoration activities.



Flowchart B - Conifer Competition

Are conifers present?

If conifers are present on the site, it will need to be determined which trees should be preserved and which trees present a current or future threat to the restoration of oak habitat.

Are large scattered ponderosa pine present?

Ponderosa pine is a component of eastside oak-pine woodland habitat, and provides important habitat for some wildlife species.

Are oaks overtopped by Douglas-fir?

Encroachment and overtopping of oak by Douglas-fir represents a considerable threat to the long-term viability of oak stands.

Will oaks be threatened by overtopping or ladder fuel buildup if young conifers are allowed to grow freely?

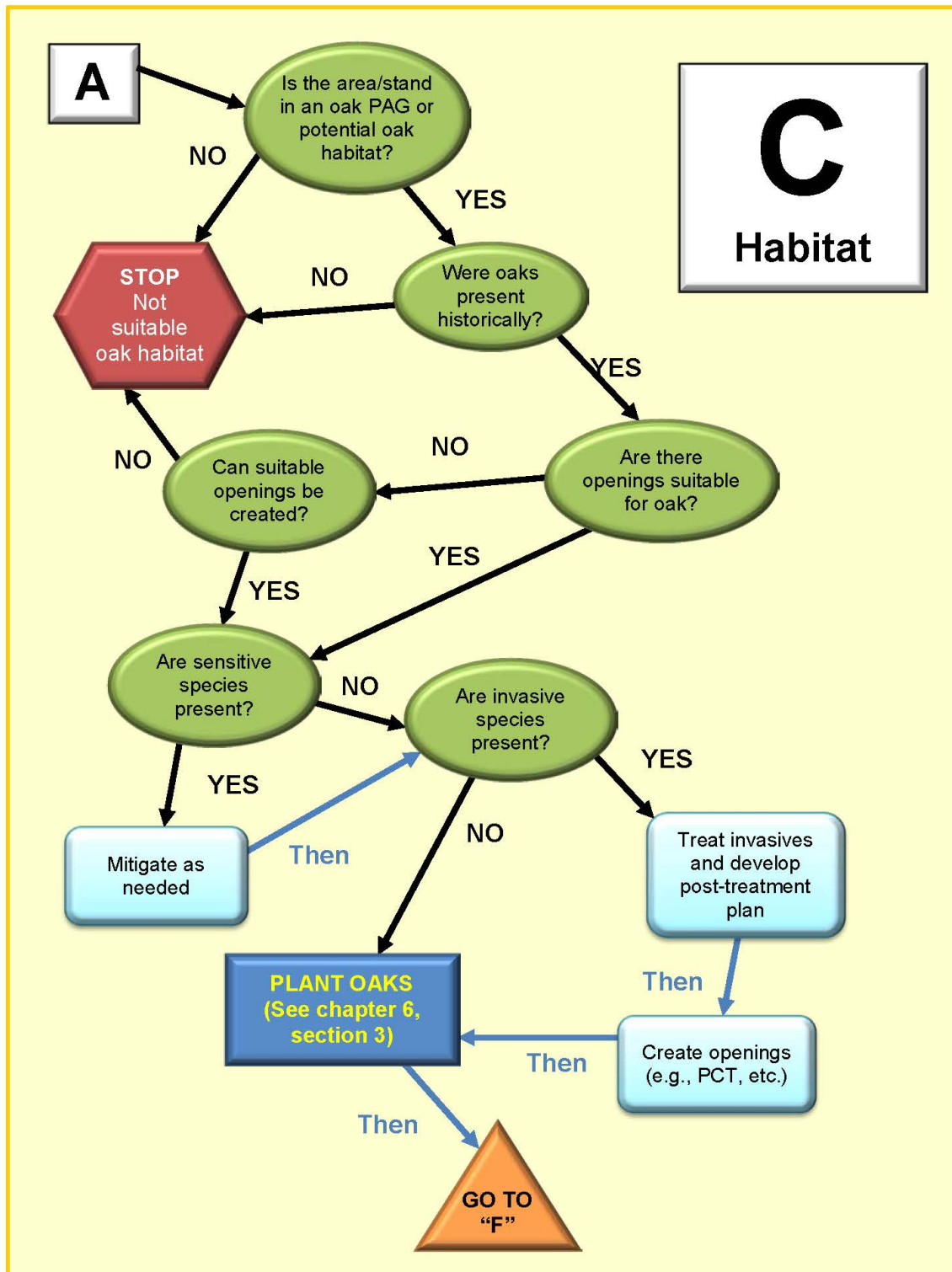
Stands with a high density of small trees may require treatment to reduce fuel ladders and the threat of crown fire. Young Douglas-fir that does not currently overtop oaks will likely do so in the future if left to grow freely.

Are sensitive species present?

If sensitive species are present (including vertebrates, invertebrates, fungi, and vascular and non-vascular plants), restoration activities must not negatively impact these species.

Are invasive species present?

If invasive species are present, restoration activities may inadvertently create conditions that give these species a competitive advantage over native species. Soil disturbance, and changes in vegetative composition, light, and soil water availability, can trigger increases in invasive species. Thus, management of invasives must be included in restoration planning.



Flowchart C - Habitat

Is the area/stand in an oak plant association group (PAG) or potential oak habitat?

If oaks are not present and the site is not in an oak PAG, it is likely not suitable for oak habitat restoration.

Were oaks present historically?

If it is likely that oak woodland or savanna was present in the area historically, even if it was not present on the specific site, then it may be suitable for restoration.

Are there openings suitable for oak?

Oak woodland and savanna habitat is characterized by a low-density overstory; oak trees require full sunlight to develop broad, spreading crowns. The presence of scattered pines is acceptable, but few, if any, Douglas-fir should be present.

Can suitable openings be created?

Are there any restrictions in place that would prevent substantial manipulation of the overstory, including removal of most or all Douglas-fir trees (if present) and removal or thinning of young ponderosa pine (if present)?

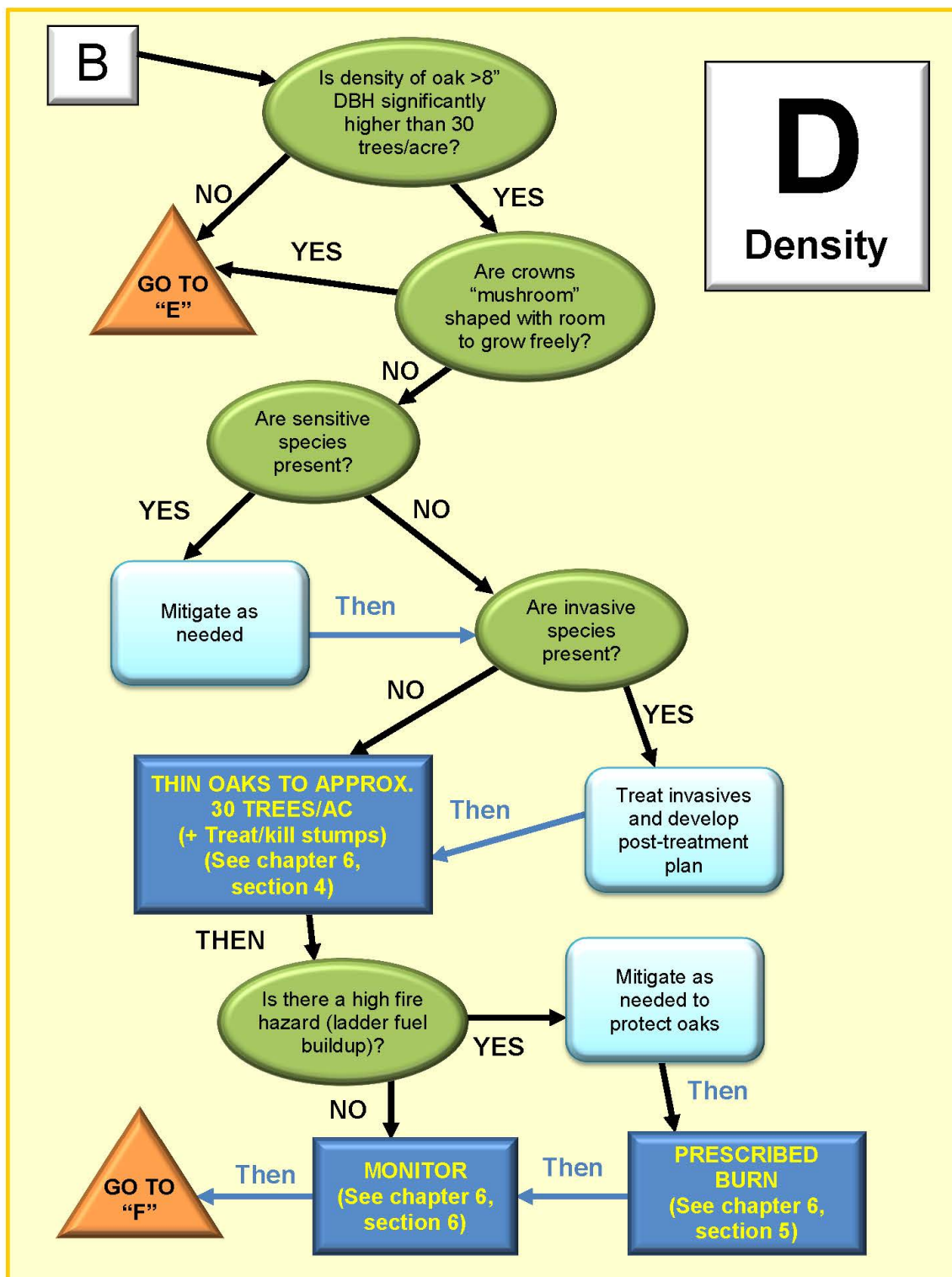
Are sensitive species present?

If sensitive species are present (including vertebrates, invertebrates, fungi, and vascular and non-vascular plants), restoration activities must not negatively impact these species.

Are invasive species present?

If invasive species are present, restoration activities may inadvertently create conditions that give these species a competitive advantage over native species. Soil disturbance, and changes in vegetative composition, light, and soil water availability, can trigger increases in invasive

species. Thus, management of invasives must be included in restoration planning.



Flowchart D - Density

Is density of oak >8" DBH significantly higher than 30 trees/ac?

It is believed that many oak stands historically were of low density. Although there are no absolute guidelines, a suggested target density for mature oak trees is a maximum of approximately 20 to 40 trees per acre. This provides trees with sufficient room to grow freely, producing broad, "mushroom-shaped" crowns.

Are crowns "mushroom" shaped with room to grow freely?

Historical oak woodland and savanna habitats were characterized by a low-density overstory in which oak trees developed broad crowns and the understory received a large amount of sunlight. Habitat features such as cavities and large, spreading limbs are achieved when oak trees have ample room to grow freely.

Are sensitive species present?

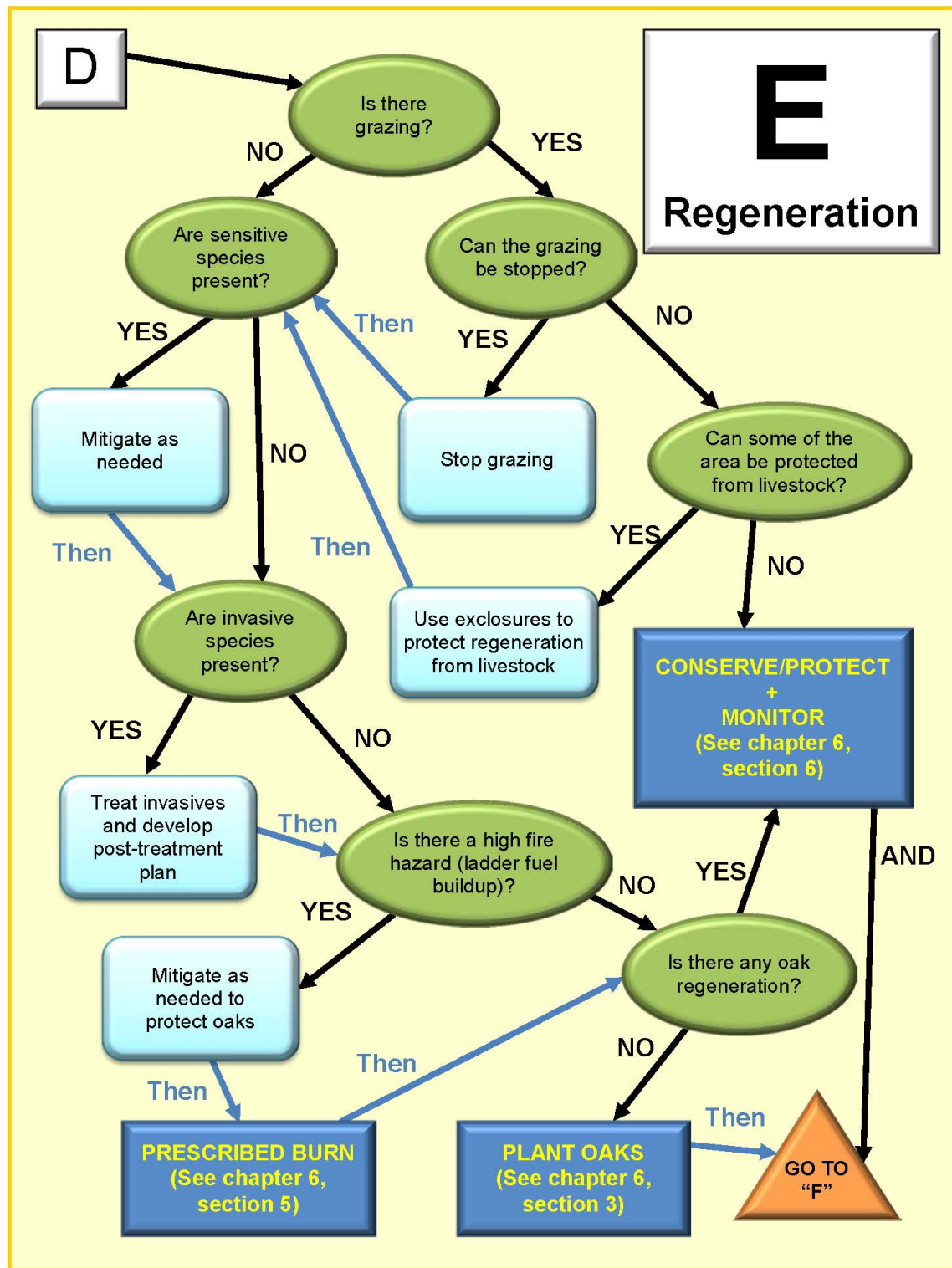
If sensitive species are present (including vertebrates, invertebrates, fungi, and vascular and non-vascular plants), restoration activities must not negatively impact these species.

Are invasive species present?

If invasive species are present, restoration activities may inadvertently create conditions that give these species a competitive advantage over native species. Soil disturbance, and changes in vegetative composition, light, and soil water availability, can trigger increases in invasive species. Thus, management of invasives must be included in restoration planning.

Is there a high fire hazard (ladder fuel buildup)?

Following a prolonged period of fire suppression, many stands have accumulated significant ladder fuels, often as young trees or shrubs.



Flowchart E - Regeneration

Is there grazing?

Grazing by livestock can damage oak sprouts, affecting regeneration. Grazing also can lead to replacement of native bunchgrasses by cheatgrass and other nonnative species.

Can the grazing be stopped?

Oak may regenerate on grazed sites after grazing is terminated.

Are sensitive species present?

If sensitive species are present (including vertebrates, invertebrates, fungi, and vascular and non-vascular plants), restoration activities must not negatively impact these species.

Can some of the area be protected from livestock?

If exclosures are installed, oak regeneration can occur in those areas.

Are invasive species present?

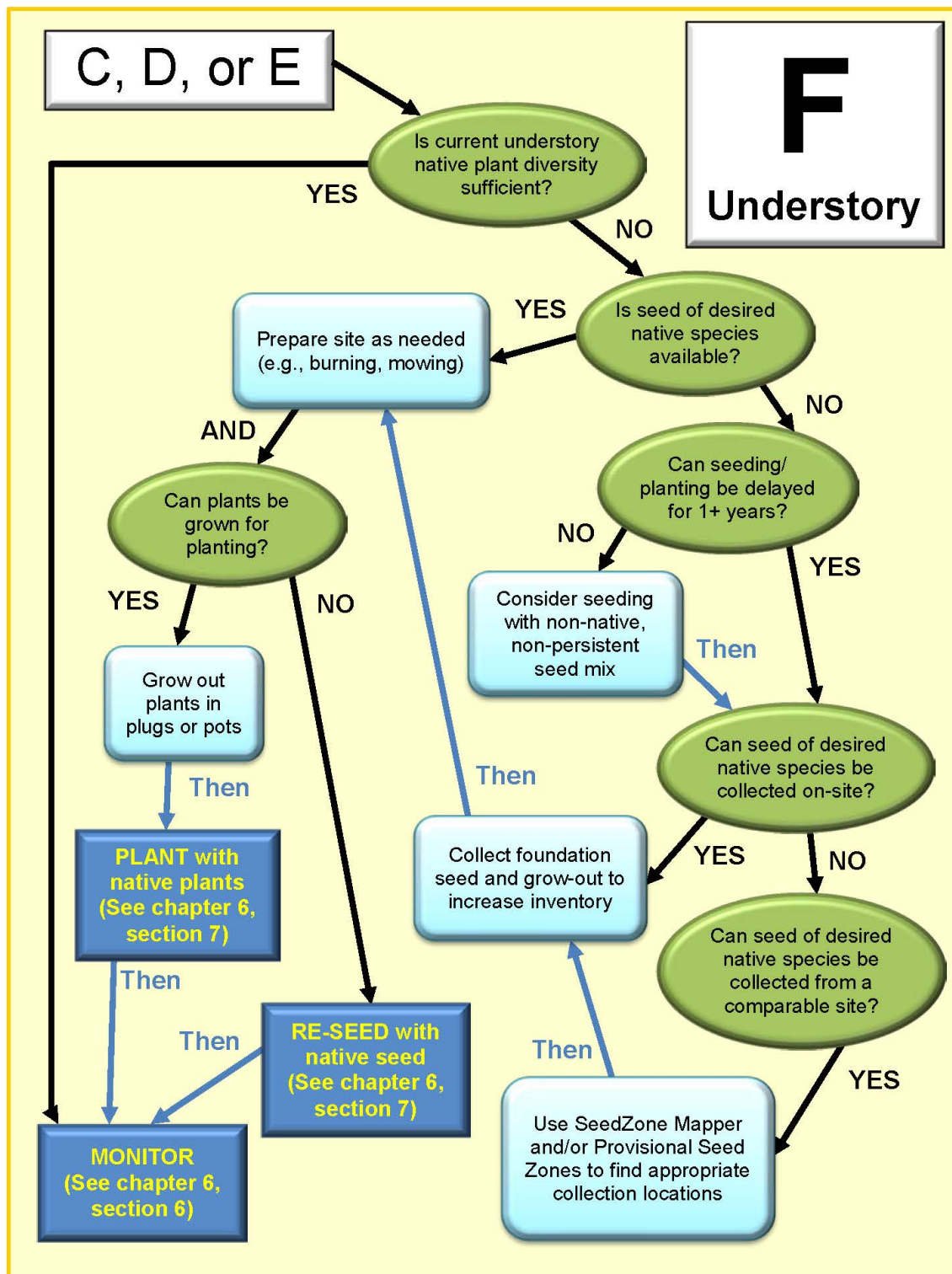
If invasive species are present, restoration activities may inadvertently create conditions that give these species a competitive advantage over native species. Soil disturbance, and changes in vegetative composition, light, and soil water availability, can trigger increases in invasive species. Thus, management of invasives must be included in restoration planning.

