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Land Managers Guide to Whitebark Pine Restoration in the Pacific Northwest Region

2009–2013

Cover Photos

Main photo and inset photo; Robin Shoal, USFS; sidebar photos—verbenone pouch on large whitebark pine tree, Connie Mehmel, USFS; cone cages in whitebark pine tree crown, Robin Shoal, USFS; nursery-grown whitebark pine seedling, Jude Danielson, USFS; whitebark pine seedlings ready for planting, Chris Jensen, USFS.

Land Managers Guide to Whitebark Pine Restoration in the Pacific Northwest Region 2009–2013

September 2008

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Introduction

Purpose of the Land Managers Guide

The purpose of this guide is to provide practical information about techniques to conserve and restore whitebark pine, for use by land managers in Oregon and Washington who administer land containing whitebark pine habitat. Few whitebark pine restoration projects have taken place in Oregon and Washington; most of the literature currently available refers to projects implemented in the Rocky Mountains. A great deal of that information is transferable across the range of the species, but ecological and habitat differences between the Rockies and the Pacific Coast portions of the range of whitebark pine mean that restoration assumptions and practices developed for whitebark pine in the Rocky Mountains may need to be adapted to the different conditions in Washington and Oregon.

Relationship of this guide to the Whitebark Pine Restoration Strategy for the Pacific Northwest

This land managers guide is a companion to the *Whitebark Pine Restoration Strategy for the Pacific Northwest* (Aubry et al. 2008). Although the managers guide can stand alone as a practical guide to restoration techniques and decision-making, it contains a great deal less detail than the strategy does with regard to the ecology of whitebark pine, its habitat in Oregon and Washington, and the threats to the species that have led to its current need for active conservation and restoration. The restoration strategy identifies seed zones and conservation areas, describes conditions within those conservation areas to the best of our current knowledge, and recommends restoration goals and priorities for management units within the conservation areas.

Land managers wishing to implement whitebark pine restoration or conservation activities should first consult the strategy to see what management units have been identified within their forest or district, what the restoration goals are for those units, and the reasoning behind those goals. Then, by using this land managers guide in combination with more detailed local knowledge of stand conditions, managers can select restoration techniques to achieve those goals. The land managers guide is a tool for deciding which restoration techniques are appropriate for local conditions; it does not contain detailed instructions for prescribing and implementing restoration projects.

The land managers guide discusses six primary techniques used in whitebark pine conservation and restoration:

- Cone collection,
- Planting seedlings,
- Thinning,
- Mountain pine beetle treatment,
- Pruning, and
- Fire management.

Following the presentation of the techniques is a discussion about assessing stand-level restoration and conservation needs. Four case studies are provided to illustrate whitebark pine restoration activities that have been implemented in Oregon and Washington.

Whitebark pine: range, habitat, distribution, and ecology

Whitebark pine (*Pinus albicaulis* Engelm.) is a five-needled pine that occurs only in mountainous regions of western North America. There are two distinct portions of the species' range, divided north-to-south by the lowlands of the Columbia Plateau (fig. 1). A few isolated stands in southeastern British Columbia and northeastern Washington loosely connect the eastern and western portions of the range.

The eastern, inland portion of the range of whitebark pine includes the Rocky Mountains from Alberta to Wyoming. Isolated populations also occur in some of the high Great Basin ranges of Nevada. The western, Pacific Coast portion includes the British Columbia Coast Range mountains in Western Canada, and extends southward to the Sierra Nevada of California. Whitebark pine populations tend to be scattered and

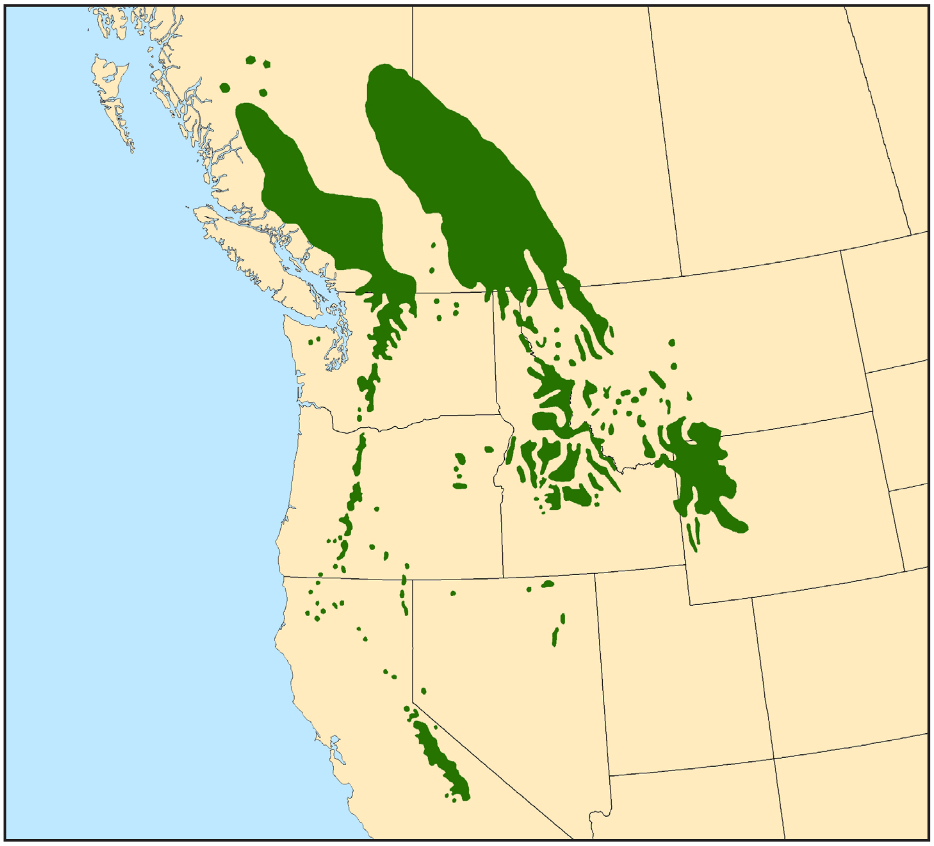


Figure 1. Range of whitebark pine (U.S. Geological Survey 1999)

spotty because of the often discontinuous distribution of favorable habitat on high mountain peaks and ridges. In Washington and Oregon, whitebark pine grows in the Cascade Range and in the Olympic, Kettle River, Selkirk, Blue, Wallowa, Paulina, Yamsey, North Warner, and Siskiyou Mountains. In Oregon and Washington, whitebark pine's lower elevational limit increases as one moves from the northwest to the southeast: in Washington's North Cascades, whitebark pine occurs from about 1,525 m (approximately 5,000 ft) and up, while in Oregon's southern Cascades the species begins to appear at 1,975 m (approximately 6,500 ft).

Whitebark pine is a medium-sized tree that can reach heights of 21 m (70 ft) and may be taller on especially favorable sites. Its thin bark is pale gray and appears whitish at a distance, hence its common name. Smooth on young trees, the bark separates into plates with age (Kral 1993). Whitebark pine has a straight to twisted trunk and a spreading conical, rounded, or irregular crown. Multiple stems representing a single tree or several very closely spaced trees are common in open stands.

Whitebark pine is a minor stand component in mixed-species stands near its lower elevational limit; it is best known as an upper timberline species associated with open subalpine parkland landscapes, where whitebark pine occurs in pure stands or with subalpine fir (*Abies lasiocarpa*). Other conifer species that occur with whitebark pine include lodgepole pine (*Pinus contorta*), Engelmann spruce (*Picea engelmannii*), subalpine larch (*Larix lyallii*), western white pine (*Pinus monticola*), mountain hemlock (*Tsuga mertensiana*), and Shasta red fir (*Abies ×shastensis*). In especially harsh timberline sites whitebark pine takes on a stunted krummholz growth form. Within its range, whitebark pine is typically the last tree species to occur before subalpine parkland gives way to treeless subalpine tundra.

Depending on environmental conditions, whitebark pine is either an early seral species or a climax species. It is shade-intolerant and can thrive in poor soils and harsh, relatively dry conditions unsuitable for other tree species. Whitebark pine is an early colonizer of disturbed sites such as burned areas, landslides, and

A multiple-stem clump of young whitebark pines showing pale bark.

A clump of mature whitebark pines.

Mature whitebark pine with broad, rounded crown.

Whitebark pine in krummholz form.

avalanche slopes (Tomback and Kendall 2001). At lower elevations it is eventually out-competed by more shade-tolerant tree species. On sites that are less productive or protected—upper elevations, rocky ridges, windswept slopes, dry southern exposures—whitebark pine is often the climax tree species, forming pure stands of widely spaced individual trees or tree clusters.

Robin Shoal, USFS

LuRay Parker, Wyoming Game and Fish

Donna Dewhurst, USFWS

While the seeds of most North American conifers are wind-dispersed, whitebark pine relies almost exclusively on a bird, the Clark's nutcracker (*Nucifraga columbiana*), for seed dispersal (Tomback 1982, 2001; Lanner 1996). The seeds of whitebark pine are large, wingless, and highly nutritious. They are borne in indehiscent cones—cones that do not open or fall from the tree on their own. The Clark's nutcracker harvests seeds from the cones on the trees and caches a portion of those seeds for later retrieval. The germination and survival of seeds from unretrieved nutcracker caches, when they are placed in sites amenable to germination and seedling survival, provide the primary regeneration mechanism for whitebark pine.