Is there a high fire hazard (ladder fuel buildup)?

Following a prolonged period of fire suppression, many stands have accumulated significant ladder fuels, often as young trees or shrubs.

Is there any oak regeneration?

Long-term viability of oak habitat requires successful reproduction. However, it is unclear at what interval this reproduction occurred historically on the eastside. Some southwestern Oregon stands appear to have had pulses of regeneration at multidecadal intervals, whereas reproduction may have established more frequently in other stands (Gilligan and Muir 2011). A stand with no young oak trees indicates that past conditions have been unsuitable for regeneration, and managers may want to consider planting oak to supplement natural regeneration.



Flowchart F - Understory

Is current understory native plant diversity sufficient?

Does the understory composition meet restoration objectives? Objectives for the understory may be based on presence of sensitive or indicator species, diversity metrics, or other measures.

Is seed of desired native species available?

Restoration of the native understory usually requires seeding or planting of plugs grown from wild-collected seed.

Can seeding/planting be delayed for 1+ years?

Some areas may need to be revegetated immediately to prevent soil erosion and/or establishment of invasive species. In these cases, seeding with a mix of non-persistent, non-native species may be beneficial.

Can seed of desired native species be collected on-site?

When restoring native understory plants, local seed sources have the highest likelihood of success.

Can seed of desired native species be collected from a comparable site?

If no seed source of the desired native species is available on-site or nearby, seed can be collected from comparable sites within the same provisional seed zone.

SeedZone Mapper and Provisional Seed Zones available at:
http://www.fs.fed.us/wwetac/threat_map/SeedZones_Intro.html

Can plants be grown for planting?

If there is not an immediate need for revegetation, planting plugs is likely to result in higher success and will use less seed than broadcast seeding.

CHAPTER 6. MANAGEMENT ACTIONS

This section includes additional information and resources for seven types of management actions that appear in the flow diagrams in the previous chapter.

1. Map and Inventory at the Stand Level

Rationale for implementation

Spatial data collected at the stand level can be combined with data on ownership boundaries, topography, soils, invasive and sensitive species, climate, hydrology, and other elements to provide a broad ecological context to inform management decisions. In addition to maps, inventories of existing overstory and understory vegetation are essential for making management decisions.

Description

Mapping and inventory procedures should delineate each stand type if multiple types are present within the restoration area. It also may be important to record locations where specific treatments need to be applied, such as treatments targeting invasive species. Similarly, it may be useful to map key ecological features, such as pockets of large, remnant oak trees.

Stand-level inventories of overstory and understory vegetation provide quantitative information necessary for making decisions on restoration treatments. Inventory data also provide documentation of baseline conditions that can later be used to evaluate the efficacy of restoration treatments. When inventorying oak trees, it may be useful to measure additional variables such as crown size, crown shape, or height to live crown.

Practical considerations

The oak habitat mapping project of the Northwest Habitat Institute (NWHI) is the largest such project in the eastside region that includes both spatial data on oak stands as well as associated descriptors of overstory condition. The maps do not include information on understory vegetation, however. The NWHI oak habitat maps include the Mt. Hood National Forest and a portion of the Columbia River Gorge National Scenic Area (fig. 2). Owing to the size, recentness (2006-2010), and quality of the NWHI dataset, it is recommended that future mapping efforts produce data that are compatible with the NWHI data (e.g., overstory classification using the same protocols). The NWHI protocols should serve only as a starting point, however; future mapping should not be strictly limited to collecting only the variables recorded by NWHI.

Consequence of no action

Mapping and inventorying are essential for making and documenting management decisions.

Key sources of information

The NWHI protocol is available at http://nwhi.org/inc/data/gisdata/data/willamette/Mt_Hood_NF_oak.zip for download.

2. Release from Conifer Encroachment

Rationale for implementation

Oregon white oak is a climax tree species only on sites that are marginal for tree growth—for example, extremely dry sites—and on sites where oak is perpetuated by repeated disturbance, such as regular fire. Without repeated disturbance, the rate at which an Oregon white oak woodland succeeds to a conifer stand is correlated with the amount of available growing-season soil moisture. Thus, in the absence of regular fire, conifer establishment and eventual overstory dominance becomes more likely with increasing rainfall and deeper soils.

On relatively moist oak sites, Douglas-fir is the tree species most likely to encroach upon and eventually dominate oak woodlands in the absence of fire. Because Douglas-fir grows more rapidly than oak and reaches a much greater maximum height, it is capable of overtopping and suppressing oak trees, which leads to their eventual death. The influence of encroaching Douglas-fir on oak woodland habitat and understory vegetation is dramatic and relatively rapid. Ponderosa pine also competes with oak on drier sites. Given a lack of disturbance, these conifer species have the potential to regenerate in dense “doghair” stands of young trees, which can create a significant fuels problem.

In restoring oak woodlands to their historical structure, removing or reducing conifer competition is often a necessity. Where overstory conifers compete with oak trees and where dense stands of young conifers occur, their removal is a necessary first step in restoring microclimatic conditions suitable for native plant and animal

species. Additionally, conditions for broadcast burning—commonly part of the restoration process—are improved by reducing the conifer density in such stands.

Description

Release of Oregon white oak woodlands from encroaching conifers has been implemented west of the Cascade Crest (Devine and Harrington 2006; Harrington and Devine 2006), in transitional eastside-westside stands in the Columbia River Gorge (pers. comm., Robin Dobson, U.S. Forest Service), and in eastside oak stands (pers. comm., Whitney Olsker, U.S. Forest Service and Lindsay Cornelius, Columbia Land Trust).

A study in western Washington showed no adverse effects of completely releasing oak trees from overtopping conifers in a single-entry operation (Devine and Harrington 2006, 2013). Trees were partially to mostly shaded prior to release, but the dramatic change in microclimate following release had no apparent adverse effects on trees. Instead, the release significantly increased the oak trees’ stem growth and acorn production and stimulated formation of new (epicormic) branches.



A 200-year-old oak overtopped by a 40-year-old Douglas-fir.

For various reasons, it is sometimes not possible to perform a complete removal of encroaching overstory conifers. The alternative is to remove conifers in multiple phases. In this situation, removal of the conifers that are closest to the oak trees will temporarily increase the oaks' access to sunlight and belowground resources. It should be noted that, over time, the other nearby conifers will expand their crowns and roots into created gaps, reducing the amount of growing space that was temporarily created for the oak trees. Another option is to create larger gaps, releasing entire patches or clumps of oak trees. Compared to complete release from conifers, these methods of partial release produce a smaller benefit for the oak trees (Devine and Harrington 2006, 2013). They may, however, sustain the oak trees until a subsequent conifer removal is implemented.

Practical considerations

- Logging contractors must understand the objective of the release is to preserve the oak.
- Harvest operations removing large, overtopping conifers from among oak trees have the potential to significantly damage the oak. Logging contracts should clearly specify practices that will minimize damage to oak trees, as well as define acceptable levels of

damage to oak trees and penalties for exceeding these levels.

- If a conifer cannot be removed without significant damage to nearby oak trees, it may be desirable to girdle the tree or inject herbicide, thereby creating a snag.
- Removal of smaller-diameter conifers is also very important; they are fuel ladders as well as the next generation of overstory competition.
- Removal of large conifers may cause substantial disturbance to the understory and forest floor. Exposed soil becomes an ideal seedbed for invasive or undesirable plants. Plans for managing a post-release understory should be developed before treatment.
- Logging equipment entering a restoration site should be cleaned and inspected to prevent introduction of additional invasive species.
- Removal of large conifers has the potential to create a large amount of slash, which must then be eliminated (e.g., piled and burned).
- After conifers are removed, reproduction is still likely owing to seeds or seedlings that are present, or from seeds from adjacent stands. Periodic control of reproduction, using fire, mechanical, or chemical control, will often be necessary. If any large conifers are left in the overstory, these will be a seed source, increasing the likelihood of seedling establishment.

Consequence of no action

Because Oregon white oak is shade-intolerant at maturity, overtopping by conifers—especially Douglas-fir—will result in crown dieback and eventual mortality of oak trees. Douglas-fir also creates a shaded forest understory microclimate that is not suitable for the native understory species of Oregon white oak communities or for broadcast burning. Ponderosa pine may provide



Mark Williams, BLM

Oak crowded by dense, young ponderosa pine; the fuel ladder created by these young pines is a significant threat to the oak.

significant competition for soil water, even when the crowns of the pine trees do not directly overtop the oaks.

Key sources of information

Devine, W.D.; Harrington, C.A. 2006. Changes in Oregon white oak (*Quercus garryana* Dougl. ex Hook.) following release from overtopping conifers. *Trees – Structure and Function*. 20:747-756. http://www.fs.fed.us/pnw/olympia/silv/publications/ot/544_DevineHarrington2006b.pdf

Devine, W.D.; Harrington, C.A. 2013. Restoration release of overtopped Oregon white oak increases 10-year growth and acorn production. *Forest Ecology and Management*. 291: 87-95. <http://dx.doi.org/10.1016/j.foreco.2012.10.053>

Two research papers describing oak growth, acorn production, and epicormic branching following release from Douglas-fir on a westside site.

Gould, P. J.; Harrington, C.A. 2008. Evaluation of landscape alternatives for managing oak at Tenalquot Prairie, Washington. Gen. Tech. Rep. PNW-GTR-745. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 45 p. http://www.fs.fed.us/pnw/pubs/pnw_gtr745.pdf

This paper presents a Puget Sound Region case study in which the outcomes of several different management scenarios are modeled for a mixed Oregon white oak-Douglas-fir stand. The landscape-level analysis used GIS, a forest growth model (ORGANON), and landscape visualization software (EnVision).

Harrington, C.A.; Devine, W.D. 2006. A practical guide to oak release. USDA

Forest Service General Technical Report GTR-PNW-666. <http://www.treeseearch.fs.fed.us/pubs/21921>

An illustrated guide to releasing oak trees from conifers, based on experiences in western Washington.

Vesely, D.; Tucker, G. 2004. The landowner's guide for restoring and managing Oregon white oak habitats. Bureau of Land Management, Salem District, Salem, Oregon. http://www.blm.gov/or/districts/salem/files/white_oak_guide.pdf

A detailed guide to many aspects of oak woodland management, including release of oak from conifers. Uses westside examples.

Other references

Devine, W.D.; Harrington, C.A.; Peter, D.H. 2007. Oak woodland restoration: understory response to removal of encroaching conifers. *Ecological Restoration*. 25(4): 247-255. <http://dx.doi.org/10.3368/er.25.4.247>

Devine, W.D.; Harrington, C.A. 2007. Release of Oregon white oak from overtopping Douglas-fir: effects on soil water and microclimate. *Northwest Science*. 81(2): 112-124. <http://dx.doi.org/10.3955/0029-344X-81.2.112>



Burning piles after thinning small-diameter pine.

Mark Williams, BLM

3. Planting Oak

Rationale for implementation

Restoration sites may include areas from which oak has been extirpated or areas where the density of oak trees, including seedlings and saplings, is below desirable levels. Because natural regeneration may be episodic and may require years or decades to occur, planting is usually a more practical method of establishing new trees.

Description

Oak may be planted as seedlings or as acorns; however, planted seedlings appear to have a much higher likelihood of success than planted acorns on eastside sites (pers. comm., Jim Evans, The Nature Conservancy). Planted acorns may incur very high levels of predation, and the acorns that germinate are vulnerable to environmental stressors in their first year, particularly desiccation (Fuchs et al. 2000). Seedlings that have been grown in containers or nursery beds typically have a higher rate of establishment.

In addition to treating exotic or undesirable vegetation prior to planting oak seedlings or acorns, post-planting cultural treatments are important for increasing the rate of seedling establishment (Devine and Harrington 2010). Treatment needs vary by site but may include protection from browsing and rodent damage, control of competing vegetation, or irrigation. Repeated site visits for the purpose of applying and maintaining cultural treatments and assessing additional seedling protection needs are highly beneficial during the first several years after planting.

Practical considerations

- The cost of establishing oak trees through planting can be significantly increased by the need for pre- and post-planting treatments. On some sites, significant levels of competition from undesirable herbaceous or woody

vegetation will necessitate pre-planting control treatments as well as multiple treatments after planting. Although irrigation is rarely a practical option, it also adds significant cost to establishment.

- Planting oak seedlings in clusters may potentially reduce the cost of some cultural treatments. For example, weed control may be applied to an “island” of planted oak seedlings.
- Planting of oak seedlings may temporarily limit options for prescribed fire because young seedlings are likely to be top-killed during a burn. The amount of fuels present and the proximity of fuels to individual seedlings will influence the likelihood of top-kill. One possible method of preserving the young oak is to apply fire-retardant foam around seedlings or clusters of seedlings prior to burning. If a prescribed burn is planned, it may be more efficient to burn prior to planting.



Warren Devine

Oak seedlings planted at Swauk Valley Ranch (WA) with weed control (plastic mulch) and drip irrigation.

- After oak seedlings have established robust root systems, most will sprout following top-kill, but establishment of such root systems may take several years post-planting. The diameter of the base of the stem is correlated with the size of the root system and likely is also correlated with a seedling's chance of surviving top-kill. Sprouting following top-kill often results in multiple stems, or a shrubby tree, and thus it will take additional time for one of these stems to naturally attain dominance.
- Planted seedlings or acorns should be derived from parent trees in the same region that they are to be planted. As noted in the genetics section of the introduction, Huebert (2009) suggested that seed of westside Oregon white oak can be moved between areas differing by as much as 0.75 in. of summer precipitation or as much as 1.8 °F in mean temperature of the warmest month, with minimal risk of being poorly adapted to the new environment. But because these guidelines were developed for westside populations of Oregon white oak, it remains unclear whether they are directly applicable to eastside populations. Certainly, seed from the westside should not be moved to the eastside, and vice versa.

Consequence of no action

In the absence of planting, oak must be regenerated through natural means, which is feasible only if a nearby seed source is available. Even if a seed source is present, natural regeneration is episodic and may not meet the desired timeline of a restoration project.

Key sources of information

Bakker, J.D.; Colasurdo, L.B.; Evans, J.R. 2012. Enhancing Garry Oak seedling performance in a semiarid environment. *Northwest Science*. 86(4): 300-309. <http://dx.doi.org/10.3955/046.086.0406>

The only eastside Oregon white oak planting study of which we are aware; discusses a variety of cultural treatments.

Blume, L. 2009. Garry oak restoration in central Washington: planting technique evaluation and preliminary target identification through stand characterization. M.S. Thesis, University of Washington, Seattle, WA.

A thesis providing some additional details on the eastside Oregon white oak planting study (Bakker et al. 2012).

Devine, W.D.; Harrington, C.A. 2010. Planting native oak in the Pacific Northwest. USDA Forest Service General Technical Report PNW-GTR-804. <http://www.treesearch.fs.fed.us/pubs/34610>

Using westside studies, this report summarizes a wide variety of research results on growing and planting Oregon white oak seedlings. It is intended for a broad audience, including managers and landowners.

McCreary, D.D. 2001. Regenerating rangeland oaks in California. Oakland, CA: University of California Sierra Foothill Research and Extension Center. 62 p. <http://www.californiaoaks.org/ExtAssets/Regenerating%20Rangeland%20Oaks%20in%20California.pdf>

Summarizes a wide range of information on various aspects of planting and naturally regenerating California oak species. Though not specific to Oregon white oak, this information is relevant to eastside work, given the arid climate of the examples that McCreary discusses.

Other references

Clements, D.R.; Luginbill, S.; Jordan, D.A.; Van Dragt, R.; Pelant, R.K. 2011. Techniques to promote Garry oak seedling growth and survival in areas with high levels of herbivory and competition. *Northwest*

Science. 85: 172-181.

<http://www.bioone.org/doi/abs/10.3955/046.085.0208>

An in-depth study of browsing and rodent effects on planted seedlings. Study was located on Salt Spring Island, BC, and Whidbey Island, WA.

Devine, W.D.; Harrington, C.A. 2008. Influence of four tree shelter types on microclimate and seedling performance of Oregon white oak and western redcedar. USDA Forest Service Research Paper RP-PNW-576.

<http://www.treeseearch.fs.fed.us/pubs/30417>

Research on the effects of several tree shelters on a westside site.

Devine, W.D.; Harrington, C.A.; Kraft, J.M. 2010a. Acorn storage alternatives tested on Oregon white oak. Native Plants Journal. 11(1): 65-76.

http://www.fs.fed.us/pnw/pubs/journals/pnw_2010_devine001.pdf

The only research that we are aware of on cold storage of Oregon white oak acorns.

Devine, W.D.; Harrington, C.A.; Leonard, L.P. 2007. Post-planting treatments increase growth of Oregon white oak (*Quercus garryana* Dougl. ex Hook.) seedlings. Restoration Ecology. 15(2): 212-222.

<http://www.treeseearch.fs.fed.us/pubs/29660/>

Results of westside research on several planting techniques. This publication is more technical than the 2010 report by Devine and Harrington (PNW-GTR-804).

Devine, W.D.; Harrington, C.A.; Southworth, D. 2010b. Improving root growth and morphology of containerized Oregon white oak seedlings. Tree Planters' Notes. 53(2):29-34.

<http://naldc.nal.usda.gov/download/41642/PDF>

Detailed information on several techniques for growing Oregon white oak seedlings in containers.

Fuchs, M.A.; Krannitz, P.G.; Harestad, A.S. 2000.

Factors affecting emergence and first-year survival of seedlings of Garry oaks (*Quercus garryana*) in British Columbia, Canada. Forest Ecology and Management. 137: 209-219. [http://dx.doi.org/10.1016/S0378-1127\(99\)00329-1](http://dx.doi.org/10.1016/S0378-1127(99)00329-1)

A field study in British Columbia examining a variety of factors that influence regeneration of Oregon white oak from acorns. Relevant to direct seeding and natural regeneration.

Southworth, D.; Carrington, E.M.; Frank, J.L.; Gould, P.J.; Harrington, C.A.; Devine, W.D. 2009.

Mycorrhizas on nursery and field seedlings of *Quercus garryana*. Mycorrhiza. 19(3):149-158.

<http://dx.doi.org/10.1007/s00572-008-0222-1>

Information on the important role of mycorrhizas in regeneration of Oregon white oak.

4. Thinning Oak Stands

Rationale for implementation

Some oak stands are characterized by a high density of relatively small oak trees, many of which are similar in height and age. Such stands usually initiate following disturbance; for example, trees may have originated from sprouts after a stand-replacing wildfire or after a harvest that included removal of mature oak trees. The trees of dense oak stands typically have relatively narrow crowns, because the high number of trees per acre limits individual growing space. Often, there are large clumps of trees, possibly all originating as sprouts from the same stump. When a dense stand is thinned and competition is reduced, the growth rate of the residual oak trees is likely to increase significantly (Gould et al. 2011).

The primary reasons for thinning dense oak stands are:

- **Wildfire susceptibility**—in areas prone to wildfire, the structure and fuel loads of these stands have the potential to make them relatively susceptible to a high-severity, stand-replacing fire. Thinning could be used to substantially reduce ladder fuels.
- **Habitat improvement**—this dense stand structure is not representative of the more open, fire-maintained Oregon white oak stands that were likely common historically. The historical stand structure has many potential habitat benefits for wildlife and native vegetation.

Description

The goal of this treatment is to increase the rate at which a stand of large, well-spaced oak trees

develop. These trees will ideally have large, spreading limbs and broad crowns, which are associated with a high level of acorn production (Peter and Harrington 2009) and habitat for a variety of wildlife species (Larsen and Morgan 1998).

The specific thinning prescriptions applied to dense, young oak stands will vary. However, the general objective is to retain the largest trees with the broadest crowns. Suppressed trees, and trees with relatively narrow crowns, should be removed; these trees compete with the larger trees but will likely never become important overstory components. To achieve a stand of trees with broad, spreading limbs, the target stand density should be a spacing that is greater than the diameter of the desired mature crown. The diameter of the desired mature crown should be determined by measuring such trees within the stand, if present. If not, it may be useful to measure crown diameter of mature trees in another stand located on a similar site. As an example, if the desired mature crown diameter is 25 ft, with an additional 10 ft opening between crowns, then the theoretical spacing would be 35 ft (36 trees/ac). When calculating the desired spacing, it is also important to allow for future mortality. If 25 percent mortality is anticipated before the trees reached maturity, then the stand in this



Dense young oak stands may regenerate from seed, or more often, from sprouting after a disturbance.

example should be thinned to 48 trees/ac. Because oaks frequently grow in clumps, it may be desirable to treat a small clump as a single tree in these spacing calculations.

Several Oregon white oak thinning projects have been implemented in recent years, although the only project with results thus far was one conducted on the westside:

- The Columbia Land Trust conducted four restoration projects that included thinning of oak stands and oak-pine stands in Klickitat and Skamania Counties, WA, between 2004 and 2011. They installed permanent monitoring plots at each site to collect overstory and understory data (pers. comm. Lindsay Cornelius, Columbia Land Trust).
- The Mt. Hood National Forest Barlow Ranger District has conducted precommercial thinning in oak-ponderosa pine stands, which included removal of stems up to 8 in. diameter (pers. comm., Whitney Olsker, USFS).
- The Bureau of Land Management Spokane District has thinned dense stands of young oak using a crown-release strategy to promote growth of the larger trees (pers. comm., Mark Williams, BLM).
- The Forest Service Pacific Northwest Research Station installed a small thinning trial in a western Washington oak stand. Eighty percent of trees were removed from a young, dense oak stand (basal area reduced from 122 to 33 ft²/ac), with the largest trees (averaging 5.6 in. diameter) favored for retention. Diameter of those residual trees increased by 1.2 in. during the 8 years after thinning, compared to only 0.7 in. for similarly sized trees in an adjacent, unthinned oak stand. The smaller trees in that unthinned oak stand (i.e., the trees equivalent to the ones that were cut in the thinned stand) grew by only 0.2 in. diameter during the 8 years (data on file, Olympia Forestry Sciences Laboratory). Seventy-one percent of the

stumps sprouted. Although some of these sprouts remain vigorous, many did not survive to age 10.

Although longer term data on the results of Oregon white oak thinning treatments are not yet available, forest growth models (Forest Vegetation Simulator and ORGANON) have projected substantial improvements in stand structure—shifts toward more open stands with increased growth of larger trees—as a result of thinning oak stands (Gould et al. 2008, 2011).

Practical considerations

- Thinning a dense stand creates a large amount of slash, even if the harvested stems are removed for timber or firewood. Slash is typically piled and burned, but in some stands it may be desirable to lop and scatter.
- Most Oregon white oak trees, particularly younger trees, vigorously sprout after they are cut or top-killed. This is an adaptation to fire and other disturbances; however, these sprouts could produce a new cohort of young trees, which would negate the benefits of thinning. Strategies that have been tested for reducing oak stump sprouting include:
 - Apply herbicide to fresh stumps within a few hours of when trees are cut. Application of glyphosate was very effective in preventing sprouting (pers. comm. Mark Williams, BLM).
 - Apply herbicide to stump sprouts after they have formed. This was very effective in killing sprouts and preventing subsequent sprouting (pers. comm. Mark Williams, BLM).
 - Leave stumps at least 3 ft high (i.e., “high-stumping”). This only slightly reduced the number of sprouts per stump. (pers. comm. Mark Williams, BLM; McDonald 1969).

- Use a tree injector such as the Hypo-hatchet[®] to apply herbicide to the stump (Kossuth et al. 1980).¹ Injection technique is important; sprouting was not controlled when stumps were not properly injected (pers. comm. Mark Williams, BLM).
- Oak trees often grow in clumps (perhaps originating as sprouts from a single stump). Together, the crowns of a clump of trees may have the same shape as a single, large open-grown tree. Thus, it may be desirable to treat a clump of trees as a single tree and retain all of its stems (or alternatively, remove all of its stems). Alternatively, it may be possible to thin a large clump with many stems so that the dominant stems are retained. Stems within a clump probably share a common root system; thus, herbicide should not be applied to these stems unless the objective is to kill the entire clump.

Consequence of no action

If not thinned, dense young oak stands will eventually self-thin, as smaller trees die as a result of competition, and the remaining trees become dominant in the canopy. However, because growth of oak is relatively slow, this process of self-thinning is likely to proceed very slowly (i.e., multiple decades). Furthermore, during the self-thinning period, very dense stands will not provide the habitat benefits of a more open stand and also may be more susceptible to crown fire owing to fuel ladders. Finally, it is doubtful that the trees that eventually become dominant through the self-thinning process will ever exhibit the broad, spreading crowns of trees that developed at lower stand densities.

Key sources of information

Gould, P.J.; Harrington, C.A.; Devine, W.D. 2011 Growth of Oregon white oak (*Quercus garryana*). Northwest Science. 85: 159-171.
<http://dx.doi.org/10.3955/046.085.0207>

This paper describes revisions to the Forest Vegetation Simulator (FVS) to improve its modeling of Oregon white oak growth and survival based on factors such as stand density, site productivity, and tree size. The revisions are based on data from forest inventories (e.g., FIA, CVS) and research plots throughout much of the species' range. The paper also discusses seasonal diameter growth patterns of Oregon white oak, which have not previously been studied in this species.

Gould, P.J.; Marshall, D.D.; Harrington C.A. 2008. Prediction of growth and mortality of Oregon white oak in the Pacific Northwest. Western Journal of Applied Forestry. 23: 26–33.
http://www.fs.fed.us/pnw/pubs/journals/uncaptured/pnw_2008_gould001.pdf

Describes refinements made to the ORGANON stand-development model for Oregon white oak, which significantly improve the model's accuracy in predicting growth and mortality of oak trees.

¹ The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

5. Prescribed Burning

Rationale for implementation

Native Oregon white oak communities are highly adapted to fire, and, prior to European settlement, fire was likely an important component of nearly every oak community in the Pacific Northwest. Furthermore, except where it is a climax species on very dry sites, Oregon white oak depends on fire to reduce competition from its less fire-tolerant conifer associates. Relatively frequent, low-intensity fire reduces accumulation of fuels and maintains the characteristic, open understory historically associated with Oregon white oak habitat. It also creates forest floor conditions suitable for the native understory species adapted to these ecosystems.

Key ecological goals of prescribed burning in Oregon white oak stands include:

- Reducing fuel loads. Accumulation of woody fuels including shrubs and young trees could increase the potential for damage to overstory oaks if a high-intensity wildfire were to occur. Because these overstory oaks are usually 100 years of age or older, their loss would alter stand structure for many years.
- Maintaining stand density of native tree species at historical levels to increase health and resiliency of the residual trees and to provide wildlife habitat. Although fire may be used to *maintain* lower density stands, it is not necessarily the most effective tool for *reducing* stand density. Other treatments such as thinning or chemical control may be more effective for reducing density of small trees.
- Controlling regeneration of invading tree species such as Douglas-fir. Such trees would not have been present in large numbers on most sites under the historical fire regime because seedlings and young saplings are readily killed by fire.

Description

Although there are many regulatory and environmental issues that limit its application as a management tool, prescribed burning effectively maintains the disturbance regime that was historically an integral component of most Oregon white oak communities. Today, a major factor affecting how and where prescribed fire is applied in oak stands is accumulation of fuels, which is a function of a site's productivity (especially moisture availability) and past management. Because most stands have had infrequent or no fire for many decades, one or more mechanical treatments are often necessary to reduce woody fuels prior to broadcast burning. Stands may be thinned precommercially or commercially depending on the size of the trees, stand density, species, and local management objectives and constraints. It is generally necessary to minimize logging slash by piling and burning; small-diameter wood may be used for firewood or piled and burned prior to broadcast burning.

Practical considerations

- There are numerous policies and regulations that limit the use of prescribed fire. Air quality concerns and wildfire risk may significantly restrict the burning season. These may be navigated by experienced personnel, who also coordinate with nearby landowners and other stakeholders.
- Because it is not possible to apply fire at historical frequencies, lands must be prioritized using a landscape-level management strategy. Various restoration guides have recommended prescribed fire intervals ranging from 3 to 15 years (Larsen and Morgan 1998).
- Site productivity influences the rate of woody fuel accumulation, and thus will determine the frequency at which fire, or fire in conjunction with mechanical treatment, is needed. For example, on a moist, productive site,

regeneration of conifers, shrubs, or other tree species may be relatively rapid compared to a very dry site.

- Prior to prescribed burning, consider how best to protect important habitat elements such as oak snags or large, remnant trees.
- Young Oregon white oak trees, including seedlings and saplings, may be top-killed by fire (Tveten and Fonda 1999) but will usually sprout from basal buds; mature trees will also sprout, although the likelihood of sprouting decreases with age. Mature oak trees, and its common associate, ponderosa pine, are resistant to damage from low-intensity surface fires owing to relatively thick bark.
- Fire models, such as First Order Fire Effects Model (FOFEM) can be used to predict a variety of fire effects, including tree mortality (<http://www.firelab.org/science-applications/fire-fuel/111-fofem>).

Consequence of no action

Consequences vary depending on the site. On moister sites, where Douglas-fir is prevalent, lack of fire results in encroachment and eventual transition of the stand to a Douglas-fir-dominated overstory. The shrub layer may increase substantially in the absence of fire, and the understory will change as shading from conifers increases. On drier sites where Douglas-fir regeneration is limited to specific microsites, the density of oak and pine will increase well beyond levels that would have existed under the historical fire regime. Similarly, on sites where oak is the dominant tree species, stand density is likely to be substantially higher than historical levels, impacting habitat conditions and potentially increasing susceptibility to crown fire.

Key sources of information

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Washington, D.C.: Island Press. 493 p.

This book includes a section on Oregon white oak woodlands with an extensive summary of what is known regarding historical fire regimes.

Agee, J.K. 1994. Fire and weather disturbances in terrestrial ecosystems of the eastern Cascades. Gen. Tech. Rep. PNW-GTR-320. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 52 p.
http://www.fs.fed.us/pnw/pubs/pnw_gtr320.pdf

This publication focuses on the fire history of the eastern Cascades; it includes discussion of what is known about fire in oak woodland ecosystems.

Other references

Engber, E.A., Varner, J.M.; Arguello, L.A.; Sugihara, N.G. 2011. The effects of conifer encroachment and overstory structure on fuels and fire in an oak woodland landscape. *Fire Ecology*. 7(2): 32-50.
http://norcalrxfirecouncil.org/uploads/Engber_et_al_2011.pdf

This study quantifies fuels and fire intensity across a range of oak community types in the Bald Hills of California; however, the climate at the study site is comparable to that of the Pacific Northwest westside rather than the eastside.

Tveten, R.K.; Fonda, R.W. 1999. Fire effects on prairies and oak woodlands on Fort Lewis, Washington. *Northwest Science*. 73(3): 145-158.

A westside study that examines the effects of fire on native and non-native vegetation of oak and prairie habitats. Discusses top-kill of oak trees of various sizes.

Wright, C.S.; Agee, J.K. 2004. Fire and vegetation history in the eastern Cascade Mountains, Washington. *Ecological Applications*. 14(2): 443-459.

<http://www.arcfuels.org/maggie/AGER%202011.Data/PDF/wright%20eastern%20cascades%202004.pdf>

Although this study does not focus on oak woodland or savanna, it provides valuable information about historical fire frequency in the eastern Cascade Range.

6. Monitoring

Rationale for implementation

Monitoring is vital for documenting changes in oak ecosystems following management or in the absence of management. It has the potential to improve understanding of ecological processes in these ecosystems and to provide a sound basis for implementing management strategies. Monitoring is essential for determining the success of a treatment and for identifying potential improvements in restoration methodology.

Description

Monitoring is the process of repeatedly assessing a resource to provide quantitative information on changes over time. The choice of what variables to monitor should be based on restoration objectives and on what variables are ecologically meaningful to the Oregon white oak ecosystem.

Tree growth, survival, and regeneration, and understory plant cover, may be monitored using a variety of sampling approaches, many of which are described in the documents referenced below. In addition to vegetation, other variables that may be relevant include fuels, soil parameters, wildlife, climate, and pest and pathogen damage.

Photo point monitoring is a powerful tool for documenting the effects of restoration treatments and conveying that information to the public. Photos can be used to show treatment effects, to show vegetation development over time, and to illustrate “before and after” conditions. Precisely executed photo point monitoring can also be used to provide quantitative information on vegetation development over time (Hall 2002).

Practical considerations

- To show the effect of any treatment or of multiple treatments, a control or adjacent untreated reference area should also be monitored. This is the only way to effectively demonstrate the magnitude of the treatment effect; therefore, it is vital that the control area be a typical representation of what would have occurred in the absence of the applied treatment.
- Sampling should be sufficient to capture anticipated changes, given that vegetation responses are often quite variable. Sampling strategies can be based on past experience and knowledge or, for larger or more formal monitoring projects, may be planned on the basis of statistical strength.
- Consider seasonality of sampling, and which plant species will be present (e.g., if sampling in summer, some forbs will have senesced and



Whitney Olsker, US Forest Service

Photo point monitoring, showing the stand structure before (left) and after (right) thinning.

will not be measureable).

- Some variables are important ecologically but are unlikely to change, except over many years. For example, annual measurements of certain soil or fuels variables may not be necessary.
- A vital component of a monitoring plan is scheduling and budgeting for re-measurements.
- Data should be archived in a way that is accessible, and resilient to personnel changes.

Consequence of no action

Without baseline and follow-up data, there will be no sound basis for demonstrating whether a particular management strategy or project is successful in meeting its objectives. Similarly, without monitoring, it may not be possible to track or document loss of diversity or ecological function on sites that are potential candidates for restoration.

Key sources of information

Curtis, R.O.; Marshall, D.D. 2005. Permanent-plot procedures for silvicultural and yield research. Gen. Tech. Rep. PNW-GTR-634. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 66 p.
<http://treesearch.fs.fed.us/pubs/9425>

This is an excellent manual on establishment of permanent plots to monitor long-term tree growth. Although it is written primarily for monitoring conifer forests, the methods can be applied to any type of forest or woodland.

GOERT [Garry Oak Ecosystems Recovery Team]. 2011. Restoring British Columbia's Garry oak ecosystems: principles and practices. Victoria, Canada: Garry Oak Ecosystems Recovery Team. 520 p.
http://www.goert.ca/gardeners_restoration/restoration.php

This guide contains a useful chapter on monitoring, titled "Ecological Inventory and Monitoring" (chapter 7).

Hall, F.C. 2002. Photo point monitoring handbook. Part A: Field procedures; Part B: Concepts and analysis. Gen. Tech. Rep. PNW-GTR-526. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 48 p.
<http://www.treesearch.fs.fed.us/pubs/3255>

A detailed guide to photo point monitoring, using relevant examples.

Vesely, D.; Tucker, G. 2004. The landowner's guide for restoring and managing Oregon white oak habitats. Bureau of Land Management, Salem District, Salem, Oregon.
http://www.blm.gov/or/districts/salem/files/white_oak_guide.pdf

This guide briefly discusses practical approaches for monitoring oak stands.

7. Managing Understory Plant Species

Rationale for implementation

Most existing Oregon white oak communities in the Pacific Northwest have an understory composition and/or structure that differs from that which existed historically. This is often a result of a lack of regular fire and the introduction of non-native species, often through grazing practices. Non-native, invasive plant species compete with native species for limited resources and often alter Oregon white oak ecosystems through their influences on ecosystem processes such as fire regime and nutrient cycling (GOERT 2011). Overstory treatments (e.g., oak thinning or conifer removal) will have substantial effects on the understory environment through increased sunlight, and potentially through increased soil moisture or soil disturbance; these impacts should be considered when evaluating potential understory restoration treatments.

Description

A variety of tools may be used for managing the understory of Oregon white oak ecosystems. These include prescribed fire, planting, sowing seed, mechanical treatments, chemical treatments, biological controls, and manual pulling of non-native species in sensitive areas. Specific prescriptions depend upon local site conditions, plant species present, resource availability, and restoration objectives. Much remains unknown about the response of eastside oak communities to restoration treatments, including the effects of prescribed fire. A partial listing of studies on this subject appears below. As with westside oak communities, there are numerous non-native species that have established and are impossible or impractical to eliminate from the ecosystem.

Practical considerations

- In treating or monitoring invasive species, collaboration among agencies, local governments, conservation organizations, and landowners is essential for efforts to achieve landscape-scale efficacy.
- Heavy grazing reduces the cover of native species including elk sedge, bluebunch wheatgrass, and Idaho fescue. After heavy grazing or soil disturbance, eastside oak stands are then particularly susceptible to invasion by weeds (Lillybridge et al. 1995).



Seeding burn pile footprints.