The relationship between the Clark's nutcracker and whitebark pine is considered a co-evolved mutualism (Tomback 1982, Lanner 1996). Co-evolved features in the nutcracker include its strong pointed bill and the sublingual pouch in which it transports the seeds; co-evolved features of the tree include its multiply branched, rounded growth habit, with cones borne upright on the ends of the upswept branches. The bird-mediated seed dispersal of whitebark pine allows the seeds of whitebark pine to be dispersed farther from the parent tree than seeds of wind-dispersed tree species; nutcrackers have been observed transporting and caching whitebark pine seed up to 12.5 km (approximately 8 miles) from the harvest stand (Tomback 1978). In the Washington Cascades, nutcrackers have been observed transporting and caching whitebark pine seed up to 30 km (18 mi) from the parent tree (Lorenz and Sullivan, in prep.), although most caches are placed much closer to the harvest site (Hutchins and Lanner 1982; Dimmick 1993; Lorenz pers. comm., 2008). It also provides whitebark pine with the ability to be an early pioneering species on disturbed sites, including those well beyond the dispersal range of wind-dispersed seeds (Tomback and Linhart 1990).

The seeds of whitebark pine are highly nutritious and provide a significant source of food for many species of wildlife, including nutcrackers and other birds, pine squirrels and other rodents, and both black and grizzly bears. Highly important, from a management perspective, is the essential role whitebark pine seeds play in the diet of grizzly bears (*Ursus arctos horribilis*), a federally listed endangered species. In the Northern Rockies, recovery of grizzly bear populations is closely linked to the health of whitebark pine stands and the availability of adequate whitebark pine cone crops (Mattson et al. 2001). In the North Cascades of Washington, whitebark pine is not considered a primary food source because expansive whitebark pine forested habitat is not as extensive or abundant as it is in the Rocky Mountain Region. Grizzly bears are opportunistic foragers on whitebark pine seed in the North Cascades. However, whitebark pine seeds will be an important component of the grizzly bear food resources, if recovery efforts are to be successful (Rohrer, pers. comm., 2008).

Why the concern about whitebark pine?

The future of whitebark pine is of substantial concern in Oregon and Washington as well as throughout its range because of the species' acute vulnerability to infection by the non-native fungus *Cronartium ribicola* (cause of white pine blister rust), its susceptibility to infestation by mountain pine beetle (*Dendroctonus ponderosae*), its risk of being destroyed in large and intense wildfires, and the likelihood of its being replaced in some subalpine mixed conifer forests by more shade-tolerant tree species, a trend that is attributed to fire exclusion (Tomback 2001, Schwandt 2006). There are also significant concerns about the impacts of climate change, particularly warming, on this high-elevation, cold-adapted species (Warwell et al. 2006). In the absence of timely management activities, there is reason to believe that the currently observed decline of whitebark pine will continue and may become irreversible, particularly in some locations (Schwandt 2006).

Conservation and Restoration Techniques

Cone collection

Cone (seed) collection is at the heart of whitebark pine restoration. Whitebark pine seed is needed for three main purposes: blister rust resistance testing; restoration (operational) plantings; and *ex-situ* (seed bank) gene conservation. Enough seed can be collected in a single cone collection project to accommodate all

Blister rust canker on a whitebark pine branch.

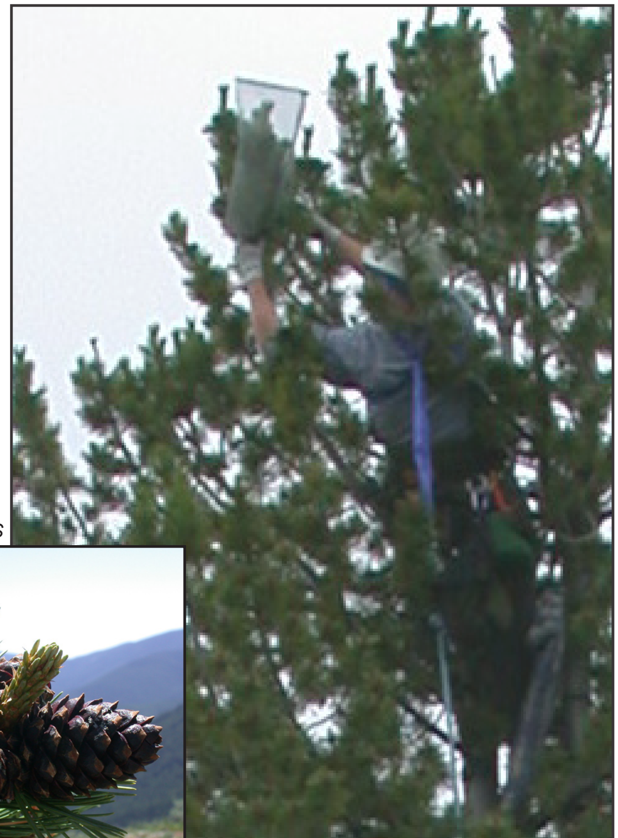
Blister rust has killed this whitebark pine sapling.

Robin Shoal, USFS

Blister rust canker on the bole of a whitebark pine tree.

three objectives. Depending on the purpose for which the seed is to be used, there are different approaches to selecting the individual trees from which to collect. In all cases, climber safety and proper training are paramount if the trees are to be climbed to access the cones. See the Forest Service's *National Tree Climbing Guide* (Davis 2005) for training and equipment requirements, how to identify hazards that may prevent a tree from being safely climbed, and additional information about safely climbing trees. Note that climbing spurs should not be used on whitebark pine—the spurs damage the species' thin bark.

Cones of whitebark pine must be protected from depredation by animals—chiefly the Clark's nutcracker, but also squirrels and chipmunks. Wire mesh "cone cages" are installed around the cones as early in the collection season as possible, typically as soon as snowmelt allows access to the stand. To ensure that the seeds are as ripe as possible at collection time, the cages are removed and the cones collected as late in the season as is logistically feasible. For detailed information about the cone collection process itself, see the *Whitebark Pine Cone Collection Manual* (Ward et al. 2006).

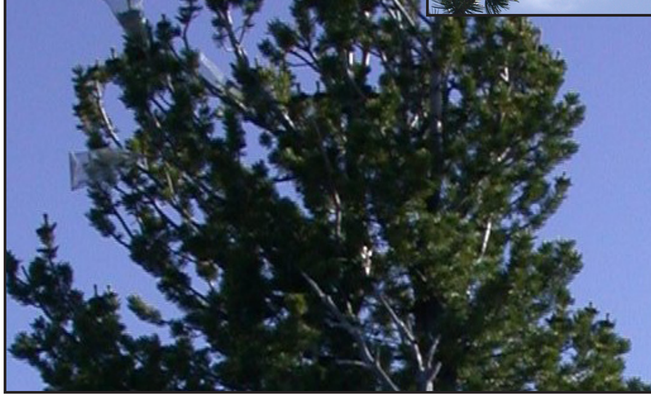

Jamie Cannon, USFS

U.S. Forest Service certified tree climber caging whitebark pine cones.

Robin Shoal, USFS

Maturing whitebark pine cones are rounded, purplish, and usually sticky with sap.

Close-up of an installed cone cage.


Robin Shoal, USFS

Cone cages installed in the crown of a whitebark pine tree.

Whitebark pine cones are also targeted by a number of species of cone and seed insects, including the fir coneworm (*Dioryctria abietivorella* (Grote)) and western conifer seed bug (*Leptoglossis occidentalis* Heidemann) (Kegley et al. 2001). Impacts of seed and cone insects on whitebark pine have not been well-evaluated (Goheen, pers. comm., 2008). Insects have not been a significant problem in whitebark pine cone collections received to date by the Dorena Genetic Resource Center (Dorena GRC) (Berdeen, pers. comm., 2006). If a selected cone collection site were to show high levels of infestation by these insects, an entomologist should be consulted to consider methods for reducing the impact of the insects on the caged cones.

Collecting cones for blister rust resistance testing

For blister rust resistance testing, trees should be selected for visual evidence of potential rust resistance. The following stand and tree selection guidelines are designed to maximize the potential for identifying relatively rust-resistant trees in the field. These guidelines have been adapted from more detailed selection criteria developed for the Rocky Mountain portion of whitebark pine's range (Mahalovich and Dickerson 2004):

Stand-level selection

In many cases there may be few cone-bearing stands from which to choose. All stands considered should be located in habitat where cone-bearing whitebark pines typically occur. Where there are several stands within a single restoration area, the choice of which stand to collect from can be guided by stand characteristics, blister rust infection levels, and accessibility. Relative to the other stands under consideration, the chosen stand should have a high blister rust infection rate, with multiple cankers on each infected tree. The stand should have a good cone-bearing history, with many trees bearing numerous cones per tree; and it should be readily accessible, ideally by road.

Tree-level selection

Once a suitable stand has been selected, it is a good idea to collect from as many trees as is possible or practical; three is an absolute minimum and ten a good upper target. The trees ultimately selected for cone collection for rust resistance testing should be relatively free of blister rust symptoms compared to the other trees in the stand. The selected trees should be separated from each other by 100 m (300 ft) or more. Rust resistance testing requires a minimum of 150 seeds per tree. Twelve to 15 cones per selected tree should be sufficient to achieve this minimum. Cones from each selected tree should be kept separately, not mixed with cones from any other tree. If there is mountain pine beetle activity nearby, the selected trees can be protected with verbenone pouches (see mountain pine beetle treatment section).

Collecting cones for restoration (operational) planting

For cone collections intended as a source of locally adapted seedlings for restoration plantings (operational collections), selected trees within a stand should be separated from one another by a minimum of 30 m (100 ft). Less emphasis can be placed on apparent blister rust resistance for trees selected as seed sources for restoration plantings than when selecting trees for blister rust resistance testing, but it's still a good idea to target trees that appear to be relatively healthy. The trees need to have a sufficient cone crop—at least 50 cones per tree. A good target is to collect from 10 to 12 trees per stand, using 10 to 15 cone cages per tree, with each cage enclosing at least two maturing cones. Spreading designated cone-source trees across several stands will reduce the risk of losing these trees to fire, beetles, and other disturbances. Unless there is a need to keep each tree's cones separate, cones collected for operational purposes can be bulked (combined) by site, management unit, conservation area, or seed zone. Seed should not be mixed across seed zones.