Lindsay Cornelius, Columbia Land Trust

- Restoration of the pre-settlement understory may be impossible; however, it may be feasible to achieve similar ecosystem function with a different assemblage of plant species. An understory community with the appropriate balance of life-forms (e.g., forb, grass, shrub) may be important for some wildlife species. Conversely, other wildlife species require specific plant species.
- Disturbance associated with restoration activities such as thinning and prescribed fire may, in some cases, temporarily increase a

site's vulnerability to invasive species.

However, burning may also be a useful site preparation technique for planting or seeding.

- Advance planning is necessary if seed or plugs are to be produced, because it may take multiple years to implement production in a greenhouse or garden facility.
- Small-scale seedbed tests may provide important information when conducted in advance of large-scale seeding.

Consequence of no action

Consequences of no action depend upon many site-specific factors and are best evaluated in light of the restoration priorities for a given site. No action would typically result in the understory remaining in its current condition, and potentially degrading over time. Abundance of non-native species is unlikely to decrease under no action.

Key sources of information

Murray, C.M. 2007. General Decision Process for Managing Invasive Plant Species in Garry Oak and Associated Ecosystems (GOEs). Prepared for the Garry Oak Ecosystems Recovery Team and The Nature Conservancy of Canada. 8 p.
http://www.goert.ca/documents/General_Decision_Process_revised.pdf

A brief description of the decision-making process regarding invasive species management; it includes many important considerations involved in the process.

GOERT [Garry Oak Ecosystems Recovery Team]. 2011. Restoring British Columbia's Garry oak ecosystems: principles and practices. Victoria, Canada: Garry Oak Ecosystems Recovery Team. 520 p.
http://www.goert.ca/gardeners_restoration/restoration.php

This is a comprehensive guide to Oregon white oak ecosystem restoration. It focuses on

British Columbia habitats, but presents general information that is applicable to any Oregon white oak restoration project.

Other references

Busse, D.; Simon, A.; Riegel, M. 2000. Tree-growth and understory responses to low-severity prescribed burning in thinned *Pinus ponderosa* forests of central Oregon. *Forest Science* 46(2): 258-268.
http://www.fs.fed.us/psw/publications/busse/psw_2000_busse002.pdf

The growth of ponderosa pine and associated understory vegetation was evaluated for a 6-yr period following spring underburning of surface fuels. Shrub cover, dominated by Purshia tridentata, declined significantly following burning and remained well below preburn levels, even though one-fourth of all burned Purshia plants successfully resprouted. Total herbaceous vegetation cover and production were unaffected by burning, while species diversity increased slightly.

Conrad, C.E.; Poulton, C.E. 1966. Effect of a wildfire on Idaho fescue and bluebunch wheatgrass. *Journal of Range Management* 19(3): 138-141.
<http://www.jstor.org/stable/10.2307/3895397>

An accidental burn of a sagebrush-grass community created an opportunity to investigate some factors that affect the susceptibility of Idaho fescue and bluebunch wheatgrass to damage by fire. The former was more susceptible than the latter. Factors associated with relief increased and those associated with grazing prior to the burn decreased the detrimental effects of fire.

Ellsworth, L.M.; Kauffman, J.B. 2010. Native bunchgrass response to prescribed fire in ungrazed mountain big sagebrush ecosystems. *Fire Ecology* 6: 86-96.
<http://fireecology.org/docs/Journal/pdf/Volume06/Issue03/086.pdf>

Native bunchgrasses (bluebunch wheatgrass, Thurber's needlegrass, squirreltail, and Sandberg bluegrass) positively responded to prescribed fire through increases in reproductive efforts and high rates of survival following fires.

Harrod, R.J.; Fonda, R.W.; McGrath, M.K. 2008. Vegetation response to thinning and burning in a ponderosa pine forest, Washington. Northwest Science 82(2): 141-150. <http://dx.doi.org/10.3955/0029-344X-82.2.141>

The study evaluated, over 9 years, the effects of thinning and burning on vegetation response in a ponderosa pine/pinegrass forest in the eastern Cascade Mountains of Washington. Thinning trees and removing excess fuels, coupled with low-intensity fall prescribed burns, offers a promising management strategy for restoring the pre-settlement structure.

Metlen, K.M.; Fiedler, C.E.; Youngblood, A. 2004. Understory response to fuel reduction treatments in the Blue Mountains of Northeastern Oregon. Northwest Science 78 (3): 175-184. <http://treesearch.fs.fed.us/pubs/20383>

Graminoid cover was not influenced by treatment, forb cover was reduced in treatments that included thinning, and shrub and total cover were reduced in treatments that included burning. Resilience of community diversity to fire and the consistent effect of burning on individual species demonstrate their adaptation to frequent low-intensity fire, and the subsequent moderate impact of low thinning and fall prescribed burning on understory vegetation.

Patton, B.D.; Hironaka, M.; Bunting, S.C. 1988. Effect of burning on seed production of bluebunch wheatgrass, Idaho fescue, and Columbia needlegrass. Journal of Range Management 41(3): 232-234.

<http://ojssandbox.library.arizona.edu/index.php/jrm/article/viewFile/17376/15415>

Idaho fescue seed production was greater on a 5-year-old burn than on the control plot. Columbia needlegrass seed production was markedly greater on a 2-year-old burn than on adjacent unburned areas. The percentage of filled florets and the number of seeds per inflorescence tended to be greater on burned plots for all three species.

Uresk, D.W.; Cline, J.F.; Rickard, W.H. 1976. Impact of wildfire on three perennial grasses in south-central Washington. Journal of Range Management 29(4): 309-310.

<http://ojssandbox.library.arizona.edu/index.php/jrm/article/viewFile/14924/12961>

In a south-central Washington sagebrush-bluebunch wheatgrass community, bluebunch wheatgrass responded to burning by increased vegetative and reproductive performance. Burning decreased the vegetative and reproductive vigor of Cusick bluegrass and Thurber needlegrass.

Wright, H.A. 1985. Effects of fire on grasses and forbs in the sagebrush-grass communities, pp. 12-22 In: Sanders, K., J. Durham, [and others] (eds.) Rangeland Fire Effects -proceedings of a symposium. USDI Bur. of Land Manage., Idaho State Office and Univ. of Idaho. Boise, ID. <http://books.google.com/books?id=aMc-kJxStIoC>

A review of the effects of fire, and season of fire, at the species level, for many native and nonnative species of sagebrush-grass communities. Cites numerous publications from the 1940s through the 1970s.

CHAPTER 7. RECOMMENDATIONS

Landscape-Scale Planning

- **Map oak habitat**—After compiling all existing spatial data, determine the data gaps so that a comprehensive map can be created of eastside oak on National Forest System lands. Mapping should include collection of stand attribute data in a format that is compatible with that of the Northwest Habitat Institute project on the Mt. Hood National Forest.
- **Prioritize sites**—Develop a protocol—reflecting oak ecosystem restoration goals at the forest level—to assess the restoration priority of any potential restoration site. An example of a quantitative prioritization approach using habitat value, threats, and sensitive species, appears in phase 2 of chapter 4. This prioritization system should be used as a guide; because there are many factors to incorporate during planning, results of prioritization ranking should not be considered definitive when strategizing at the landscape level.
- **Strategize at the landscape level**—After mapping has been completed and a protocol for site prioritization developed, combine these data sources to plan restoration activities in light of landscape-level considerations such as habitat connectivity and occurrences of sensitive species. This should be a collaborative process across all eastside National Forest System lands and should also consider the habitats on adjacent lands under other ownerships.

Individual Restoration Projects

- **Set restoration targets**—For each local restoration project that is implemented, define appropriate restoration targets that are measureable and attainable.

- **Conduct outreach and collaborate**—Conduct proactive public outreach as an initial step in all restoration projects. Collaborate with other agencies and groups to share knowledge, experience, and resources.
- **Monitor**—Restoration projects should include a monitoring component to measure if restoration targets have been met. Monitoring will also provide information on treatment responses; when available, information on treatment responses should be shared among forests and other cooperators.

Research Needs

- **Genetics of eastside oak**—Complete a study of the genetic structure of eastside oak populations. Andy Bower (Olympic National Forest) is presently leading this effort. Key questions remain regarding the genetic differentiation of eastside and westside oak.
- **Understory management, including effects of fire**—A number of studies have been conducted on the influence of fire on various native and nonnative understory species (examples listed in chapter 5, section 7). But information is still needed on the long-term response of understory species to fire and other treatments.
- **Density management in oak-pine stands**—Guidelines are needed for releasing oak from younger ponderosa pine and managing oak-pine stand density.
- **Oak regeneration**—Although a number of recent studies addressed Oregon white oak regeneration on the westside, we are aware of only one published oak planting study on the eastside (Bakker et al. 2012) (a follow-up study is underway in the same area; pers. comm., Jim Evans, The Nature Conservancy). Additional planting research could further explore the efficacy of various cultural treatments. Additional research is also needed on the production and storage of acorns for

regeneration purposes. For example, does viability improve if acorns are stored at sub-freezing temperatures or under different gas environments?

- **Historical and potential extent of eastside oak habitat**—If the extent of historical oak habitat is to guide future restoration work, then additional work is needed to compile and digitize historical map data. However, given anticipated climate change effects and the long-term effects of fire suppression and grazing, the extent of current and future suitable habitat is likely to differ from that of historical habitat.
- **Protection from fire**—Is it possible to effectively protect young trees or priority remnant trees during prescribed fire or even wildfire? One possibility is a fire-retardant foam.

CHAPTER 8. CASE STUDIES

A series of oak habitat restoration case studies are presented here to provide insight based on the experiences of regional practitioners. These projects are in various stages of completion.

Case Study 1: Goldendale Fuels Reduction and Oak Woodland Restoration

Prepared by Mark Williams

Project Personnel

Bureau of Land Management, Spokane District, Wenatchee Field Office; Mark Williams (forester); Richard Parrish (fuels manager); Chris Sheridan (restoration coordinator); Eric Riener (burn boss); Nick Stanton (natural resource specialist); Anjolene Price (forestry technician); Tim Murphy (forester); J.A. Vacca (wildlife biologist); Erik Ellis (wildlife biologist).

Site

The 53-acre project area is located in the Rock Creek

Drainage in Klickitat County, WA, approximately 10 miles north of the town of Goldendale. The area includes oak-pine woodland, oak savanna, and open grassland habitats. Plant communities found within the unit are: Oregon white oak/common snowbrush and white oak/bluebunch wheatgrass. In addition to large remnant oaks and pines, the stands contained thickets of dense, small-diameter trees (350 trees/acre pine <12 in. diameter), often of low vigor. In that condition, the stand was susceptible to stand-replacing fire and loss of wildlife habitat.

Objectives

Enhance oak communities, bringing them closer to pre-settlement conditions; improve wildlife habitat including conditions conducive to mast production and cavity creation; reduce susceptibility to catastrophic fire; restore areas of native understory; and provide a site to demonstrate to the public the implementation and results of restoration techniques.

The desired future condition of the oak woodlands is a spatially variable mosaic of tree age classes. The desired future condition of the conifer-oak woodlands is a mix of pine, fir, and oak of multiple cohorts; these stands should be open to the extent that trees exhibit



Before (above) and after (right) photos of the Goldendale Fuels Reduction and Oak Woodland Restoration, showing the reduction in small stems.



Mark Williams, BLM



Mark Williams, BLM

Burning piles of thinning residue.

open-grown character. Desired understory conditions feature dominance by native bunch grasses, primarily bluebunch wheatgrass, Sandberg's bluegrass, and Idaho fescue, with shrub cover of less than 10 percent.

Treatments

Thinning and release—Thinning, applied in summer 2010, was focused on removing smaller oak and conifer stems that provide fuel ladders, while retaining desirable trees. Viable remnant oaks (i.e., those with ≥ 30 percent live crown) were released by removing all overtopping competitors within 40 ft. The younger oak woodlands and oak-pine cohorts were thinned toward the long-term goal of achieving a residual canopy cover of 30 to 60 percent (50 to 200 trees/acre; 14- to 40-ft spacing). The largest viable oaks from the younger cohort (and trees with stick nests or cavities) were favored for retention. Density of the residual stand was spatially variable and was designed to allow trees to eventually attain an open-grown form. Thickets of small, naturally clumpy oaks were thinned as clumps, each treated as either a “take clump” or a “leave clump” (a clump consisted of 3 to 10 stems).

Thinning residue treatments—Materials suitable for firewood were

piled separately for utilization; small sawlogs were also separated and taken to a small home-based sawmill. Unusable materials were piled and burned in fall 2011. Burn areas were then sown with native seed. Post-treatment surface fuels did not exceed 3 tons/acre in the combined 1-, 10- and 100-hour fuel classes.

Treating stumps—Oak stumps were left up to 3 ft in height in some areas to discourage sprouting. In other areas, the herbicide glyphosate was applied to oak stumps immediately after cutting; where stumps sprouted, glyphosate was applied to sprouts. Handheld Hypo-hatchet® tree injectors were used to inject herbicide into stumps in other areas.

Pruning—Trees in non-thinned areas were pruned to a crown base height of at least 5 ft; trees that could not maintain vigor with a 5-ft crown base were removed unless they were not fuel ladders.

Future plans

Broadcast burning and seeding with native species. Monitoring is planned.

Funding

Funding was provided by Bureau of Land Management.



Mark Williams, BLM

Post-treatment view of Goldendale Fuels Reduction and Oak Woodland Restoration.

Case Study 2: Columbia Land Trust Oak Restoration: Dillacort Creek, Logging Camp Creek, Bowman Creek, and Little White Salmon – Wind Rim

Prepared by Lindsay Cornelius

Project Lead

Columbia Land Trust; Ian Sinks, Stewardship Manager, and Lindsay Cornelius, Stewardship Lead

Partnerships

Dillacort Creek and Logging Camp Creek projects—Pacific Stewardship, LLC (Darin Stringer); other partners who provided funding or participated in planning consultations included Eugene BLM, Washington Department of Fish and Wildlife (WDFW) (David Anderson, Sue VanLeuven), U.S. Forest Service (Robin Dobson), National Fish and Wildlife Foundation, U.S. Fish and Wildlife Service (USFWS), and Washington Department of Natural Resources (WDNR). Ongoing funding is being provided by WDFW (Habitat and Access Program) and USFWS (Partners for Fish and Wildlife Program) for future restoration efforts.

Bowman Creek project—Funding for the project was provided by Neil Cameron (private estate), North American Wetlands Conservation Act, American Bird Conservancy, and in-kind donations from Mount Adams Resource Stewards (MARS) (Jay McLaughlin). Consulting foresters Jay McLoughlin (MARS) and Darin Stringer (Pacific Stewardship, LLC) helped with layout and field design. Project approach was peer reviewed by WDFW, WDNR, Yakama Nation, and Washington Department of Ecology (WA DOE).

Little White Salmon – Wind Rim project—Pacific Stewardship, LLC (Darin Stringer), USFWS – Little White Salmon Fish Hatchery (Speros Doulos), and WDFW.

Sites

The Dillacort Creek, Logging Camp Creek, and Bowman Creek sites are located in the Klickitat River watershed, which contains a mosaic of oak and mixed oak-conifer forests, woodlands, and savannas. Oak growth forms are diverse and depend on a variety of factors that include aspect, soil depth, fire history, grazing, and past management activities such as logging. Understory plant communities vary from relatively intact native bunchgrass and forb communities to non-native, invasive annual grasses and other weedy species.

The Wind Rim site is positioned above Drano Lake, east of the Little White Salmon River and on the north rim of the Columbia River. Oregon white oak and ponderosa pine persist where soils are rocky and shallow along the bluffs and farther north where soils have restricted the encroachment of Douglas-fir. The oak habitat along the Columbia River represents an important corridor between the Willamette Valley and Puget Trough oak habitat and the east cascades oak habitat. Historically, Douglas-fir was likely a component of this woodland habitat but was limited in extent by soil type and fire.

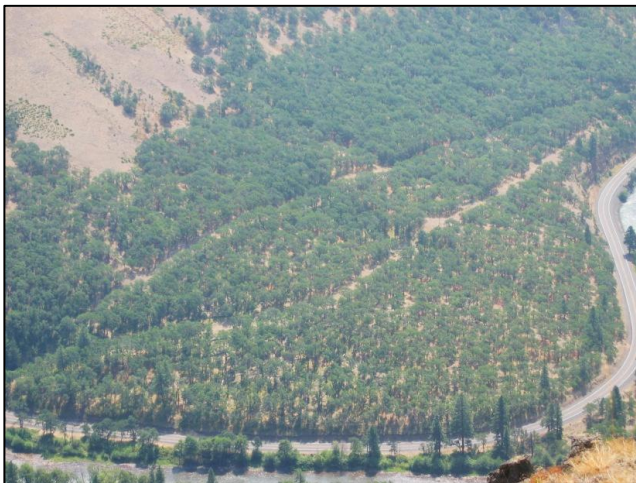
Dillacort Creek

Pretreatment conditions—The project consisted of two areas: a 130-ac treatment area and a 20-ac area. The 130-ac area was predominantly oak woodland and savanna. The stands, while uniformly dominated by oak (<1 percent conifer cover), varied in density from 200 trees/ac to greater than 1,200 trees/ac. Overstory cover ranged from 25 to 100 percent. Previous management activities include fire suppression, logging (oak for firewood), and grazing. The 20-acre treatment area focused on a west-facing bench where mature ponderosa pine (>4 ft diameter) and oak were encroached upon by a younger, dense cohort of oak and pine. Past management activities in that area include fire suppression, grazing, and logging.

Treatments—In the 130-ac treatment area, a "mosaic thinning" (an approach creating a spatially variable distribution of size classes and crown structures) was

Before

After



Lindsay Cornelius, Columbia Land Trust

Dillacort Creek, before (left column) and after (right column) thinning treatments.



Lindsay Cornelius, Columbia Land Trust

The Lightfoot™, Integrated Resource Management's lightweight machine used for harvesting small-diameter stems and masticating brush.

applied between July and October 2004. Hand-felling and piling were used on steeper slopes (≤ 60 percent slope). On shallower slopes, mechanical shearing was performed using the Lightfoot™, a small rubber-tracked machine that allows low-impact tree harvesting and brush reduction. The thinning treatment included an experimental thinning approach around identified western gray squirrel nests to reduce impacts on nesting squirrels. The approach reduced fuels and fire risk and released oak and pine from competition with neighboring trees, while maintaining aerial “escape corridors” radiating out from nest trees. This approach also increased down wood levels by leaving woodpiles, while reducing fine

fuels that contribute to high-intensity fire. Understory treatment plots were installed to test methods of annual grass suppression and native grass establishment, including herbicide application, prescribed fire (winter 2004 and 2005), and seeding.

The 20-ac treatment area was thinned in October 2010 to release mature oak and pine and to reduce ladder fuels. Crews hand-felled trees and piled slash, covering piles for later burning. Additional thinning was conducted in spring 2011, and resulting slash piles were burned the following winter. No understory treatments were applied in this area, and no western gray squirrel nests were present.