Collecting cones for *ex-situ* gene conservation

The goal of *ex-situ* gene conservation is preservation of the full range of genetic variation. The *Whitebark Pine Restoration Strategy* (Aubry et al. 2008) contains an *ex-situ* gene conservation plan that describes the number of individual tree collections that need to be made in the different conservation areas across the region. Seed for this purpose should be collected from randomly selected trees distributed throughout the conservation area, with no consideration given to tree form, size, age, or apparent blister rust resistance. A minimum of 800 seeds per tree (about 25 to 30 healthy cones) is required for long-term storage. As a loose rule of thumb, if cone collections are to be made for either rust resistance testing or operational purposes, one additional tree per collection site should be selected for *ex-situ* gene conservation.

Planting seedlings

Planting whitebark pine seedlings is a primary focus of the restoration strategy. Reasons for planting seedlings include:

- To restore whitebark pine to areas where its populations have been reduced by the impacts of natural and anthropogenic agents (blister rust, mountain pine beetle, fire, climate change);
- To increase the numbers of living whitebark pine on the landscape and to provide future seed sources, especially in areas where local seed sources have been diminished;
- To diversify stand demographics in older stands with little or no natural regeneration;
- To provide additional material to the process of natural selection for resistance to white pine blister rust; and
- To provide additional material to increase the resilience of the species in its adaptation to changing climate.

Planting may be indicated for stands that have recently burned, stands that have been heavily affected by blister rust, areas where mortality from mountain pine beetles has reduced the local seed source, and stands with low age-class diversity. For thinning or fire-based restoration treatments, planting should be considered as part of the overall prescription, especially in areas with high levels of blister rust infection. Outplanted seedlings should come from a seed source within the same seed zone in which the planting will occur. Whitebark pine seed zones (fig. 2) and seed movement guidelines for Oregon and Washington are described in the restoration strategy.

Projects that are not focused specifically on whitebark pine restoration present additional opportunities for planting whitebark pine. Whitebark pine seedlings are likely to be an appropriate plant material for many projects that entail revegetation after natural or anthropogenic disturbance in whitebark pine habitat. This list includes restoration of damaged high-elevation recreation resources such as heavily used trails and camping areas, post-fire revegetation, and even road construction and maintenance.

Determining whether appropriate seed is available

The first step in planning a whitebark pine restoration planting is to determine whether enough appropriate seed is available. For the Forest Service's Pacific Northwest Region (Region 6), whitebark pine seed for rust resistance testing is stored at the Dorena GRC on the Umpqua National Forest in Oregon. Bulked tree seed for restoration or reforestation for Region 6 forests is stored at the Forest Service Bend Seed Extractory in Bend, OR, or the Forest Service J. Herbert Stone Nursery in Central Point, OR. If there is not enough seed available, planting plans will have to be put on hold, and seed collection becomes the immediate priority (see Cone Collection section). If there is sufficient appropriate seed, conducting cone collections to replace the seed used for the project should be an integral part of the restoration planting process.

Planting 2-year old seedlings is recommended. In the only comprehensive whitebark pine seedling survival study to date, 3-year-old whitebark pine seedlings did not show greater survival in the field than 2-year-old seedlings (Izlar 2007), so it is unlikely that an additional season of nursery growth (which adds to the cost of the seedlings) would provide any advantage.

Both the Dorena GRC and the Forest Service Coeur D'Alene Forest Nursery can grow whitebark pine seedlings for restoration plantings. The supervisory operations forester at either location may be contacted for seedling orders. Whitebark pine seedlings take at least 2 years to produce, so inquiries about seed availability must be made a minimum of 2 years in advance; the seedlings themselves should be ordered no later the beginning of November—for example, order seedlings in October of 2010 for a planting scheduled for fall of 2012 (Riley, pers. comm., 2008; Eramian, pers. comm., 2008).

Germination in whitebark pine is highly variable. Germination data for pre-existing seed lots will determine how many seeds to start with for a given seedling order. For newly collected seed lots intended for immediate seedling production, routine X-ray and tetrazolium (TZ) tests can help guide the decision

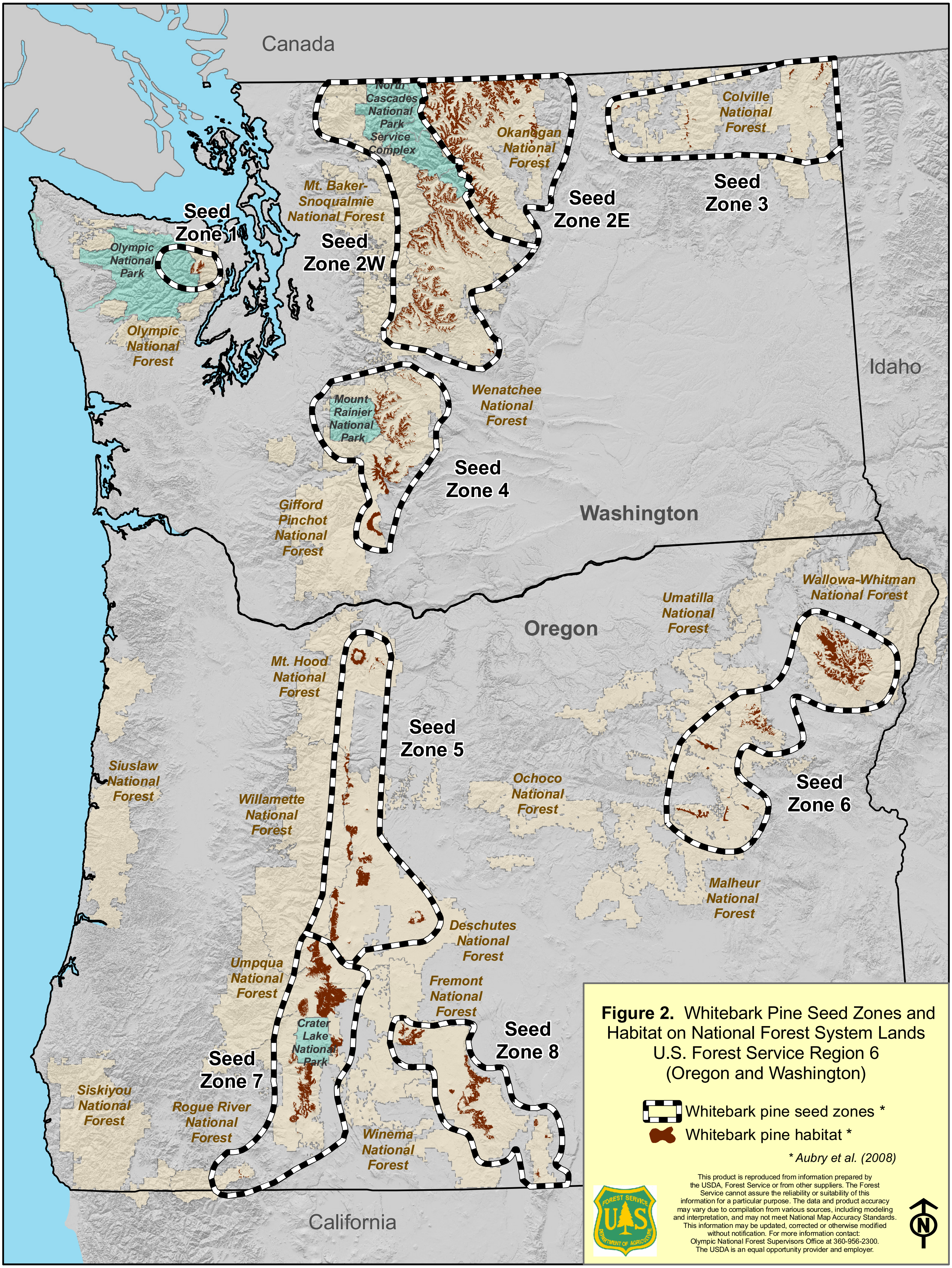


Figure 2. Whitebark Pine Seed Zones and Habitat on National Forest System Lands U.S. Forest Service Region 6 (Oregon and Washington)

Don Pigott, USFS

Whitebark pine seeds in the cone.

Richard Sniezko, USFS

Extracted whitebark pine seeds.

Jude Danielson, USFS

Whitebark pine seedling in its first year.

Chris Jensen, USFS

Two-year old seedlings ready to be planted.

Richard Sniezko

Whitebark pine germinant

Growing Seedlings

Whitebark pine seedlings are typically grown in 10-cubic-inch tubes or "cells." The seedlings produce abundant roots, so the cells are full of well-developed roots after two growing seasons. Although the use of larger cells has not been tested, it might be a good idea to use 16- or 25-cubic-inch cells for seedlings intended for extremely harsh planting sites. These larger cells will also be full of roots after two growing seasons, and the larger, deeper root masses might help boost survival. Comparative testing under field conditions of seedlings grown in the two cell sizes may provide some guidance about which cell size to specify.

about how many seeds will be needed. Whitebark pine displays delayed germination in the field (McCaughey and Tomback 2001), so there may be an advantage to using seed that has been in storage for a year or two. The process for growing whitebark pine seedlings is to stratify the seed, sand or nick the seed coats, germinate the seeds, and hand-sow the germinants (Riley, pers. comm., 2008; Eramian, pers. comm., 2008).