Logging Camp Creek

Pretreatment condition—The 60-acre project area was a mixed oak-conifer woodland with a relatively heavy Douglas-fir component; the area bordered a Douglas-fir plantation. The project area was managed for timber, grazing, and more recently, an unauthorized marijuana grow operation.

Treatments—A mosaic thinning was applied in 2004. The treatment was similar to that of the 130-ac

treatment area Dillacort Creek, but here there was a greater emphasis on removal of encroaching Douglas-fir as opposed to oak density reduction.

Bowman Creek

Pretreatment condition—The 150-ac project area included single-aged (95 years) ponderosa pine (120 to ≥ 500 trees/ac), with scattered oak at densities ranging from

just a few trees per acre to over 400 trees/ac. Some of the larger oaks showed evidence of crown dieback owing to overtopping pines. The understory consisted



Lindsay Cornelius, Columbia Land Trust

Logging Camp Creek, post treatment.



Lindsay Cornelius, Columbia Land Trust

Creating snags at Bowman Creek.

of nonnative annual grasses with a significant but scattered component of native grasses and forbs. The site also includes a wet meadow and a seasonally wet riparian area, as well as more than 800 western gray squirrel nests scattered throughout the project area. Past management activities include logging, prescribed fire (applied at least 2 decades earlier by a private landowner), grazing, and motorized recreation (ATV and motorcycle).

Treatments—The prescription varied across the project area according to stand density and species composition. The focus was reducing stand density by approximately 25 percent; however, in some instances, where oak were prevalent or stand density was particularly high, density was reduced by as much as 60 percent. Prescriptions were carefully tailored around western gray squirrel nest trees to ensure at least two escape routes where stand density warranted harvesting within 50 ft of

nest trees. The stand was marked to cut, with squirrel trees and reference trees (for monitoring purposes) marked to leave. Nest trees, mature oaks, and other unique resources were retained (e.g., residual older Douglas-fir or pine, other hardwoods).

Because the site was flat with a grassy understory, and accessible by vehicle, a track-mounted carrier with a single grip processor head was used for harvesting, a tracked CAT with swing-boom grapple for skidding and yarding, a track-mounted shovel for loading, and 6-axle log trucks for hauling. To reduce ground disturbance, boles were processed in the air and slash was left within 60 ft of roads or skid trails to be hand piled. Machine operators were successful in minimizing soil disturbance by processing and limbing logs in the air, piling efficiently, and reducing the number of turns by tracked vehicles during operations. The presence of several historical logging roads and skid trails made this approach successful and efficient. Operations were limited to dry or frozen soil conditions to minimize rutting and compaction, and hand falling was used in wet meadows or along riparian or wetland edges. Slash piles will be burned in winter, and disturbed soils will be seeded with native grass seed mix. Proceeds from the timber helped to offset project costs.



Lindsay Cornelius, Columbia Land Trust

Removing dense pine at Bowman Creek.

Following treatment, 20 snags were created by American Bird Conservancy and Pacific Stewardship, LLC, and six Lewis's woodpecker nesting boxes were installed throughout the property. Snags were created by girdling at various heights between 20 and 40 ft above the ground in ponderosa pine (15 to 20 in. DBH). In addition to these hand-girdled snags, the machine operator topped 1 to 2 trees per acre at approximately 15 to 20 ft aboveground to create additional snag resources. Because the property does not have a wide variety of age classes, snags will continue to be created as trees mature.

Little White Salmon – Wind Rim

Pretreatment condition—This 12-ac project area was an Oregon white oak and ponderosa pine woodland overtopped by Douglas-fir. Past management activities include logging.

Treatments—The stand was aggressively released from encroaching Douglas-fir in 2008. Most Douglas-fir trees were removed from the stand, with the exception of some >20 in. diameter that did not compromise any oak trees with mature or otherwise unique structure. A rubber-tire harvester forwarder system was used to harvest, limb, process, and haul logs to a landing outside the project area, minimizing ground disturbance. The area was seeded and patrolled for noxious weeds twice annually in the years since.



Harvester at work in the Wind Rim Stewardship Unit.

The stand has responded noticeably to treatment, both in the canopy and the understory, and is a stunning visual example of oak release, particularly when juxtaposed with the neighboring stand that is managed as industrial forestland. The USFWS, which surrounds the property on two sides, has adopted the same prescriptions and in 2012 released oaks in the area surrounding the Wind Rim property.

Future Plans

Planned treatments across the Klickitat Watershed include additional oak release and thinning efforts, specifically around mature, open-grown trees that show signs of stress such as crown dieback. Funding is being pursued to continue work in the understory.

Bowman Creek, with its flat terrain, lack of fuels and ladder fuels in particular, and network of roads, would be the ideal property to experiment with controlled burns, although none are planned in the near future.

Although it is fairly clear that release and thinning activities improve individual tree vigor, it is less clear what impacts these activities have on crown shape and cavity development in mature trees. Where stands lack large diameter, open-grown trees with lateral branches large enough to create cavities, gaps will be created to help establish a new cohort in densities that will allow for open growth forms.

Monitoring and treatment of conifer encroachment, accumulation of fuels, and elevated stand density will continue. In the absence of fire, mechanical manipulation of oak habitat seems to offer the best surrogate.

Monitoring

More than 200 permanent monitoring plots throughout the treatment areas have been installed to assess stand responses. The plots will be remeasured at a 10-year interval, with the first remeasurement scheduled for 2014. Measurements include tree height, diameter, condition,

Before**After**

The Wind Rim Stewardship Unit, before (left column) and after (right column) thinning treatments.

basal area, stem density, fuels, understory composition (percentage cover), and western gray squirrel nest locations and abundance. Pre- and post-treatment photo monitoring was used, as well as photography from aerial vantage points from the opposite ridge line.

Funding

Dillacort Creek and Logging Camp Creek—

Thinning treatments were supported by a grant from BLM and Forest Restoration Partnership. Additional funding was provided by the Wildlife Forever Foundation and WDFW Landowner Incentive Program (LIP).

The Columbia Land Trust has received a grant from the National Fish and Wildlife Foundation Native Plant Conservation Initiative to implement the native plant understory trial restoration plots and to apply the most practical and effective technique to a larger 10-ac area. This project was also partially funded by the WDFW LIP grant.

The 20-ac treatment area at Dillacort Creek was funded by WDFW Habitat and Access Program, WDNR Forest Health Initiative, and WDFW Landowner Incentive Program. Ongoing efforts are funded by WDFW and the USFWS Partners for Fish and Wildlife Program.

Bowman Creek—Funding was provided by North American Wetlands Conservation Act (part of a larger million-dollar grant in the region), Neil Cameron (private estate), and American Bird Conservancy (Neotropical Migratory Bird Conservation Act).



The Wind Rim Stewardship Unit, four years after treatment; ongoing management responsibilities include monitoring and weed control.

Lindsay Cornelius, Columbia Land Trust

Proceeds from the timber helped to offset project costs.

Little White Salmon – Wind Rim—Funding was provided by WDFW LIP and from timber receipts.

Lessons learned

- It is important to think long-term in oak management, as it may take decades to determine whether some of the objectives have been successfully met. Thus, it is important to document baseline conditions and to identify a monitoring approach that can be reasonably implemented over a long period of time. The intensity of thinning treatments was intentionally varied within each stand to preserve spatial heterogeneity and to demonstrate impacts of different thinning approaches over time.
- Gap creation to help establish open-grown oaks as a recruitment strategy for future cavity development is under consideration. It is uncertain whether the trees in the dense,

doghair cohorts that are typically thinned will result in structures that eventually produce larger cavities.

- The Klickitat Watershed is characterized by very steep slopes; thus, the thinning mechanism was limited to hand crews for much of the terrain. For this reason, slash and boles could not reasonably be transported off site. Boles were left on the ground or piled in some instances for wildlife, and slash was piled for burning. Burning on the steepest slopes proved difficult, and efforts to pile were abandoned where pile collapse was likely to cause burning material to fall uncontrolled downhill.
- During implementation—especially in the beginning—it is important to be onsite and to visit crews regularly. Hand crews that were accustomed to fuels reduction projects felled several desirable large oak snags on day one, before they were located and directed otherwise.
- Oak trees have clearly responded to thinning with epicormic branching. Poison oak increased in the understory immediately post-treatment in most locations. The native plants seeded in the burn piles are being monitored to see how they fare in the long term. Despite the head start that these seeded species received, it already appears that they do not compete well with the annual species when the site is under light grazing pressure.
- In areas where historical land uses may have included logging or grazing, aggressive weed control efforts may be necessary immediately following entry, even if not using equipment, as seed already present may be released by restoration treatments.
- Able-bodied, hardy volunteers can do a lot on these projects. They have helped with much of the restoration work: assisting with wildlife, legacy tree, acorn crop, rare plant, western gray squirrel nest and noxious weed surveys; weed removal; marking and cutting small

trees; building and burning slash piles; and seeding and surveying trial plots. Volunteer crews helped ignite and control small, experimental understory burns in several trial plots.

Case Study 3: Rock Thin

Prepared by Whitney Olsker

Lead Agency

U.S. Forest Service, Mt. Hood National Forest

Personnel

Kim Valentine, Eastside Fire Management Officer, Whitney Olsker, Eastside Silviculturist, and Nancy Lankford, Forest Silviculturist (Mt. Hood National Forest); Beth Willhite, Entomologist, and Holly Kearns, Plant Pathologist (Pacific Northwest Region Westside Insect and Disease Service Center, Sandy, OR); Josh Moulton, Oregon Department of Fish and Wildlife (ODFW).

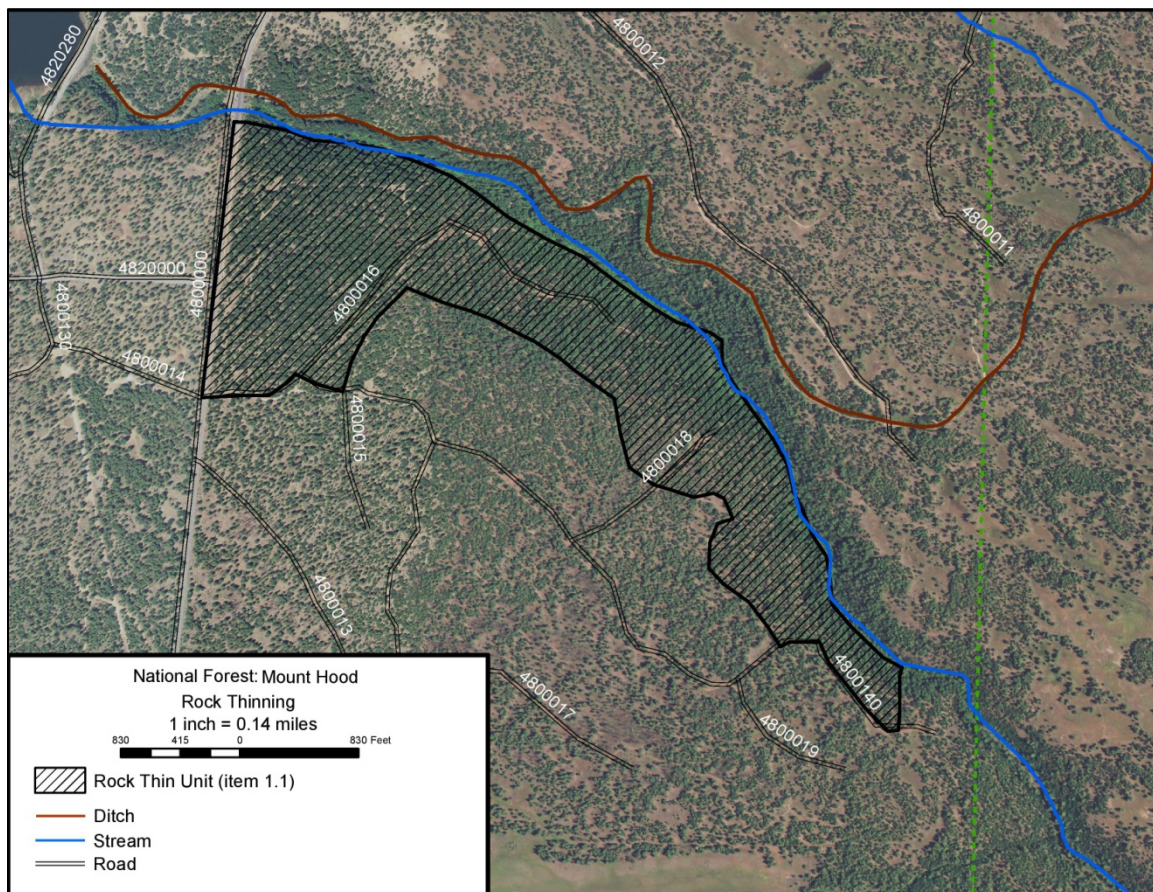
Site

The treatment area was 123 ac along the south side of Rock Creek in the Barlow Ranger District, Mt. Hood National Forest (T4S R11E sections 13 and 24). The site is dominated by pine-oak plant communities, with minor representation of Douglas-fir plant communities

along creek corridors. The overstory is primarily ponderosa pine and Oregon white oak in the uplands and a mix of Douglas-fir, grand fir, ponderosa pine, and Oregon white oak along the creek. Prior to treatment there were approximately 300 to 500 stems per acre. The diameter range was predominantly 0 to 16 in., with 2 to 3 large (i.e., ≥ 21 in. diameter) ponderosa pine or Douglas-fir trees per acre. A prescribed burn was conducted in the stand 6 to 7 years prior to treatment. Some mortality of ponderosa pine has been observed in the stand.

Treatments

The project consisted of precommercial thinning (i.e., stems < 8 in. diameter) on 123 ac. An emphasis was removal of small-diameter material from around legacy ponderosa pine (≥ 21 in. diameter) and large Oregon white oak (≥ 15 in. diameter). Post-treatment density was approximately 80 trees per acre, equivalent to a spacing of 24 by 24 ft. The treatment was accomplished through hand thinning; slash produced was hand piled. Leave areas needed to



Before**After**

Rock Creek, before (left column) and after (right column) thinning treatments.

protect wildlife and fish habitat, including a buffer along Rock Creek, were identified by district specialists and left untreated.

Future plans

Pile burning will be completed in fall 2013, and underburning will be completed by fall 2014 or 2015, depending on completion of nearby projects. Other projects to be completed in the next couple of years are thinning and piling north of Rock Creek and thinning around ODFW land in the southern portion of section 24. After thinning and pile burning activities are completed, a larger underburn will be conducted with ODFW throughout sections 13 and 24.

Monitoring

Permanent photo points were established to monitor the progress of the treatments and the impacts on the stand.

Funding

Funding sources were R6 Forest Health Protection group through the “Prevention/Suppression/Restoration Projects Fund” and Mt. Hood Fuels funds (WFHF).

Case Study 4: Burdoin Mountain

Prepared by Roland Rose

Lead Agency

U.S. Forest Service Columbia River Gorge National Scenic Area (CRGNSA)

Personnel

2006 oak restoration: Diana Ross, Robin Dobson, Chuti Fiedler of CRGNSA; collaborative group from various entities.

2010 stewardship: Roland Rose, Robin Dobson, Darren Kennedy, Brett Carre of CRGNSA; collaborative group from various entities.

Site

2006 oak restoration: Location was the Courtney Road Units, Burdoin Mountain, below Coyote Wall (170 ac). The site was 85 percent oak woodlands and 15 percent oak savanna, with dry eastside xeric soils. Seventy-five percent of the stand was overtopped by Douglas-fir at the inception of the project.

2010 stewardship: Location was the east side of upper Catherine creek (113 ac). The site was 70 percent oak woodlands, 25 percent mixed conifer, and 5 percent oak savanna, with dry eastside xeric soils. The site has an east-northeast aspect and is more shaded than many Catherine Zone project areas. Oak woodlands were 95 percent overtopped by Douglas-fir prior to treatment.

Treatments

For both projects, conifers <8 in. diameter were thinned, larger conifers were limbed, larger oaks and ponderosa pines were released, and cut materials were piled and burned in preparation for planned future underburns.

Monitoring

For both projects, vegetation plots are in place, and photo points have been established.

Funding

The 2006 oak restoration work was funded by a combination of WF, VW, SP and HF funding. The 2010 work was funded through stewardship funds.

Lessons Learned

2006 oak restoration: Initial plans to thin the oak units have become highly contentious. Piling of cut oak material is not cost effective; it is preferable to lop and scatter if oaks are thinned.

2010 stewardship: Lop and scatter after oak thinning has been adopted and has proven to be far more cost-effective than piling. Collaborative decisions still limit thinning to a light spacing, but future test plots are planned to demonstrate effectiveness of wider spacing. However, NEPA-based decisions do not allow for that yet. Though sometimes met with opposition, the use of equipment is effective and produces a high quality of work, given the right contractor.



Oak stand after treatment, with numerous piles of conifer slash.

Case Study 5: Collins Slide

Prepared by Roland Rose

Lead Agency

U.S. Forest Service Columbia River Gorge National Scenic Area (CRGNSA)

Personnel

2006 oak release (original 05 CE units): Diana Ross, Robin Dobson, Chuti Fiedler, and Darren Kennedy of CRGNSA; Washington Department of Fish and Wildlife (WDFW).

2009 oak release (WDNR agreement Phase 1 & 2): Roland Rose, Robin Dobson, Darren Kennedy, and Brett Carre of CRGNSA; David Anderson (WDFW).

2012 DNR oak restoration agreement: Roland Rose, Robin Dobson, Darren Kennedy, and Brett Carre (CRGNSA); David Anderson (WDFW).

Site

Collins Slide, located between Wind and Dog Mountain along SR14. The site is 95 percent oak woodland: a riparian, mid-Cascade, river-level, oak-adapted woodland. Annual precipitation in this westside-eastside transitional area averages 40 in. Historically, a mix of ponderosa pine and Oregon white oak likely was maintained through a combination of natural fire and indigenous burning. Oak woodlands were 95 percent overtopped by Douglas-fir prior to treatment.

In a 2006 oak release, 62 ac were treated. In a 2009 oak release, treatment was planned for 220 ac; 110 ac have been accomplished to date. The 2012 work treated 40 ac.

Treatments

2006 oak release: All conifers <8 in. diameter were cut, larger conifers were limbed, and cut materials were piled and burned in preparation for planned future underburns.

2009 oak release: All conifers <8 in. diameter were cut, larger conifers were limbed, and cut materials

were piled and burned in preparation for planned future underburns. Oaks >8 in. diameter and ponderosa pines >20 in. diameter were released by removing all Douglas-fir (diameter <20 in.) within a 30-ft radius. Underburns are planned.

2012 DNR oak restoration agreement: In addition to the 2009 prescription, oak trees were released by creating snags: 100 snags every 3 to 5 years, in three phases.