Determining how many seedlings to order

Outplanted whitebark pine seedlings show variable survival in the field. In 14 plantings of whitebark pine monitored in 2006 for third-, fourth-, or fifth-year survival, survival rates ranged from 10 percent to 78 percent (Izlar 2007). A general guideline is to expect up to 50 percent mortality in the first few years (Jenkins, pers. comm., 2008). An additional consideration is anticipated mortality of the surviving saplings due to blister rust. Blister rust resistance testing for whitebark pine in the Pacific Northwest Region is underway at the Dorena GRC. Early results reveal some levels of resistance in particular families (Sniezko et al. 2007), but testing is still in its early stages. Additional seed collections need to be made and more tests conducted before sufficient numbers of resistant parent trees are identified in the field. Until that time the blister rust resistance of the available seedlings will be unknown, and it will be necessary to plant enough seedlings to allow for some seedling mortality due to blister rust.

Young trees are killed more quickly by blister rust than are large trees, so it is reasonable to believe that the rate of blister rust incidence and mortality in young trees will be greater than that in larger trees in the same vicinity. For example, if a blister rust survey shows that 15 percent of live whitebark pines of all size classes greater than 1.4 m (4.5 ft) tall in or near the target stand are infected with blister rust, then it can be reasonably assumed that up to 15 percent of the out-planted seedlings may eventually become infected, and some of these will probably die of the disease before reaching maturity.

To determine the number of seedlings needed, start with the establishment goal (the desired number of seedlings to reach maturity), and estimate the survival rate at each stage (survival rate = 1 minus mortality rate): early post-planting mortality, blister rust mortality prior to maturity, and miscellaneous other causes of mortality. Dividing the establishment goal by the survival rates will yield the number of seedlings needed. (See box below for a scenario that works out the math.)

Seedling planting guidelines

A set of draft planting guidelines for whitebark pine was presented at the Forest Service Region 1 Reforestation Workshop in Missoula, MT, on March 4, 2008. These guidelines (McCaughey et al., in prep.) are a revised version of an earlier set of guidelines (Scott and McCaughey 2006), updated to incorporate the findings of Izlar's (2007) study of seedling survival. Below is a summary of the draft guidelines, augmented by additional references:

- Reduce overstory competition to increase light availability (see Thinning section, below).

A Scenario for Estimating Seed Needed and for Ordering Seedlings

Based on the densities of nearby reference whitebark pine stands, a small restoration planting prescription has a goal of establishing 100 new whitebark pine trees that will grow to maturity. Blister rust surveys in the vicinity found that 20 percent (0.20) of live whitebark pines were infected with blister rust. There is already sufficient seed in storage that can be used for this site. Assuming that 50 percent of the out-planted seedlings will survive the first 3 years after planting, and that 10 percent of those surviving seedlings would be killed by blister rust before reaching maturity (yielding a blister rust survival rate of 1 minus 0.10, or 0.90), the math needed to figure out how many seedlings to order would go like this:

Starting with the establishment goal of 100 trees, divide that value by the proportion of seedlings expected to survive the first few years after planting (in this case 0.50); then divide that result by the proportion of seedlings expected to survive blister rust (0.90). For this example, the equation is ((100 ÷ 0.50) ÷ 0.90), which equals 222.

If only early seedling mortality and blister rust mortality were considered, a total of 222 seedlings would need to be ordered and planted to establish 100 new trees in this stand. Realistically, some of the planted seedlings that survive the first few years after planting are likely to die from miscellaneous other causes before reaching maturity, succumbing to physical or environmental factors such as trampling, antler rubbing, rodent nibbling, avalanche, severe weather, or drought. If it were assumed that an additional 10 percent of the seedlings would die from such causes, dividing those 222 seedlings by 0.90 (the "other causes" survival rate of 1 minus 0.10) brings the total seedling order to 247, or about two-and-a-half times the establishment target.

When the seedlings are ordered, the nursery will take this equation one step further and divide the desired number of finished seedlings by the known or estimated germination rate of the seed lot in order to determine how many seeds to stratify.

In summary:

Seedling order = Trees ÷ P ÷ B ÷ M (equivalently, seedling order = Trees ÷ (P x B x M)), where:

Trees = establishment target (the number of mature trees to be established)

P = early post-planting survival rate (1 minus expected early mortality rate)

B = blister rust survival rate (1 minus expected blister rust mortality rate)

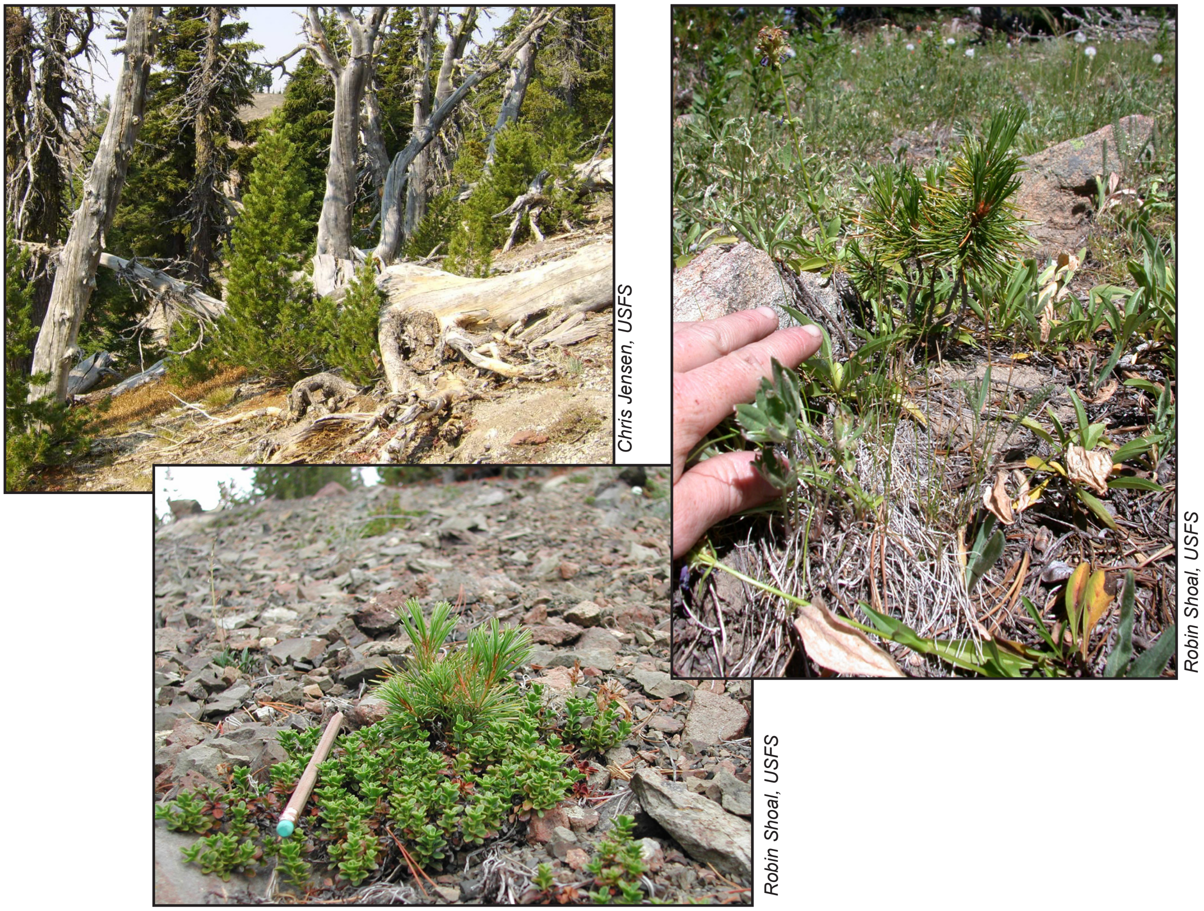
M = miscellaneous "other causes" survival rate (1 minus expected "other causes" mortality rate)

- Reduce thick understory vegetation (especially grasses and sedges) from the immediate vicinity of planted seedlings to reduce competition for available soil moisture. An exception is grouse whortleberry (*Vaccinium scoparium*); whitebark pine has been found to grow especially well in association with this species (Perkins 2004).
- Avoid planting in burned lodgepole pine stands; lodgepole pine typically regenerates quickly with high numbers of seedlings per acre and will rapidly out-compete whitebark pine.
- Do not plant in mixed plantings with other conifers. Whitebark pine is likely to be out-competed by faster growing tree species such as lodgepole pine, Douglas-fir, and Engelmann spruce.
- Avoid planting in swales or frost pockets; young whitebark seedlings do not appear to be frost hardy during certain times of the growing season. Young seedlings can also be uprooted and killed by the physical effects of frost heaving (Kajimoto 2002). Ridge tops or exposed slopes are generally more suitable planting sites.
- Plant seedlings in microsites that will protect the seedlings by providing soil stability, moderating soil temperatures, providing shade and shelter, and increasing available soil moisture. A microsite can be created by a rock, log, stump, or live tree or shrub located upslope or to the side of the seedling. The selection and relative location of features that create protective microsites are crucial to seedling survival (Izlar 2007, Mellman-Brown 2005, Resler et al. 2005).
- To avoid long-term inter-tree competition, do not overcrowd planted trees. Adjust spacing guides based on expected survival. Spacing in a whitebark pine restoration planting is likely to be fairly irregular, based on the densities and patterns of nearby reference stands and on the availability of suitable microsite features.
- Plant seedlings when soil moisture is adequate. Planting seedlings in the fall is probably the best choice (Riley, pers. comm., 2008; Eramian, pers. comm., 2008). Heavy snow makes most whitebark pine sites inaccessible into late June or mid July, so early planting is generally impractical anyway. Planting during hot, dry summer conditions risks exposing the seedlings to drought, heat stress, and desiccation. Planting seedlings in the fall after there is adequate soil moisture allows roots more time to become established, thereby reducing frost heaving of seedlings. It also gives them the advantage of spring moisture from snowmelt before their first summer season.