Monitoring

Vegetation plots are in place, and photo points have been established.

Funding

The work was funded by a combination of WF, VW, SP and HF funding.

Lessons Learned

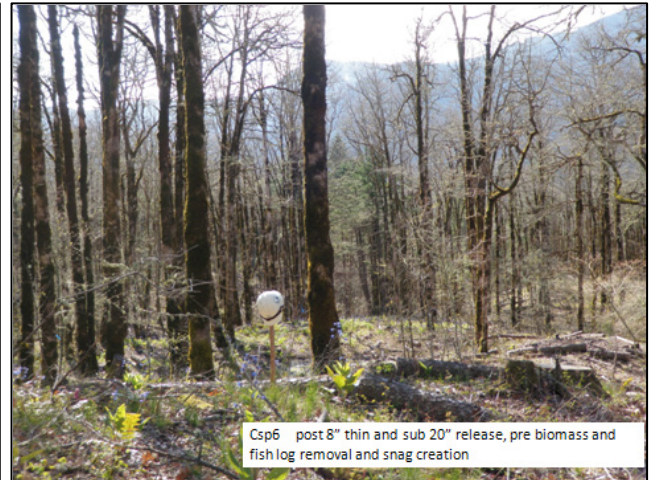
2006 oak release: Initial treatment spacing was very light. Additional treatments pushed out the spacing by removing larger, overtopping Douglas-fir trees; this was more effective.

2009 oak release: Reviews from oak release experts suggest a more aggressive spacing could be beneficial. Having the heavy equipment option would have been desirable in terms of cost effectiveness and end product. Having a high percentage of the large woody debris on the ground will make underburning very difficult in the future, owing to smoke concerns.



Columbia River Gorge National Scenic Area

Understory returning after oak release at Collins Slide.

Before <20-in. release**After <8-in. thin and <20-in. release**

Columbia River Gorge National Scenic Area

Collins Slide, before and after a <20-in. release (Douglas-fir <20-in. removed to release oak and pine).

Case Study 6: Catherine Creek

Prepared by Roland Rose

Lead Agency

U.S. Forest Service Columbia River Gorge National Scenic Area (CRGNSA)

Personnel

2007 oak restoration (C1 & C2) and 2008 oak restoration (Tracy Hill): Diana Ross, Robin Dobson, Chuti Fiedler, and Darren Kennedy of CRGNSA; collaborative group from various entities.

2009 oak restoration #1 and #2 (Cath 09 PC and AB units): Diana Ross, Robin Dobson, Chuti Fiedler, Roland Rose, and Darren Kennedy of CRGNSA; collaborative group from various entities.

2010 oak restoration (Cath Service 2010), 2010 stewardship: Roland Rose, Robin Dobson, Darren Kennedy, and Brett Carre of CRGNSA; collaborative group from various entities.

2011 Catherine/Collins oak restoration (FH2011 release and contract): Roland Rose, Robin Dobson, Darren Kennedy, and Brett Carre of CRGNSA; Geoff Aschoff (WDNR); WDFW; collaborative group from various entities.

2012–2025 underburns: Roland Rose, Christine Plourde, Robin Dobson, Darren Kennedy, and Brett Carre of CRGNSA; collaborative group from various entities.

Sites

2007 oak restoration (C1 & C2): Upper Catherine Creek area, west of Catherine Creek, along Bonneville Power Administration lines (203 ac). Composition is oak woodlands (90 percent) and oak savanna (10 percent), with dry eastside xeric soils. Oak woodlands were 85 percent overtopped by Douglas-fir prior to treatment.

2008 oak restoration (Tracy Hill): Upper Catherine Creek area, between Catherine Creek and Major Creek, along Tracy Hill (63 ac). Composition is oak

woodlands (80 percent) and oak savanna (20 percent), with dry eastside xeric soils. Oak woodlands were 85 percent overtopped by Douglas-fir prior to treatment.

2009 oak restoration #1 (Cath 09 PC units): West of lower Major Creek to above Rowland lake (330 ac). Composition was oak woodlands (65 percent), mixed conifer (20 percent), and oak savanna (15 percent). Dry eastside xeric soils. Oak woodlands were 95 percent overtopped by Douglas-fir prior to treatment.

2009 oak restoration #2 (Cath 09 AB units): West of lower Major Creek (306 ac). Composition was oak woodlands (50 percent) and mixed conifer (50 percent). Dry eastside xeric soils. The site had an east-northeast aspect and was more shaded than many Catherine Zone project areas. Oak woodlands were 100 percent overtopped by Douglas-fir prior to treatment.

2010 oak restoration (Cath Service 2010): East side of upper Catherine creek (113 ac). Composition was oak woodlands (70 percent), mixed conifer (25 percent), and oak savanna (5 percent). Dry eastside xeric soils. The site had an east-northeast aspect and was more shaded than many Catherine Zone project areas. Oak woodlands were 95 percent overtopped by Douglas-fir prior to treatment.

2010 stewardship: Units start just west of middle Catherine Creek and span both forks of Major Creek with intermixed ownership between units (645 ac). Composition is oak woodlands (60 percent) and mixed conifer (40 percent). Dry eastside xeric soils. Oak woodlands were 85 percent overtopped by Douglas-fir prior to treatment.

2011 Catherine/Collins oak restoration (FH2011 release and contract): Units span from Courtney Road to the west side of Catherine Creek (390 ac). Composition is oak woodlands (70 percent) and mixed conifer (30 percent), with dry eastside xeric soils. Oak woodlands were 95 percent overtopped by Douglas-fir prior to treatment.

2012–2025 underburns: Units are intermixed with private lands spanning an area from Courtney Road to Upper Major Creek. Approximately 2,000 ac will be treated. Composition is oak woodlands (70 percent) and mixed conifer (30 percent), with dry eastside xeric soils. Oak woodlands were 95 percent overtopped by Douglas-fir prior to treatment. The oak understory is currently made up of more than 60 percent invasive species.

Treatments

2007 oak restoration (C1 & C2), 2008 oak restoration (Tracy Hill), 2009 oak restoration #1 and #2 (Cath 09 PC and AB units), 2010 oak restoration (Cath Service 2010), 2010 stewardship, 2011 Catherine/Collins oak restoration (FH2011 release and contract): Conifers <8 in. diameter were thinned, larger conifers were limbed, larger oaks and ponderosa pines were released, and cut material was piled and burned in preparation for future underburns.

2011 Catherine/Collins oak restoration (FH2011 release and contract): In addition to treatments noted above, areas where conifers grow in prior to underburning must be re-treated and prepped for underburning.

2010 stewardship: only a small portion of this contract (20 percent of ground-based) has been started so far. In summer 2013 we expect helicopter units and additional ground-based work to take place.

2012–2025 underburns: The oak woodland areas had been previously thinned to reduce competition from conifers. Underburning will be applied to achieve a mosaic pattern to restore fire resiliency and maintain the current condition class. This will be followed by a



Catherine Creek 2009 oak restoration #1 after oak release and <8 inch thinning; piles have been burned, but underburning has not yet taken place.

Columbia River Gorge National Scenic Area

combination of spraying and seeding in an attempt to restore both the stand and the understory. Additional underburning is planned for the future.

Monitoring

For all projects, representative vegetation plots and photo points were established.

Funding

With the two exceptions below, all projects were funded by a combination of WF, VW, SP and HF funding.

2010 stewardship: Funded by stewardship funding.

2012–2025 underburns: Funded by a combination of WF, VW, and HF funding; will be aggressively seeking grant money for cost match for these projects.

Lessons Learned

2007 oak restoration (C1 & C2), 2008 oak restoration (Tracy Hill), 2009 oak restoration #1 and #2 (Cath 09 PC and AB units): Initial plans to thin the oak units have become highly contentious.

Piling of cut oak material is not cost effective; it is preferable to lop and scatter if oaks are thinned.

2008 oak restoration (Tracy Hill), 2009 oak restoration #1 and #2 (Cath 09 PC and AB units), 2010 oak restoration (Cath Service 2010): NEPA-based, collaborative decisions still limit thinning to a light spacing.

2010 oak restoration (Cath Service 2010): Future test plots are planned to demonstrate effectiveness of wider spacing in thinning.

2010 stewardship: Though sometimes met with opposition, the use of equipment is effective and produces a high quality of work, given the right contractor. Any ground disturbance is virtually undetectable within 2 years after the work is finished. One challenge has been the allowable length of stewardship contracts; this has led to a higher percentage of overtopped oaks dying off.



Columbia River Gorge National Scenic Area

Catherine Creek Unit PC10 before (top) and after (bottom) oak release and small-diameter thinning.

Case Study 7: Hazardous Fuel and Oak Restoration work (CRGNSA-WDNR Agreement)

Prepared by Roland Rose

Lead Agencies

U.S. Forest Service Columbia River Gorge National Scenic Area (CRGNSA) and WDNR

Personnel

Roland Rose, Robin Dobson, Darren Kennedy, and Brett Carre (CRGNSA); Geoff Aschoff (WDNR); WDFW; collaborative group from various entities.

Site

Units start just west of Courtney Road (Klickitat County, Washington) and span both forks of Major Creek, with intermixed ownership between units (427 ac). Composition is oak woodlands (60 percent) and mixed conifer (40 percent), with dry eastside xeric soils. Oak woodlands were 85 percent overtopped by Douglas-fir prior to treatment.

Treatments

Conifers <8 in. diameter were thinned, larger conifers were limbed, larger oaks and ponderosa pines were released, and cut material was piled and burned in preparation for future underburns. Areas where conifers grow in prior to underburning must be re-treated and prepped for underburning.

Monitoring

Representative vegetation plots and photo points have been established.

Funding

The work was funded by a combination of WF, VW, SP and HF funding.

Lessons Learned

Collaborative efforts with the WDNR for use of the Larch Honor Camp crews has proven to be the most cost effective work force, aside from heavy equipment.

Case Study 8: Rowena 2007 Oak Restoration

Prepared by Roland Rose

Lead Agency

U.S. Forest Service Columbia River Gorge National Scenic Area (CRGNSA)

Personnel

Diana Ross, Robin Dobson, Chuti Fiedler, and Darren Kennedy (CRGNSA); collaborative group from various entities.

Site

Upper Rowena units on both sides of McCall Point (387 ac). Composition is oak woodlands (70 percent), mixed conifer (20 percent), and oak savanna (10 percent), with dry eastside xeric soils. Oak woodlands were 65 percent overtopped by Douglas-fir prior to treatment.

Treatments

Conifers <8 in. diameter were thinned, larger conifers were limbed, larger oaks and ponderosa pines were released, and cut material was piled and burned in preparation for future underburns.

Monitoring

Representative vegetation plots and photo points have been established.

Funding

The work was funded by a combination of WF, VW, SP and HF funding.

Lessons Learned

Many of the oak trees are being released too late to recover, prompting us to more aggressively release them in future projects. We were limited in many cases to narrow spacing (20 ft), owing to the collaborative process. Review by the collaborative group in 2011 revealed a desire of the entire group to thin more aggressively: to a 40-ft spacing.

Case Study 9: Seven Mile Fuels Treatment Restoration Project

Prepared by Roland Rose

Lead Agency

U.S. Forest Service Columbia River Gorge National Scenic Area (CRGNSA)

Personnel

Roland Rose, Christine Plourde, Robin Dobson, Darren Kennedy, and Brett Carre (CRGNSA); collaborative group from various entities; Oregon Department of Fish and Wildlife (ODFW).

Site

Units are intermixed with private lands east of Mosier, Oregon, along Hwy 30 to Rowena, and uphill to the Rowena crest. To date, 130 of a planned 2,100 ac have been treated. Composition is oak woodlands (70 percent) and mixed conifer (30 percent), with dry eastside xeric soils. Oak woodlands were 95 percent overtopped by Douglas-fir prior to treatment. The oak understory is currently made up of more than 90 percent invasive species.

Treatments

Oak woodlands had been previously thinned to reduce competition from conifers. Underburning in a mosaic pattern to restore fire resiliency and maintain current condition class will be followed by spraying and seeding in an attempt to restore both the stand and the understory. Additional underburning is planned.

Monitoring

Representative vegetation plots and photo points have been established.

Funding

Funded by a combination of WF, VW, Turkey Federation, Rocky Mountain Elk, Oregon Hunters Association, ODFW and HF funding.

Lessons Learned

Burning at the hotter end of the prescription was preferable. Follow-up spray and seeding is critical to

move towards a healthy oak understory. An excellent article describing the restoration work in the CRGNSA was published in *The Gorge* magazine's summer 2012 issue (<http://gorge.journalgraphicsdigital.com/sum12/>).

Case Study 10: D10 Underburn

Prepared by Roland Rose

Lead Agencies

U.S. Forest Service Columbia River Gorge National Scenic Area (CRGNSA) and WDNR

Personnel

Diana Ross, Robin Dobson, Chuti Fiedler, Rod Altig, and Darren Kennedy (CRGNSA); collaborative group from various entities.

Site

West of Rowena Creek along Oregon Hwy 30 (37 ac). Composition is oak woodlands (45 percent), oak savanna (15 percent), and open grassland (40 percent), with dry eastside xeric soils. Oak release from conifers was not a problem on this unit. In the oak woodlands, heavy accumulation of downed dead oak from over-shading, and abundance of small sapling ponderosa pine, oak, and Douglas-fir, was pushing the condition class and potential for fire mortality.

Treatments

Underburn in a mosaic; burn as many saplings (<2 in. diameter) as possible to reduce future competition and maintain fire resiliency of the woodland.

Monitoring

Representative vegetation plots and photo points have been established.

Funding

Project was funded by HF funding.

Lessons Learned

Burning on the hotter end of the spectrum is beneficial; post-burn seeding of certified weed-free grass and wildflower mix was very effective. Natural acceleration of wildflowers in the oak understory and open grass areas was a good public relations opportunity.

CHAPTER 9. ADDITIONAL RESOURCES

Working Groups

The three working groups listed are focused primarily on westside oak ecosystems. However, a small number of their members work on the eastside, and some of the information that they provide is also relevant to eastside ecosystems.

Cascadia Prairie Oak Partnership

This group communicates primarily through an email listserv. To join the listserv, send an email to listserv@listserv.wa.gov with the following info in the body (not in the subject) of the email: Subscribe CPOP-L <firstname> <lastname>.

The partnership also maintains a website with a library of technical documents relevant to restoration of prairies and oak habitats (<http://cascadiaprairieoak.org/>).

The South Puget Sound Prairie Landscape Working Group

The South Puget Sound Prairie Landscape Working Group is an informal group striving to promote and improve the management and planning of conservation actions on the prairies and associated habitats of South Puget Sound (<http://www.southsoundprairies.org/>).

The Garry Oak Ecosystems Recovery Team

The Garry Oak Ecosystems Recovery Team (GOERT) is a non-profit organization dedicated to the recovery of Garry oak and associated ecosystems in Canada and the species at risk that inhabit them. The organization is very active and maintains a website with information on a variety of topics related to oak habitat restoration in Canada (<http://www.goert.ca/>).

Key Publications

Included here is a list of key publications that address a broad range of management issues associated with Oregon white oak management in the Pacific Northwest.

Duba, J.J., ed. 2011. Northwest Science: Cascade prairie-oak partnership special issue. Northwest Science 85(2): 83-439.
<http://www.bioone.org/toc/nwsc/85/2>

This special issue of the journal Northwest Science includes papers on oak and prairie management and research that were presented at a 2010 meeting of the Cascadia Prairie-Oak Partnership. Although the papers focus on westside ecosystems, this is a useful summary of the latest work in the area of Oregon white oak ecosystem restoration.

GOERT [Garry Oak Ecosystems Recovery Team]. 2011. Restoring British Columbia's Garry oak ecosystems: principles and practices. Victoria, Canada: Garry Oak Ecosystems Recovery Team. 520 p.
http://www.goert.ca/gardeners_restoration/restoration.php

This is a comprehensive guide to Oregon white oak ecosystem restoration. It focuses on British Columbia habitats, but presents general information that is applicable to any Oregon white oak restoration project.

Harrington, C.A.; Kallas, M.A., comps. 2002. A bibliography for *Quercus garryana* and other geographically associated and botanically related oaks. Gen. Tech. Rep. PNW-GTR-554. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 115 p.
<http://www.fs.fed.us/pnw/pubs/gtr554.pdf>

This is a comprehensive list of publications on Oregon white oak; it also includes relevant publications on other species. Although this

was published in 2002, it also was converted to an online, searchable database, which has been significantly updated since then (<http://www.fs.fed.us/pnw/olympia/silv/oak-studies/oak-bibliography.shtml>). Many of the online references include abstracts.

Larsen, E.M.; Morgan, J.T. 1998. Management recommendations for Washington's priority habitats: Oregon white oak woodlands. Olympia, WA: Washington Department of Fish and Wildlife. 37 p. <http://wdfw.wa.gov/publications/00030/wdfw00030.pdf>

These management recommendations were developed for the State of Washington, and this is one of the few documents that address management of eastside Oregon white oak stands.

Vesely, D.; Tucker, G. 2004. The landowner's guide for restoring and managing Oregon white oak habitats. Bureau of Land Management, Salem District, Salem, Oregon. http://www.blm.gov/or/districts/salem/files/white_oak_guide.pdf

A detailed guide to many aspects of oak woodland management; focuses on the westside.

ACKNOWLEDGMENTS

The authors would like to thank Vicky Erickson, U.S. Forest Service, for providing financial and program support for this project.

We thank Nancy Lankford, U.S. Forest Service, for her role in initiating this project. We would like to thank the following people for providing technical support and advice during this project: Robin Dobson, Constance Harrington, Dave Peter, Jeanne Rice, Kim Valentine, Holly Kearns, Beth Willhite, Linda Cartwright, Jim Evans, Brett Carre

We thank Mary Carr of Forest Service Publishing Arts Staff for editorial support and Carol LoSapio, currently at USDA Animal and Plant Health Inspection Service for designing the template on which this document was based.