Monitoring for seedling survival is essential. Planting whitebark pine seedlings is a relatively new practice in the Pacific Northwest Region. Monitoring for seedling survival at least the first, third, fifth, and tenth years after planting will provide vital information for improving whitebark pine restoration practices. At a minimum, monitoring should record the status (i.e., live, dead, diseased, damaged, missing) and size (height and diameter) of each seedling; and cause of death if dead. Additional important data might include microsite characteristics, natural regeneration, and information about other plant species in the stand, both overstory and understory. Continuing to monitor at increasing intervals until the seedlings reach maturity will provide information about whitebark pine tree growth, cone-bearing age, and stand development.

Planting seeds

Direct planting of whitebark pine seeds has the potential to greatly increase the efficiency and reduce the costs and effort involved in whitebark pine restoration planting. For extremely remote or wilderness sites, direct planting of seeds might be the only feasible restoration option available. While there is currently no tested protocol for planting whitebark pine seeds in the field, a number of seeding trials are underway. One series of trials was installed near Baker City, Oregon, in fall 2005 (Schwandt et al. 2007). Of 700 total whitebark pine seed planted, 94 (13.4 percent) had germinated by mid July, 2006. Seed pre-treatments of warm stratification and seed coat scarification (nicking the seed coat) appeared to improve germination, but treatments intended to repel rodents had no significant effect (Schwandt et al. 2007). By summer 2007, a few additional seeds had germinated, but only 20 of the 94 first-year germinants were still alive (Schwandt,



Three microsites in which whitebark pine has regenerated naturally. The down tree probably provides the best protection of these three.

pers. comm., 2008). Challenges encountered in the trials included seedling desiccation due to the site's hot, dry conditions, despite the placement of down logs as microsites; heavy shrub regeneration on some trial plots that made it difficult to locate germinants; and downhill movement of the microsite logs due to snow (Schwandt, pers. comm., 2008).

There are many questions yet to be answered about direct seeding of whitebark pine in the field. The results of several existing trials are not yet in, and more field trials are planned, including pair-wise comparisons between seeds and seedlings. Techniques will undoubtedly improve, and direct seeding may become an effective method for planting whitebark pine.

Thinning

Thinning in whitebark pine stands serves several purposes: the primary purpose is removal or reduction of competing vegetation to provide better growing conditions for whitebark pine; a secondary purpose is either reduction of fuel loading or increase in fuel loading, depending on what is desired for the stand on terms of fire. Thinning can also reduce the risk of mountain pine beetle infestation (see section on mountain pine beetle treatments). In a stand with good road access and sufficient marketable lodgepole pine, commercial thinning might be an option. However, in most whitebark pine habitat in the Pacific Northwest, remote locations and the absence of commercial timber species mean that most thinning to restore whitebark pine would be non-commercial thinning. Thinning can be designed to mimic the effects of low- and moderate-severity fire (Keane and Arno 2001), and, by reducing fuel loads and fuel continuity, may safeguard the stand by helping to prevent a future ignition from becoming a stand-replacing event.

Whitebark pine is a relatively shade-intolerant species—it is less tolerant of shade than most species with which it occurs except for lodgepole pine (Arno and Hoff 1990). Reducing competing vegetation allows whitebark pine greater access to sunlight, water, and soil nutrients. Keane et al. (2007) found that silvicultural thinning resulted in a significant increase in whitebark pine diameter growth. A typical thinning prescription calls for the removal of most or all non-whitebark pine trees—typically subalpine fir, but perhaps also lodgepole pine, Engelmann spruce, and other conifer species. Trees above a certain diameter, usually 17- to 20-cm (7- to 8-in) diameter at breast height (dbh), are girdled but left standing. To ensure that a girdled tree will be killed, girdling is done twice by using a chainsaw to cut completely through the cambium at a distance of about 20 to 30 cm (8 to 12 in) between girdling rings. Trees with smaller diameters are felled by hand with chainsaws. Whitebark pines should not be cut or girdled. An exception to this might be to remove an individual whitebark pine tree that is dying from blister rust, particularly if such a tree appears to be impeding the growth of a healthy whitebark pine. Occasionally other five-needle pine species occur with whitebark pine—western white pine most frequently, but possibly sugar pine and limber pine. Figure 3 shows the overlapping ranges of these species in Oregon and Washington. In the interests of retaining high-elevation five-needled pine species, all of which have been negatively affected by blister rust, no five-needle pines should be cut or girdled in a whitebark pine restoration treatment.

Treatment of slash resulting from a restoration thinning varies depends on the fire plan for the stand. If the goal is to safeguard the stand from fire, slash should be piled well away from living whitebark pines, and the piles burned under controlled conditions. Post-burning rehabilitation of the burned ground may include covering the burned patches with live soil, and scattering seed from local native plant species over the area. If the fire plan is to encourage low- to moderate-intensity fire by either prescribed or natural ignition, slash may be lopped and scattered. It may still be advisable to keep slash well away from whitebark pines to minimize scorch damage to them. However, slash that is left unburned after whitebark pine restoration thinning treatments may serve as habitat for increasing populations of the pine engraver (*Ips pini* Say) and red turpentine beetle (*Dendroctonus valens* LeConte). These increased populations may then attack and kill residual whitebark pines (Waring and Six 2005, Furniss and Carolin 1977). Fire damage increases the susceptibility of whitebark pine to mountain pine beetles and other insects (Waring and Six 2005; Jenkins, pers. comm., 2008).

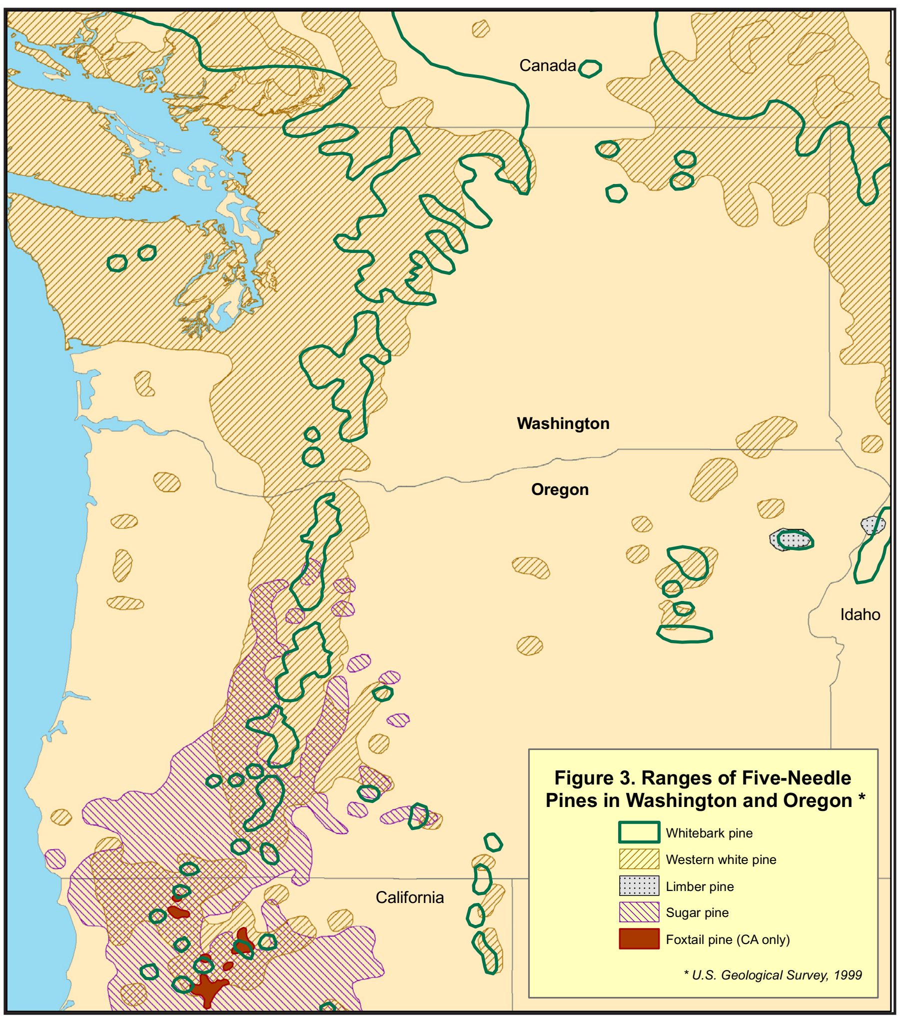


Figure 3. Ranges of Five-Needle Pines in Washington and Oregon *


Vince Novotny, USFS

Two sets of overlapping sawcuts were used to girdle competing conifers.

Mountain pine beetle treatments

Recently, mountain pine beetle (Dendroctonus ponderosae Hopkins) activity in whitebark pine has been increasing greatly throughout whitebark pine's range (McMillin 2006). Mountain pine beetle is a native insect that usually occurs at low-level, endemic populations in lower elevation pine forests, particularly in lodgepole pine. During an outbreak, populations increase to epidemic proportions and can cause widespread tree mortality. The insects can also move upward in elevation and attack higher elevation hosts such as whitebark pine. Global climate change may be contributing to the increase of mountain pine beetle activity in higher elevations (Logan and Powell 2001, Carroll et al. 2003, Campbell 2007).

Periodic mountain pine beetle outbreaks are part of the natural disturbance cycle of whitebark pine ecosystems. The extensive outbreak in the 1930s and 1940s left a legacy of whitebark pine "ghost forests" throughout the west (Logan and Powell 2001). With whitebark pine declining throughout its range because of blister rust (Tomback et al. 2001), the additional impact of mountain pine beetle is of substantial concern. An attacked tree will die within a single season. Although trees as small as 15 cm (6 in) in diameter are susceptible, mountain pine beetles preferentially attack larger diameter trees (Kegley et al. 2004), meaning that cone-bearing trees are especially at risk, as are larger-diameter rust-resistant candidate trees.