METRIC EQUIVALENTS

When you know:	Multiply by:	To find:
Acres (ac)	0.405	Hectares (ha)
Feet (ft)	0.305	Meters (m)
Inches (in.)	2.54	Centimeters (cm)
Miles (mi)	1.609	Kilometers (km)
Square miles (mi ²)	2.59	Square kilometers (km ²)

LITERATURE CITED

- Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Washington, D.C.: Island Press. 493 p.
- Agee, J.K. 1994. Fire and weather disturbances in terrestrial ecosystems of the eastern Cascades. Gen. Tech. Rep. PNW-GTR-320. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 52 p.
http://www.fs.fed.us/pnw/pubs/pnw_gtr320.pdf (21 February 2013).
- Bakker, J.D.; Colasurdo, L.B.; Evans, J.R. 2012. Enhancing garry oak seedling performance in a semiarid environment. *Northwest Science*. 86(4): 300-309.
- Blume, L. 2009. Garry oak restoration in central Washington: planting technique evaluation and preliminary target identification through stand characterization. M.S. Thesis, University of Washington, Seattle, WA.
- Bonner, F.T.; Karrfalt, R.P., eds. 2008. The woody plant seed manual. Washington, DC: U.S. Department of Agriculture, Forest Service. 1,223 p.
- Busse, D.; Simon, A.; Riegel, M. 2000. Tree-growth and understory responses to low-severity prescribed burning in thinned *Pinus ponderosa* forests of central Oregon. *Forest Science*. 46(2): 258-268.
http://www.fs.fed.us/psw/publications/busse/psw_2000_busse002.pdf (21 February 2013).
- Chappell, C.B.; Gee, M.M.; Stephens, B.; Crawford, R.; Farone, S. 2001. Distribution and decline of native grasslands and oak woodlands in the Puget Lowland and Willamette Valley ecoregions, Washington. In: Reichard, S.H.; Dunwiddie, P.W.; Gamon, J.G.; Kruckberg, A.R.; Salstrom, D.L. (eds.). Conservation of Washington rare plants and ecosystems. Washington Native Plants Society, Seattle, WA: 124-139.
- Christy, J.A. 2010. GLO historical vegetation of eastern Columbia River Gorge and east slope of Mount Hood, Oregon, 1859-1939. ArcMap shapefile, Version 2010_12. Portland, OR: Oregon Biodiversity Information Center, Portland State University.
- Clements, D.R.; Luginbill, S.; Jordan, D.A.; Van Dragt, R.; Pelant, R.K. 2011. Techniques to promote Garry oak seedling growth and survival in areas with high levels of herbivory and competition. *Northwest Science*. 85: 172-181.
<http://www.bioone.org/doi/abs/10.3955/046.085.0208> (21 February 2013).
- Coblentz, B.E. 1980. Production of Oregon white oak acorns in the Willamette Valley, Oregon. *Wildlife Society Bulletin*. 8(4): 348-350.
- Comer, P.; Faber-Langendoen, D.; Evans, R.; Gawler, S.; Josse, C.; Kittel, G.; Menard, S.; Pyne, M.; Reid, M.; Schulz, K.; Snow, K.; Teague, J. 2003. Ecological systems of the United States: a working classification of U.S. terrestrial systems. Arlington, VA: NatureServe.
<http://www.natureserve.org/library/usEcologicalsystems.pdf> (21 February 2013).
- Conrad, C.E.; Poulton, C.E. 1966. Effect of a wildfire on Idaho fescue and bluebunch wheatgrass. *Journal of Range Management*. 19(3): 138-141.
<http://www.jstor.org/stable/10.2307/3895397> (21 February 2013).
- Curtis, R.O.; Marshall, D.D. 2005. Permanent-plot procedures for silvicultural and yield research. Gen. Tech. Rep. PNW-GTR-634. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 66 p.
<http://treesearch.fs.fed.us/pubs/9425> (21 February 2013).
- Devine, W.; Aubry, C.; Bower, A.; Miller, J.; Maggiulli Ahr, N. 2012. Climate change and forest trees in the Pacific Northwest: a vulnerability assessment and recommended actions for national forests. Olympia, WA: U.S. Department of

- Agriculture, Forest Service, Pacific Northwest Region 102 p. <http://ecoshare.info/projects/ccft/> (21 February 2013).
- Devine, W.D.; Harrington, C.A. 2005. Root system morphology of Oregon white oak on a glacial outwash soil. *Northwest Science*. 79(2/3): 179-188.
- Devine, W.D.; Harrington, C.A. 2006. Changes in Oregon white oak (*Quercus garryana* Dougl. ex Hook.) following release from overtopping conifers. *Trees – Structure and Function*. 20: 747-756. http://www.fs.fed.us/pnw/olympia/silv/publications/ot/544_DevineHarrington2006b.pdf (21 February 2013).
- Devine, W.D.; Harrington, C.A. 2007. Release of Oregon white oak from overtopping Douglas-fir: effects on soil water and microclimate. *Northwest Science*. 81(2): 112-124. <http://dx.doi.org/10.3955/0029-344X-81.2.112> (21 February 2013).
- Devine, W.D.; Harrington, C.A. 2008. Influence of four tree shelter types on microclimate and seedling performance of Oregon white oak and western redcedar. Research Paper RP-PNW-576. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. <http://www.treesearch.fs.fed.us/pubs/30417> (21 February 2013).
- Devine, W.D.; Harrington, C.A. 2010. Planting native oak in the Pacific Northwest. General Technical Report PNW-GTR-804. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. <http://www.treesearch.fs.fed.us/pubs/34610> (21 February 2013).
- Devine, W.D.; Harrington, C.A. 2013. Restoration release of overtopped Oregon white oak increases 10-year growth and acorn production. *Forest Ecology and Management*. 291: 87-95.
- Devine, W.D.; Harrington, C.A.; Leonard, L.P. 2007. Post-planting treatments increase growth of Oregon white oak (*Quercus garryana* Dougl. ex Hook.) seedlings. *Restoration Ecology*. 15(2): 212-222. <http://www.treesearch.fs.fed.us/pubs/29660/> (21 February 2013).
- Devine, W.D.; Harrington, C.A.; Peter, D.H. 2007. Oak woodland restoration: understory response to removal of encroaching conifers. *Ecological Restoration*. 25(4): 247-255. <http://dx.doi.org/10.3368/er.25.4.247> (21 February 2013).
- Devine, W.D.; Harrington, C.A.; Kraft, J.M. 2010a. Acorn storage alternatives tested on Oregon white oak. *Native Plants Journal*. 11(1): 65-76. http://www.fs.fed.us/pnw/pubs/journals/pnw_2010_devine001.pdf (21 February 2013).
- Devine, W.D.; Harrington, C.A.; Southworth, D. 2010b. Improving root growth and morphology of containerized Oregon white oak seedlings. *Tree Planters' Notes*. 53(2):29-34. <http://naldc.nal.usda.gov/download/41642/PDF> (21 February 2013).
- Duba, J.J., ed. 2011. Northwest Science: Cascade prairie-oak partnership special issue. *Northwest Science* 85(2): 83-439. <http://www.bioone.org/toc/nwsc/85/2> (21 February 2013).
- Dunwiddie, P.W.; Bakker, J.D. 2011. The future of restoration and management of prairie-oak ecosystems in the Pacific Northwest. *Northwest Science*. 85(2): 83-92.
- Ehrenfeld, J.G. 2000. Defining the limits of restoration: the need for realistic goals. *Restoration Ecology*. 8: 2-9.
- Ellsworth, L.M.; Kauffman, J.B. 2010. Native bunchgrass response to prescribed fire in ungrazed mountain big sagebrush ecosystems. *Fire Ecology*. 6: 86-96.

<http://fireecology.org/docs/Journal/pdf/Volume06/Issue03/086.pdf> (21 February 2013).

Engber, E.A., Varner, J.M.; Arguello, L.A.; Sugihara, N.G. 2011. The effects of conifer encroachment and overstory structure on fuels and fire in an oak woodland landscape. *Fire Ecology*. 7(2): 32-50. http://norcalrxfirecouncil.org/uploads/Engber_et_al_2011.pdf (21 February 2013).

Fuchs, M.A.; Krannitz, P. G.; Harestad, A.S. 2000. Factors affecting emergence and first-year survival of seedlings of Garry oaks (*Quercus garryana*) in British Columbia, Canada. *Forest Ecology and Management*. 137: 209-219. [http://dx.doi.org/10.1016/S0378-1127\(99\)00329-1](http://dx.doi.org/10.1016/S0378-1127(99)00329-1) (21 February 2013).

Gedalof, Z.E.; Pellatt, M.; Smith, D.J. 2006. From prairie to forest: three centuries of environmental change at Rocky Point, Vancouver Island, British Columbia. *Northwest Science*. 80(1): 34-46.

Gilligan, L.A.; Muir, P.S. 2011. Stand structures of Oregon white oak woodlands, regeneration, and their relationships to the environment in southwestern Oregon. *Northwest Science*. 85(2): 141-158.

GOERT [Garry Oak Ecosystems Recovery Team]. 2011. Restoring British Columbia's Garry oak ecosystems: principles and practices. Victoria, BC, Canada: Garry Oak Ecosystems Recovery Team. 520 p. http://www.goert.ca/gardeners_restoration/restoration.php (21 February 2013).

Gould, P. J.; Harrington, C.A. 2008. Evaluation of landscape alternatives for managing oak at Tenalquot Prairie, Washington. Gen. Tech. Rep. PNW-GTR-745. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 45 p. http://www.fs.fed.us/pnw/pubs/pnw_gtr745.pdf (21 February 2013).

Gould, P.J.; Marshall, D.D.; Harrington C.A. 2008. Prediction of growth and mortality of Oregon white oak in the Pacific Northwest. *Western Journal of*

Applied Forestry. 23: 26–33.

http://www.fs.fed.us/pnw/pubs/journals/uncaptured/pnw_2008_gould001.pdf (21 February 2013).

Gould, P.J.; Harrington, C.A.; Devine, W.D. 2011 Growth of Oregon white oak (*Quercus garryana*). *Northwest Science*. 85: 159-171.

<http://dx.doi.org/10.3955/046.085.0207> (21 February 2013).

Gucker, C.L. 2007. *Quercus garryana*. In: Fire Effects Information System [Online]. Missoula, MT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). <http://www.fs.fed.us/database/feis/> (21 February 2013).

Habeck, R.J. 1992. *Pinus ponderosa* var. *ponderosa*. In: Fire Effects Information System [Online]. Missoula, MT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). <http://www.fs.fed.us/database/feis/> (21 February 2013).

Hall, F.C. 2002. Photo point monitoring handbook. Part A: Field procedures; Part B: Concepts and analysis. Gen. Tech. Rep. PNW-GTR-526. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 48 p. <http://www.treesearch.fs.fed.us/pubs/3255> (21 February 2013).

Hanna, I.; Dunn, P. 1997. Restoration goals for Oregon white oak habitats in the South Puget Sound region. In Dunn, P.; Ewing, K., eds. Ecology and conservation of the South Puget Sound prairie landscape. Seattle, WA: The Nature Conservancy of Washington: 231-246.

Harrington, C.A., comp. 2003. The 1930s survey of forest resources in Washington and Oregon. Gen. Tech. Rep. PNW-GTR-584. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 123 p. [plus CD-ROM].

- Harrington, C.A.; Devine, W.D. 2006. A practical guide to oak release. Gen. Tech. Rep. GTR-PNW-666. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. <http://www.treesearch.fs.fed.us/pubs/21921> (21 February 2013).
- Harrington, C.A.; Kallas, M.A., comps. 2002. A bibliography for *Quercus garryana* and other geographically associated and botanically related oaks. Gen. Tech. Rep. PNW-GTR-554. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 115 p. <http://www.fs.fed.us/pnw/pubs/gtr554.pdf> (21 February 2013).
- Harrod, R.J.; Fonda, R.W.; McGrath, M.K. 2008. Vegetation response to thinning and burning in a ponderosa pine forest, Washington. Northwest Science. 82(2): 141-150. <http://dx.doi.org/10.3955/0029-344X-82.2.141> (21 February 2013).
- Henderson, J. 2009. Modeled potential natural vegetation zones of Washington and Oregon. Olympia, WA: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. http://ecosshare.info/uploads/gis/swovz120309_metadata.htm (1 November 2012).
- Hibbs, D.E.; Yoder, B.J. 1993. Development of Oregon white oak seedlings. Northwest Science. 67(1): 30-36.
- Huebert, C.A. 2009. The ecological and conservation genetics of Garry oak (*Quercus garryana* Dougl. ex Hook). Doctoral dissertation. University of British Columbia, Vancouver.
- Kossuth, S.V.; Young, J.F.; Voeller, J.E.; Holt, H.A. 1980. Year-round hardwood control using the hypo-hatchet injector. Southern Journal of Applied Forestry. 4(2):73-76.
- Krygier, J.T. 1971. Comparative water loss of Douglas-fir and Oregon white oak: project completion report. Corvallis, OR: Oregon State University, Water Resources Research Institute and School of Forestry.
- LANDFIRE. [Homepage of the LANDFIRE Project, U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior]. 2012. [Online]. <http://www.landfire.gov/index.php> (19 July 2012).
- Larsen, E.M.; Morgan, J.T. 1998. Management recommendations for Washington's priority habitats: Oregon white oak woodlands. Olympia, WA: Washington Department of Fish and Wildlife. 37 p.
- Ledig, F.T. 1988. The conservation of diversity in forest trees. Bioscience. 38: 471-479.
- Lillybridge, T.R.; Kovalchik, B.L.; Williams, C.K.; Smith, B.G. 1995. Field guide for forested plant associations of the Wenatchee National Forest. Gen. Tech. Rep. PNW-GTR-359. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 335 p.
- Manuwal, D.A. 2003. Bird communities in oak woodlands of southcentral Washington. Northwest Science. 77(3): 194-201.
- Marsico, T.D.; Hellmann, J.J.; Romero-Severson, J. 2009. Patterns of seed dispersal and pollen flow in *Quercus garryana* (Fagaceae) following post-glacial climatic changes. Journal of Biogeography. 36(5): 929-941.
- McCreary, D.D. 2001. Regenerating rangeland oaks in California. Oakland, CA: University of California Sierra Foothill Research and Extension Center. 62 p. <http://www.californiaoaks.org/ExtAssets/Regenerating%20Rangeland%20Oaks%20in%20California.pdf> (21 February 2013).
- McDonald, P.M. 1969. Silvical characteristics of California black oak (*Quercus kelloggii* Newb.). Res. Pap. PSW-RP-53. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 20 p.

- Metlen, K.M.; Fiedler, C.E.; Youngblood, A. 2004. Understory response to fuel reduction treatments in the Blue Mountains of Northeastern Oregon. *Northwest Science*. 78 (3): 175–184.
<http://treesearch.fs.fed.us/pubs/20383> (21 February 2013).
- Moser, A.M.; Petersen, C.A.; D'Allura, J.A.; Southworth, D. 2005. Comparison of ectomycorrhizas of *Quercus garryana* (Fagaceae) on serpentine and non-serpentine soils in southwestern Oregon. *American Journal of Botany*. 92(2): 224-230.
- Murray, C.M. 2007. General decision process for managing invasive plant species in Garry oak and associated ecosystems (GOEs). Prepared for the Garry Oak Ecosystems Recovery Team and The Nature Conservancy of Canada. 8 p.
http://www.goert.ca/documents/General_Decision_Process_revised.pdf (21 February 2013).
- NatureServe. 2011. International ecological classification standard: terrestrial ecological classifications. Arlington, VA: NatureServe Central Databases. Data current as of 31 July 2011.
<http://www.natureserve.org/explorer/servlet/NatureServe?init=Ecol> (21 February 2013).
- Niemiec, S.S.; Aherns, G.R.; Willits, S.; Hibbs, D.E. 1995. Hardwoods of the Pacific Northwest. Research Contribution 8. Corvallis, OR: Forest Research Laboratory, Oregon State University. 115 p.
- Patton, B.D.; Hironaka, M.; Bunting, S.C. 1988. Effect of burning on seed production of bluebunch wheatgrass, Idaho fescue, and Columbia needlegrass. *Journal of Range Management*. 41(3): 232-234.
<http://ojssandbox.library.arizona.edu/index.php/jrm/article/viewFile/17376/15415> (21 February 2013).
- Peter, D.H.; Harrington, C.A. 2002. Site and tree factors in Oregon white oak acorn production in western Washington and Oregon. *Northwest Science*. 76(3): 189-201.
- Peter, D.H.; Harrington, C.A. 2009. Synchronicity and geographic variation in Oregon white oak acorn production in the Pacific Northwest. *Northwest Science*. 83(2): 117-130.
- Ritland, K.; Meagher, L.D.; Edwards, D.G.W.; El-Kassaby, Y.A. 2005. Isozyme variation and the conservation genetics of Garry Oak. *Canadian Journal of Botany*. 83: 1478-1487.
- Rocchio, J. 2011. Ecological integrity assessment: east Cascades oak-ponderosa pine forest and woodland. Olympia, WA: Washington State Department of Natural Resources Natural Heritage Program.
http://www1.dnr.wa.gov/nhp/refdesk/communities/pdf/eia/ec_oak_pine.pdf (21 February 2013).
- Rocchio, F.J.; Crawford, R.C. 2008. Draft field guide to Washington's ecological systems. Olympia, WA: Washington State Department of Natural Resources Natural Heritage Program.
- Scharpf, R.F.; Hawksworth, F.G. 1974. Mistletoes on hardwoods in the United States. Forest Insect and Disease Leaflet 147. Washington, D.C.: U.S. Department of Agriculture Forest Service. 8 p.
- Silen, R.R. 1958. Silvical characteristics of Oregon white oak. Silvical Series 10. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 13 p.
- Simpson, M. 2007. Forested plant associations of the Oregon East Cascades. Technical Paper R6-NR-ECOL-TP-03-2007. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 602 p.
- Sinclair, W.A.; Lyon, H.H.; Johnson, W.T. 1987. Diseases of trees and shrubs. New York: Comstock Publishing Associates, Cornell University Press. 575 p.
- Southworth, D.; Carrington, E.M.; Frank, J.L.; Gould, P.J.; Harrington, C.A.; Devine, W.D. 2009. Mycorrhizas on nursery and field seedlings of *Quercus garryana*. *Mycorrhiza*. 19(3):149-158.

<http://dx.doi.org/10.1007/s00572-008-0222-1> (21 February 2013).

Stein, W.I. 1990. *Quercus garryana* Dougl. ex Hook. In: Burns, R.M. Honkala, B.H., tech, coords. Silvics of North America. Vol. 2, Hardwoods. Agriculture Handbook 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 650-660.

Steinberg, P.D. 2002. *Pseudotsuga menziesii* var. *glauca*. In: Fire Effects Information System [Online]. Missoula, MT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). <http://www.fs.fed.us/database/feis/> (21 February 2013).

Swiecki, T.J.; Bernhardt, E.A. 2006. A field guide to insects and diseases of California oaks. Gen. Tech. Rep. PSW-GTR-197. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. 151 p.

Taylor, R.J.; Boss, T.R. 1975. Biosystematics of *Quercus garryana* in relation to its distribution in the State of Washington. Northwest Science. 49: 49-57.

Thorpe, A.S.; Stanley, A.G. 2011. Determining appropriate goals for restoration of imperiled communities and species. Journal of Applied Ecology. 48: 275-279.

Tobalske, C. 2002. Historic vegetation. Oregon Natural Heritage Program. http://navigator.state.or.us/sdl/data/shapefile/k100/historic_vegetation.zip (21 February 2013).