The use of verbenone is currently considered to be the best treatment for protecting whitebark pine from attack by mountain pine beetle at either the stand- or individual tree-level (Kegley et al. 2003, Bentz et al. 2005). Verbenone is an inhibitory, anti-aggregation pheromone that deters mountain pine beetles from attacking. This pheromone is a natural repellent produced by the insects themselves, possibly to indicate to other mountain pine beetles that a tree has been attacked and is already fully occupied.


Robin Shoal, USFS

Pitch tubes and frass on a whitebark pine bole are symptoms of mountain pine beetle attack.


Robin Shoal, USFS

A mature whitebark pine recently killed by mountain pine beetles.

Verbenone was initially registered (licensed for sale and distribution) in December 1999 to control southern pine bark beetles (U.S. EPA 2001). Before deciding on any verbenone treatment, it's a good idea to consult with a nearby USDA Forest Service Forest Health Protection entomologist or plant pathologist for information about product type and availability, timing, and other treatment planning considerations.

Verbenone is classified and regulated as a biochemical pesticide. Because of this classification, proposals that include the use of verbenone may be subject to extensive National Environmental Policy Act (NEPA) documentation. Biochemical pesticides are naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pest. Biochemical pesticides include substances, such as insect sex pheromones, that interfere with mating, as well as various scented plant extracts that attract insect pests to traps (U.S. EPA 2008).

A study in central Idaho found that mountain pine beetle attacks increased with stand densities as well as with individual tree diameter (Perkins and Roberts 2003). Thinning to reduce competition in whitebark pine stands might also reduce the risk of mountain pine beetle attack by removing lodgepole pine and reducing overall stand density.

Aerial application

Verbenone is applied in two ways: a flake form can be applied aerially to entire stands, and verbenone pouches are used to protect individual trees. The flakes can also be mixed with water and a tackifier and sprayed directly on to the trunks of individual trees (Gillette et al. 2006). The aerially applied flake form has been successful in reducing attacks in lodgepole, ponderosa, and whitebark pine (Gilette et al. 2006, Erbilgin et al. 2007, Hansen and Gillette 2007). While this technique has not been widely used in whitebark pine, it may be an efficient way to treat remote stands that are difficult to access by land (Kegley, pers. comm., 2008). A drawback to the aerial flake technique is that the flakes are polymer-based and not readily biodegradable, although the company that produces the flakes is working on a biodegradable formula (Mehmel, pers. comm., 2008).

Verbenone flakes were applied aerially to a whitebark pine stand near Bryan's Butte on the Okanogan-Wenatchee National Forest in 2007. The results of this treatment are not yet clear—there was some apparent effectiveness but the application may have been too early or too light. Effectiveness is easier to determine in individual tree treatments using verbenone pouches (Mehmel, pers. comm., 2008). Stand-level verbenone treatments are expensive, and are not yet fully proven to be effective for whitebark pine; individual tree treatment is a more proven strategy (Schwandt, pers. comm., 2008).

Therese Ohlson, USFS

The little white squares are verbenone flakes from an aerial treatment (pencil is included for scale).

Chris Jensen, USFS

Verbenone pouch used as individual tree protection treatment.

Pouch application

For individual tree treatment, verbenone pouches are attached directly to the selected whitebark pine trees with staples or nails. Pouches are attached about 3 m (10 ft) above the ground. Good results have been obtained by using two pouches stapled to each tree, on opposite sides of the bole (Kegley et al. 2003). The potentially long flight period of mountain pine beetles might suggest the efficiacy of two applications per season, one in early June and a replacement application in late July (Kegley et al. 2003). If there is mountain pine beetle activity in an area, individual tree treatment may be indicated in order to protect valuable cone-producing trees, trees that are known or suspected to be resistant to blister rust, or trees that are currently being tested for blister rust resistance.

When verbenone is intended as an area treatment rather than as an individual tree treatment, distributing the pouches throughout the stand at regular gridded intervals of 10 to 12 m (35 to 40 ft) might provide the most effective stand-level protection by creating a pheromone "plume." Proponents suggest that it is more important in this case that the pouches be evenly distributed than that they be applied exclusively to large-diameter whitebark pines (Mehmel, pers. comm., 2008). Bentz et al. (2005) found that 40 verbenone pouches applied in a grid fashion to 0.40-ha (1-ac) plots was an effective stand-level treatment in whitebark pine. Snags, other vegetation, or stakes can be used to achieve the correct spacing.

There are several sizes of pouch, and product improvement is continually underway. For either stand-level or individual tree treatments, the Wenatchee Service Center uses 7.5-g (0.26 oz) pouches, the largest pouch size currently available, and applies a single treatment of two pouches per tree. There is no rush to get the pouches out early in the season, because applying them shortly before the beetles start flying is the most effective timing (Mehmel, pers comm., 2008).

Pruning

Pruning has been used in commercial plantations of economically important five-needle pines (western and eastern white pine, and sugar pine). For western white pine, the removal by pruning of all lower branches to about 2.5 m (8 ft) up the bole can reduce blister rust mortality by half (Schnepf and Schwandt 2006). In western white pine, blister rust cankers typically occur on lower branches, with fewer infections establishing on upper branches. In whitebark pine, however, blister rust infections tend to occur throughout the tree, with no apparent pattern of higher infection rates on lower branches. The model of removing lower branches to reduce blister rust risk and mortality therefore does not apply well to whitebark pine, although in some cases removal of infected branches may be a useful tool for prolonging the lives of individual whitebark pine trees.

A stand in which pruning could be beneficial might be a small, isolated stand with few cone-bearing trees and no existing seed source that could be used for restoration planting. If this stand represents a unique ecological or aesthetic resource (say, at a popular ski area or campground), then pruning branches with blister rust cankers might be a good tool to retain live trees on the landscape, increase the stand's cone-bearing and regenerative potential, and provide ongoing recruitment of young trees as material for natural selection for blister rust resistance.

Pruning should be done by hand, with shears, loppers, or a small pruning saw. It is recommended that the branch collar should be left on the tree to leave a smaller wound. Care should be taken to minimize accidental damage to the tree. If a saw is used, making a small undercut from the bottom before cutting the branch from the top will keep the bark from peeling down the bole when the branch is cut. As with western white pine, cankers that are closer than 4 inches to the bole of the trees are probably non-prunable. It is likely that these cankers have already advanced into the bole, and pruning the branch will not remove the infection (Schnepf and Schwandt 2006).

Pruning infected branches from large trees is probably both impractical and unnecessary; these trees can live a long time with branch infections. Cankers on small seedlings should be considered non-prunable; by the time a canker on a seedling is large enough to be visible to an observer it is probably already lethal. However, removal of a cankered branch from a young tree (larger than seedling size) might provide a great benefit to the tree, because smaller diameter trees are more quickly killed by blister rust. Furthermore, the cankered branches of small trees are also more visible, more accessible, and easier to prune than on large trees. Thus, a good candidate for pruning would be an otherwise healthy small-diameter tree that is well-established, has only a few cankers (and those all at least 4 inches from the bole), and whose branches are all readily accessible for pruning from the ground with loppers, a handsaw, or a pole pruner.

Although it may extend the lives of individual trees, pruning to remove infected branches does not change the resistance of the pruned trees or the overall stand to blister rust (Schoettle and Sniezko 2007). Pruning may in fact be detrimental in the long run, if it slows the process of natural selection for blister rust resistance by keeping non-resistant individuals alive and reproducing longer (Hadfield, pers. comm., 2008). That being said, in a stand with high blister rust incidence, trees that clearly show apparent resistance to the disease—trees with no or noticeably fewer cankers or whose cankers appear inactive or dead—may be the most resistant trees in the stand. Removing prunable cankers from such trees might increase their chances of surviving to cone-bearing age and becoming important seed sources for natural regeneration, blister rust resistance testing, and restoration plantings.

A different reason for pruning might be to protect individual high-value trees from damage during low-intensity ground fires. An example here might be a cone-bearing tree with known blister rust resistance. Removing low or ground-sweeping branches from such a tree might reduce the possibility that those

Robin Shoal, USFS

A prunable canker on a young whitebark pine tree.

Robin Shoal, USFS

This canker is too close to the bole of the tree for pruning to be effective.

branches would serve as ladder fuels to carry fire up into the crown. In such a case, the pruned branches and all other slash and potential fuels should be removed from the vicinity of the tree and either lopped and scattered or piled and burned. This type of pruning of pre-identified high-value trees to safeguard them from fire could be readily incorporated into a thinning treatment.

Fire management

Fire is a natural component of whitebark pine ecosystems (Agee 1993, Arno 2001). Low- and moderate-intensity fires reduce competition from later seral conifers, shrubs, and dense grasses; such fires can also keep fuel loads low. High-intensity fire creates open areas in which whitebark pine can successfully regenerate. Whitebark pine is considered fire-dependent in fire-prone portions of its range, especially in the inland northwest and the Rocky Mountain region in particular. Where whitebark pine is fire-dependent, absence (exclusion) of fire due to active fire suppression has led to replacement of whitebark pine by more shade-tolerant conifer species, and has reduced regeneration opportunities for whitebark pine (Keane et al. 2002, Kendall and Keane 2001). Fire suppression can also lead to unnaturally high fuel loads, which increases the risk of widespread, high-intensity fires. Restoring and maintaining natural fire regimes is an important management action that can be taken to conserve whitebark pine in these areas (Keane and Arno 2001). In the Rocky Mountains, where extensive stands of whitebark pine forests occur in montane habitat, management-ignited (prescribed) fire is used as a whitebark pine restoration technique (Keane et al. 2000, Keane and Arno 2001).