Topik, C. 1989. Plant association and management guide for the grand fir zone, Gifford Pinchot National Forest. R6-Ecol-TP-006-88. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 110 p.

Tveten, R.K.; Fonda, R.W. 1999. Fire effects on prairies and oak woodlands on Fort Lewis, Washington. Northwest Science. 73(3): 145-158.

U.S. Department of Agriculture [USDA], Forest Service. 2008. Current vegetation survey, Pacific Northwest Region Forest Inventory and Monitoring.

U.S. Department of Agriculture [USDA], Forest Service. 2010a. Ecology core dataset, western Washington, Region 6 Ecology Program. <http://ecoshare.info/category/data-sets/> (22 February 2013).

U.S. Department of Agriculture [USDA], Forest Service 2010b. Forest Service Pacific Northwest Forest Inventory and Analysis FIA DataMart FIADB version 4.0. U.S. Department of Agriculture Forest Service. <http://www.fs.fed.us/pnw/fia/publications/data/index.shtml> (22 February 2013).

U.S. Geological Survey [USGS]. 1999. Digital representation of "Atlas of United States Trees" by Elbert L. Little, Jr. <http://esp.cr.usgs.gov/data/atlas/little/> (22 February 2013).

Uresk, D.W.; Cline, J.F.; Rickard, W.H. 1976. Impact of wildfire on three perennial grasses in south-central Washington. Journal of Range Management. 29 (4): 309-310. <http://ojssandbox.library.arizona.edu/index.php/jrm/article/viewFile/14924/12961> (22 February 2013).

Valentine, L.L.; Fiedler, T.L.; Haney, S.R.; Berninghausen, H.K.; Southworth, D. 2002. Biodiversity of mycorrhizas on Garry oak (*Quercus garryana*) in a southern Oregon savanna. In: Standiford, R.B.; McCreary, D.; Purcell, K.L., tech. coords. Proceedings of the 5th symposium on oak woodlands: oaks in California's changing landscape; 2001 October 22-25; San Diego, CA. Gen. Tech. Rep. PSW-GTR-184. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 151-157.

Vesely, D.; Tucker, G. 2004. The landowner's guide for restoring and managing Oregon white oak habitats. Salem, OR: Bureau of Land Management, Salem

District.

http://www.blm.gov/or/districts/salem/files/white_oak_guide.pdf (21 February 2013).

Voeks, R.A. 1981. The biogeography of Oregon white oak (*Quercus garryana*) in central Oregon. Portland, OR: Portland State University. 119 p. Thesis.

Wright, H.A. 1985. Effects of fire on grasses and forbs in the sagebrush-grass communities. In: Sanders, K.; Durham, J. [and others] (eds.) Rangeland fire effects - proceedings of a symposium. Boise, ID: USDI Bur. of Land Manage., Idaho State Office and Univ. of Idaho. p. 12-22. <http://books.google.com/books?id=aMc-kJxStIoC> (21 February 2013).

Wright, C.S.; Agee, J.K. 2004. Fire and vegetation history in the eastern Cascade Mountains, Washington. Ecological Applications. 14(2): 443-459.
<http://www.arcfuels.org/maggie/AGER%202011.Data/PDF/wright%20eastern%20cascades%202004.pdf> (21 February 2013).

APPENDIX

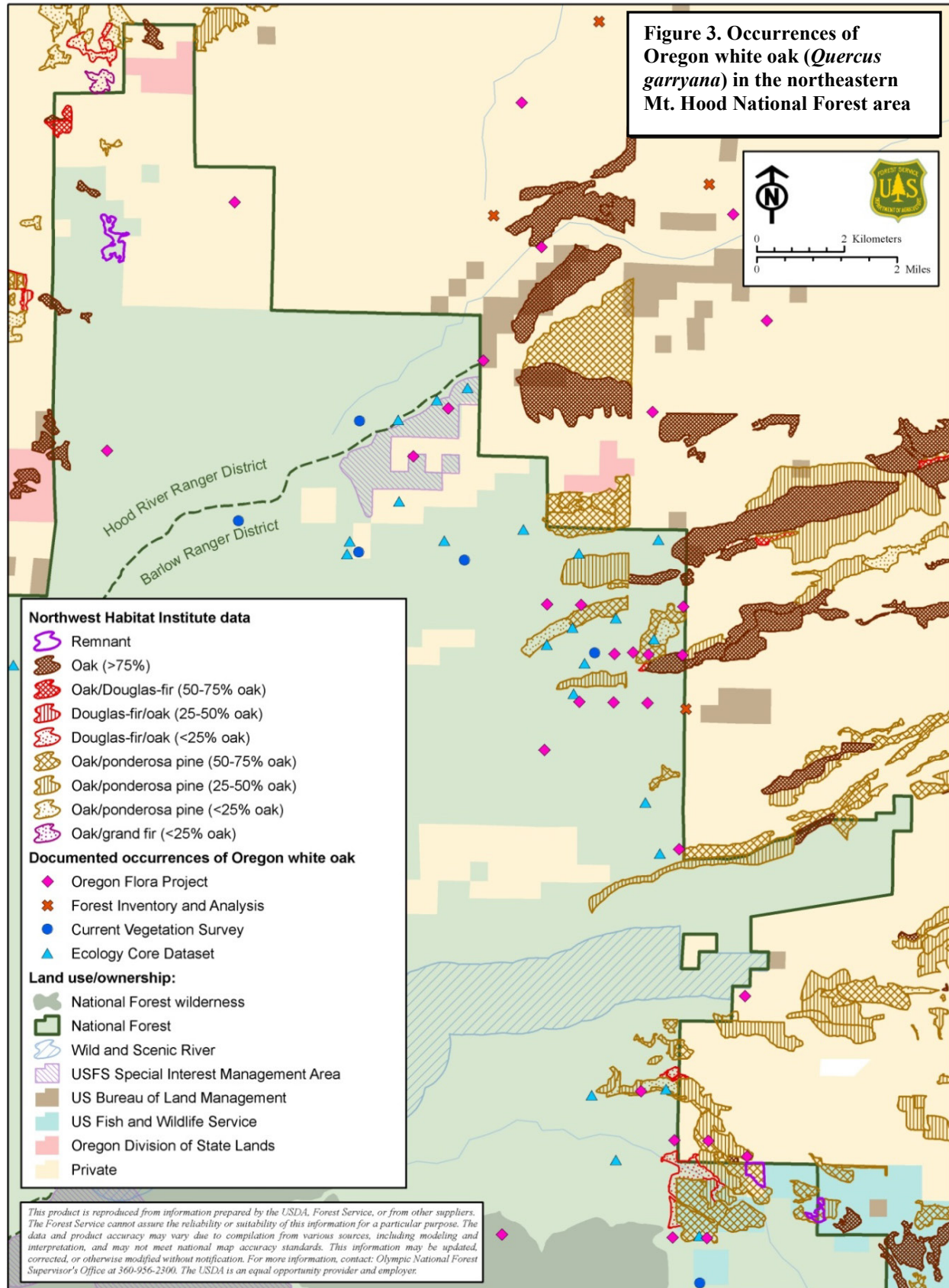
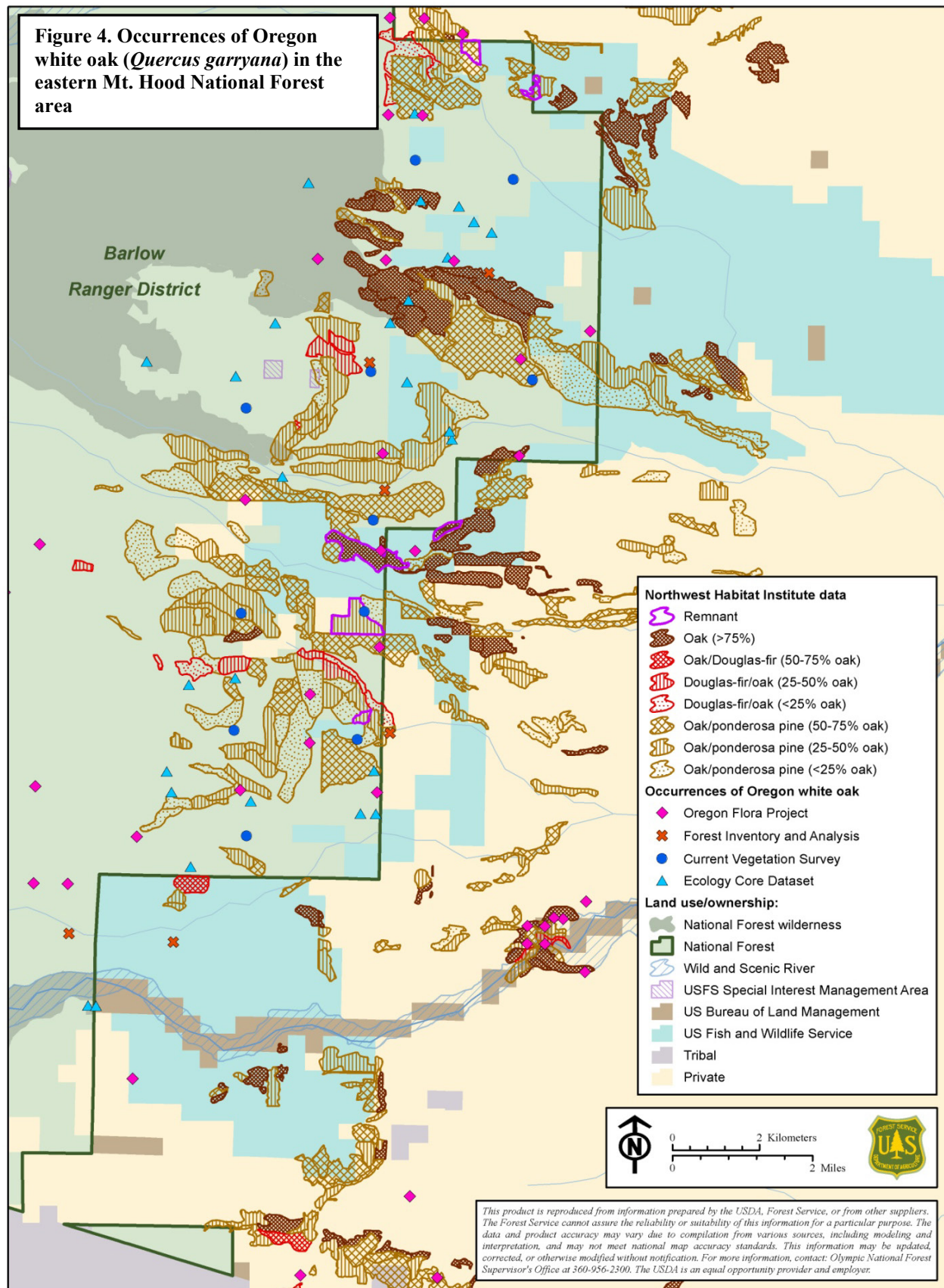
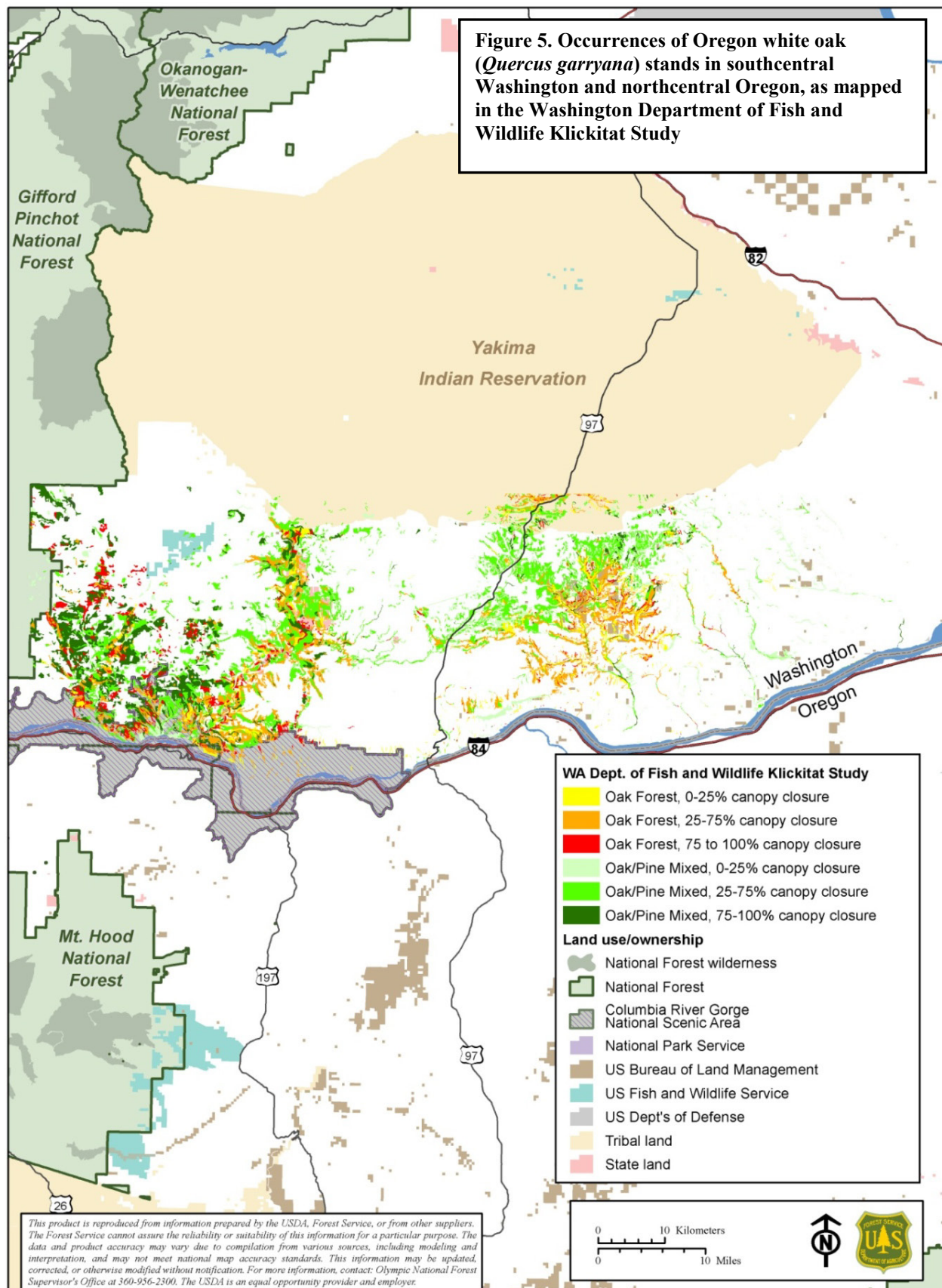
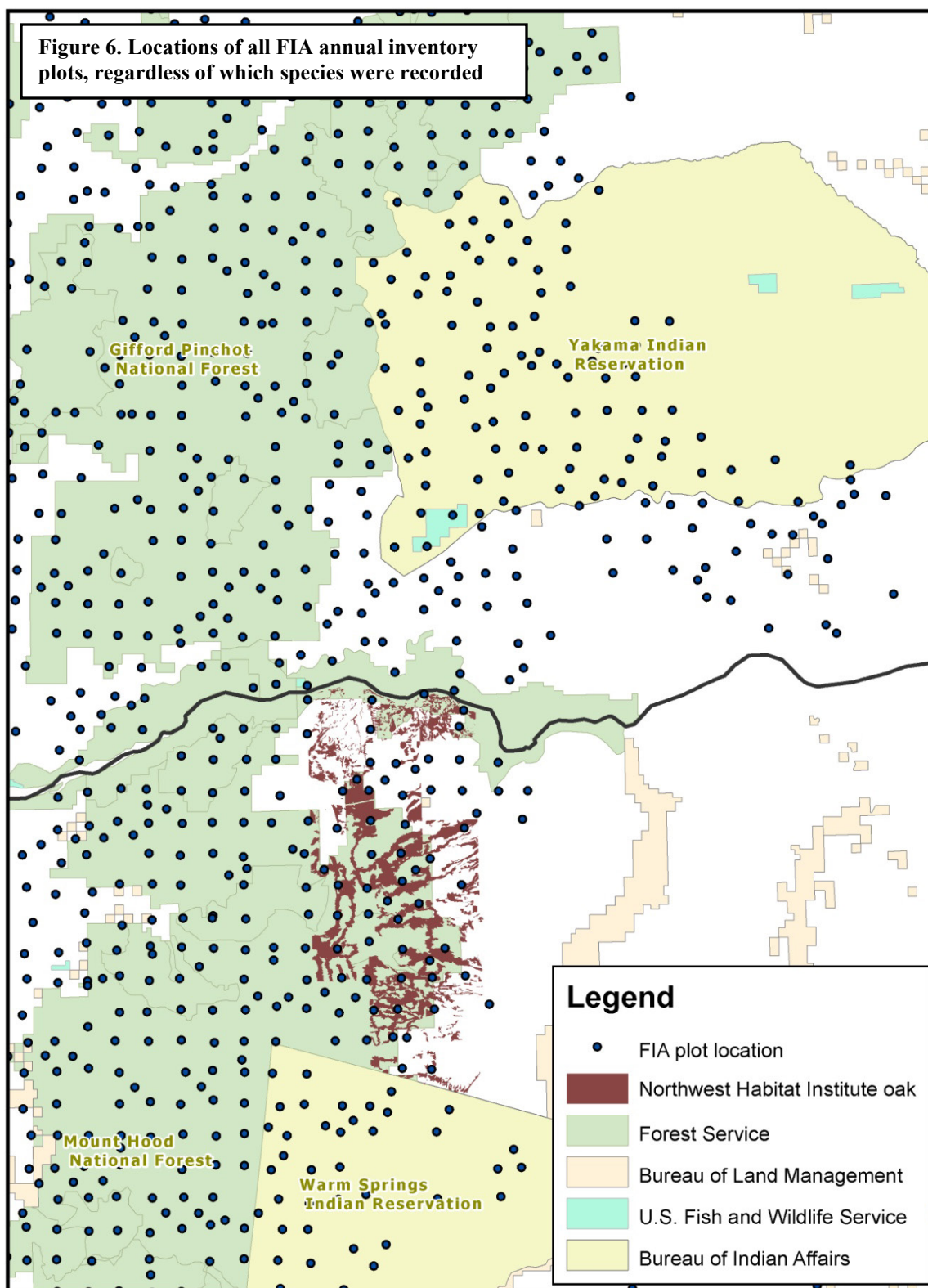


Figure 4. Occurrences of Oregon white oak (*Quercus garryana*) in the eastern Mt. Hood National Forest area







OREGON WHITE OAK RESTORATION STRATEGY FOR NATIONAL FOREST SYSTEM LANDS EAST OF THE CASCADE RANGE



**UNITED STATES
DEPARTMENT OF
AGRICULTURE**

FOREST SERVICE

**PACIFIC NORTHWEST
REGION**

MARCH 2013