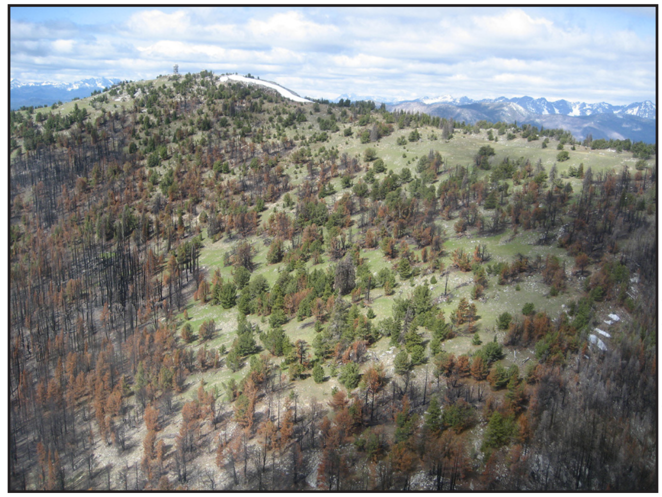
In the Pacific Coast portion of its range, where whitebark pine is both less extensive and more closely associated with subalpine habitat, the exclusion of fire from whitebark habitat is of less concern (Keane, pers. comm., 2008). East of the Cascade Crest, natural ignitions in whitebark pine habitat are fairly frequent. Because most of this territory is either in wilderness or otherwise remote, there is very little wildland-urban interface involved and therefore little cause for active fire suppression. In the wetter regions near and west of the Crest, fire is uncommon. In both situations, the open character of the subalpine habitat provides ample territory for successful whitebark pine regeneration, provided there is a healthy seed source within nutcracker caching range—up to 30 km (18 mi) (Lorenz and Sullivan, in prep.), but ideally much closer (Lorenz, pers. comm., 2008).

Reported fire return intervals in subalpine forests east of the Cascades range from 29 years to 250 years (Agee 1993). Siderius and Murray (2005) found highly variable fire return intervals in 55 whitebark pine stands: 10 to 196 years in the Washington Cascades, with generally shorter intervals farther east of the Crest; and 39 to 142 years in the Oregon Cascades. Fire intensity also varied, with high severity, stand-replacing fires occurring about every 100 to 200 years, and low severity fires occurring at intervals ranging widely from 9 years to about 70 years.

When an ignition occurs in upper subalpine whitebark pine habitat, where stands are typically patchy and understory fuels are discontinuous, the fire is likely to remain both localized and of low to moderate severity. Whitebark pine is somewhat more resistant to fire than its later seral competitors (Agee 1993), so low-to-moderate-severity fire is likely to benefit whitebark pine by reducing competing vegetation and keeping fuel loads low. If some of the cone-bearing whitebark pine trees within a stand are damaged or killed, seed from other mature trees within the stand or in nearby stands will be available to support whitebark pine regeneration on the burned site.

Although fire can thus be beneficial for whitebark pine, too much fire can be detrimental. Many fires in whitebark pine habitat originate from below. Large high-severity fires—such as the 2006 Tripod Complex Fire on the Okanogan National Forest in Washington's northeast Cascades and the 2003 B & B Complex Fire on the Deschutes National Forest in the Oregon Cascades—have the potential to severely reduce or even eliminate cone-bearing whitebark pine across an extensive landscape. Subalpine fir is highly flammable, and a fire that moves into the crowns of this species is likely to be stand-replacing, especially

A smoke plume from a large fire several ridges away from this whitebark pine habitat.



A whitebark pine stand partially burned in the 2006 Tripod Complex Fire.

where subalpine fir is relatively dense or within mature subalpine fir "islands" (Uchytil 1991). If they become plume-dominated, these crown fires are capable of sending sparks and cinders over distances in excess of a mile; resulting in additional ignitions (Bentley, pers. comm., 2008). Should the fire become intense and widespread enough that most or all cone-bearing whitebark pines within the fire perimeter are killed, seed from unburned stands within nutcracker caching range may be available to regenerate whitebark pine in the burned area. If there is no such seed source, natural regeneration of whitebark pine will be extremely slow, or may not occur at all. Planting is the only tool available for restoring whitebark pine after these large, severe fires.

While, as noted earlier, thinning is an excellent technique to reduce competition in individual whitebark pine stands and may reduce the risk of intense fires in selected high-value stands, wildland fire use (see box for definition) is a good instrument for returning and maintaining natural fire regimes in whitebark pine habitat in Oregon and Washington (Keane 2003; Murray, pers. comm., 2008; Harrod, pers. comm., 2008). Wildland fire use is likely to be both easier to implement and less expensive than either thinning or management-ignited (prescribed) fire, although the implementation of wildland fire use is opportunistic so the locations, timing, and fire intensity cannot be predicted. This puts high-valued whitebark pine stands at higher risk if fuels have not been treated prior to a fire event. Pretreatment of accumulated fuels in or near whitebark pine stands may be less damaging to the whitebark pine resource than either management-ignited fire or wildland fire use.

Forest-level plans for both management-ignited fire and wildland fire use are revised annually. An essential, pro-active restoration action for whitebark pine is to explicitly insert whitebark pine as a resource to be considered in fire plans, which should include both general guidance for fire activities and decision-making in whitebark pine habitat, as well as specific guidance for the implementation of desired fire practices in whitebark pine (Harrod, pers. comm., 2008).

Plans for management-ignited burning and treatments to reduce fuel loads in lower elevation forests surrounding whitebark pine habitat thus should specifically consider protection of the significant resources represented by high-value whitebark pine stands:

- Stands that are known or suspected to have relatively high levels of resistance to blister rust;
- Isolated stands that are locally or genetically unique;
- Productive cone-bearing stands, especially where there are no other seed sources; or
- Cone-bearing stands within the North Cascades Grizzly Bear Recovery Area.

> "Wildland fire use is the management of naturally ignited wildland fires to accomplish specific prestated resource management objectives in predefined geographic areas outlined in Fire Management Plans."
>
> *Source: U.S. Forest Service. n.d. Fire Use. http://www.fs.fed.us/fire/fireuse/index.html*

Managing wildfire over time to promote the creation of a landscape mosaic made up of different aged stands in lower elevation forests will also benefit whitebark pine (Harrod, pers. comm., 2008). The younger forest stands may also serve as effective fuel breaks for several decades post-fire, reducing the potential for fire spread into upper elevation habitats. This same landscape mosaic will also break up the homogeneity of the forest structure and potentially reduce the size and extent of mountain pine beetle outbreaks.

Global climate change is believed to be driving the current trend toward longer and more intense fire seasons in the western United States (Westerling et al. 2006). Ironically, in terms of long-term species survival, whitebark pine may currently be at a point of lowered fire tolerance because of the impacts of blister rust and recent high levels of mountain pine beetle activity within whitebark pine and adjacent lodgepole pine (Kurth, pers. comm., 2008). Managers who are considering management-ignited fire as a whitebark pine restoration technique are advised to proceed cautiously and not rush to actively reintroduce fire to whitebark pine ecosystems in the Cascades (Murray, pers. comm., 2008). The following recommendations for managing fire in the Cascade Range are adapted from Murray (2008):

- Promote fire as a natural element of whitebark pine forests when fuel loading and stand structure will support low- to moderate-intensity fire.
- Support lightning-ignited fires (wildland fire use).
- Work with pathologists to identify and protect blister rust-resistant trees.
- Plan prescribed burns based on site-specific fire regime.
- For fire-based treatments, stands with historically frequent low- and moderate-severity fires should receive highest priority.

In addition, the following two recommendations also apply:

- To reduce the potential of future stand-replacing fire events, prioritize and actively manage whitebark pine stands that are highly valued because of geographic location, recent fire survival success, or importance as cone collection sites.
- Carefully consider mountain pine beetle activity in adjacent areas and whether a management-ignited fire might attract beetles into a post-fire whitebark pine stand. Waring and Six (2005) found that mountain pine beetle attack increased the first several years after a management-ignited fire treatments.

Assessing Whitebark Pine Habitat for Stand-Level Restoration and Conservation Needs

The restoration strategy (Aubry et al. 2008) identifies whitebark pine conservation areas and management units on National Forest System lands across the range of whitebark pine in Oregon and Washington. Based on information from local and regional sources, the strategy reviews conditions within those management units, proposes management actions for each unit, and identifies the top ten management units in need of planting. In the region-wide habitat assessment undertaken for the strategy, it also became clear that there are many management units for which there is little specific information about the extent and condition of whitebark pine. Consequently, the strategy also identifies the top ten management areas that are in need of surveys to determine the condition of whitebark pine. Two resources for designing and conducting surveys are the core data attributes for whitebark pine surveys (Shoal and Aubry 2006), and the Whitebark Pine Ecosystem Foundation's methods for surveying and monitoring whitebark pine (Tomback et al. 2005).

The analysis in the restoration strategy stops at the management unit scale. Finer-scale decisions about which stand or stands within each unit to treat, which treatments to use, and how to implement them are up to local managers. It is anticipated that silviculturists, ecologists, biologists, botanists, entomologists, plant pathologists, wilderness and recreation managers, fire and fuels specialists, and interested others will work together to develop site-level proposals and prescriptions.

This land managers guide identifies six primary techniques for conserving and restoring whitebark pine ecosystems: cone (seed) collection, planting, thinning, mountain pine beetle treatments, pruning, and fire management. Decisions about which stands to restore, which restoration treatments to implement, and how to implement them are not difficult, but they are also not especially formulaic; each whitebark pine stand presents a unique set of logistical and ecological considerations that, taken in combination, will indicate which treatment types are likely to be both effective and feasible.

Logistical considerations

- Whether the stand is in designated wilderness
- Size of the stand or habitat patch
- Method and ease of access
- Geographic isolation
- Previous management investments
- Seed or seedling availability (existing seed inventory)
- Inclusion of whitebark pine in fire plans
- Existing knowledge and available information about the current conditions in the specific stand and its vicinity

Ecological considerations

- Fire history
- Mountain pine beetle activity
- Blister rust infection and resistance: stand level and individual tree level
- Stand composition (whitebark pine dominant or mixed-species)
- Whitebark pine demographics (even-aged or having a range of size and age classes)
- Presence of high-value whitebark pine trees such as rust-resistant candidates and designated seed-source trees
- Grizzly bear and other threatened, endangered, and sensitive species (TES)

Logistical considerations (including economics and policy)

- **Wilderness sites.** Wilderness management policy will influence treatment and/or implementation options within congressionally designated wilderness. Generally, management of ecosystem processes in wilderness uses a non-manipulative approach with the goal being to allow for the free play of natural processes. However, when a non-native organism (such as white pine blister rust) or some other anthropogenic factor (such as the human contribution to global climate change) alters ecological processes, this goal is put to the test. If treatment of a wilderness site is believed to be necessary, a good tool for guiding proposal and implementation decisions is the Minimum Requirements Decision Guideline (MRGD), available at http://www.wilderness.net/index.cfm?fuse=MRDG.
- **Stand or site size.** All else being equal, treating larger stands will be more cost-efficient and will probably have greater benefits than treating small stands.
- **Access.** In general, the more accessible a site is, the easier (and less expensive) it will be to treat. However, if the perceived (that is, public) value of a successful restoration project will be considerably higher in a less accessible stand, then that stand may be a strong candidate for restoration.
- **Geographic isolation**. Isolation of a potential restoration site is extremely important. If the stand or site is truly geographically isolated—the only whitebark pine community or habitat for many miles around (an extreme example being the small population in the Olympic Mountains)—then the stand should be given high priority when considering where to implement treatments. Such truly isolated stands are more vulnerable to disturbance, and are less likely to be replaced by new regeneration (Morgan and Murray 2001). However, if a stand is only relatively isolated within a management unit—beyond observed nutcracker-caching distance from other seed

sources, up to 30 km (18 mi) (Lorenz and Sullivan, in prep.)—but there are other stands available for treatment, that relative isolation may count against the stand if resources (funds and personnel) are limited and treatment in one of the other stands in the unit is likely to provide broader ecological benefit.

- **Previous management investments.** If previous successful investments such as cone collections, rust-resistance testing, restoration work, mountain pine beetle treatments, or research have been made in a stand, then the stand may warrant higher consideration for restoration treatment than a comparable stand that has never been treated. In fact, the untreated stand may serve as a control or comparison for experimental or monitoring purposes.
- **Inclusion of whitebark pine in fire plans.** If there is a fire plan that sufficiently addresses fire management in and for whitebark pine habitat, there may be little need for additional consideration of fire or fuels treatment beyond what is called for in the plan. If the fire plan does not adequately address whitepark pine, such information should be included when the plan is next revised.
- **Existing knowledge and knowledge gaps.** If knowledge of current conditions is available for some stands but lacking for other areas within the management unit, then considering treatments for stands for which information does exist should not be automatically postponed in favor of surveying the other areas.
- **Available information.** Sources of readily-available information include (but are certainly not limited to) continuous vegetation survey (CVS)/Forest Inventory and Analysis (FIA) plots, area ecology plot databases, stand exams, annual aerial insect and disease detection surveys, fire mapping, aerial photos, and seed inventory and rust-resistance data from the Dorena GRC. Local knowledge embodied in district-level Forest Service personnel, including wilderness rangers, is invaluable. Volunteers and local groups (for example, stock-packing groups, trails associations, mountaineering groups, and ecologically savvy hikers and campers) also are usually happy to observe and report on specific conditions; such volunteers can be particularly effective if given a small amount of training and straightforward field forms to fill out.

Ecological considerations

- **Fire history and mountain pine beetle activity.**
  - If fire has occurred within or near a whitebark pine stand within the past 3 or 4 years, the susceptibility to mountain pine beetle attack is heightened for surviving mature whitebark pines (Waring and Six 2005; Mehmel, pers. comm., 2008; Murray, pers. comm., 2008).
  - Fires that have occurred in lower elevation lodgepole pine forests are likely to provide effective fuel breaks for several decades if the burned area is between an ignition source and whitebark pine habitat (Harrod, pers. comm., 2008). However, in conditions of severe drought these young stands may be highly flammable (Keane, pers. comm., 2008).
  - Past activity of mountain pine beetle in adjacent lodgepole pine stands creates heavy fuels and increases potential loss of upslope whitebark pine to fire.
  - Increased mountain pine beetle activity in adjacent lodgepole pine stands increases the risk that the insects will move upslope into whitebark pine.
  - If little or no mountain pine beetle activity has been detected in the vicinity in the past 4 years, short-term risk to whitebark pine is minimal (Mehmel, pers. comm., 2008).
  - The Forest Service Region 6 aerial insect and disease detection surveys are a good source of information for assessing recent and previous mountain pine beetle activity in the vicinity of whitebark pine stands.
- **Blister rust infection and resistance: stand level and individual tree level.** These high-medium-

low blister rust infection levels are used by the U.S. Forest Service Forest Health Protection Southwest Oregon Service Center for all five-needle pines, and are based on experience with western white pine and sugar pine. This break out reflects the differences observed for highly susceptible unimproved stock, stock with some resistance, and highly resistant stock (such as the best improved stock) (Goheen, pers. comm., 2008).

- ♦ High levels of blister rust infection in a stand (50 percent or more of the whitebark pine trees have at least one blister rust canker) result in increased mortality, loss of cone production, and reduced regeneration potential. Surviving individual trees that are relatively healthy may be good candidates for blister rust resistance testing (Mahalovich and Dickerson 2004). Planting may be a good restoration method for such stands, especially if seed production is severely reduced and there are few living young trees in the stand.
- ♦ Medium levels of blister rust infection (11 to 49 percent) in a stand may suggest some relative degree of stand-level blister rust resistance, particularly if there are high levels of rust infection in the vicinity. However, topography and localized climatic conditions can also cause blister rust rates to vary greatly between nearby stands (Petrick, pers. comm., 2008; Quick 1962). Contact a Forest Health Protection plant pathologist for assistance with risk rating of sites for blister rust.
- ♦ Low levels of stand-level blister rust incidence (from none to 10 percent) across a large area may indicate resistance, but it is more likely that the prevailing climate is simply too dry to allow successful infection of whitebark pine needles by blister rust spores, a process that requires prolonged periods of high humidity. This is probably the case in southern Oregon. These stands are good candidates for pro-active conservation strategies that will increase resilience to current and future insect outbreaks and inevitable blister rust incursion (Schoettle and Sniezko 2007). Treatments include thinning, fuel reduction, seed collection, rust resistance testing, and planting to increase age-class diversity.

► **Stand composition**

- ♦ Open, whitebark pine-dominated stands have the greatest potential for long-term cone production and are high-priority candidates for conservation and restoration.
- ♦ Whitebark pine in mixed stands may benefit from thinning to reduce competition from other conifer species. Removal of lodgepole pine from these stands may also reduce the risk of mountain pine beetles attacking whitebark pine.
- ♦ Krummholz stands are not likely candidates for restoration treatments. However, these stands may prove important to the long-term survival of whitebark pine under warming climatic conditions (Millar 2007).
- ♦ Sites that exhibit adequate regeneration and multiple size classes indicate good growing conditions and a consistent local seed supply. Planting is probably not needed. These may be good sites for cone collection.
- ♦ In the case of a blister rust-infected, high-value, geographically isolated stand with no nearby alternate seed source for natural regeneration, pruning to remove blister rust cankers and/or thinning to decrease competition may slow the loss of whitebark pine and buy time for natural selection for blister rust resistance, and eventual within-stand cone production.

► **Whitebark pine demographics and high-value trees**

- ♦ Stands with greater demographic diversity (a mix of whitebark pine tree ages) will be more resilient in the face of mountain pine beetle outbreaks (Schoettle and Sniezko 2007). Emphasize promoting age-class diversity in restoration activities.
- ♦ Individual high-value trees and stands warrant extra safeguarding. Examples include existing healthy cone-bearing trees, known or potentially

rust-resistant trees, geographically isolated populations, and scattered trees and stands that have survived an extensive fire.

- **Grizzly bear and threatened/endangered/ sensitive species concerns**
  - Any whitebark pine restoration treatment that is likely to result in increased cone crops is indicated for whitebark pine habitat in the North Cascades Grizzly Bear Management Unit (all habitat in the Washington Cascades north of Snoqualmie Pass and Interstate I-90).
  - Whitebark pine restoration treatments that will also benefit other threatened, endangered, and sensitive species may receive higher forest-level priority (as well as opportunities for greater funding).

Identifying high-priority stands for planting

The restoration strategy identifies conservation areas and management units in which planting is recommended. In many of these units there are several stands that would benefit from planting. Here are criteria to consider for prioritizing stands for planting within a conservation area or management unit:

Criterion	Priority considerations
Within Grizzly Bear Recovery Area	Highest priority.
Identified as a priority site for planting in the restoration strategy	Highest priority.
Within designated wilderness	Analyze the need to plant using the Minimum Requirement Decision Guide (MRDG), available at http://www.wilderness.net/index.cfm?fuse=MRDG. Access, policy, and logistical considerations may make planting in comparable non-wilderness stands more feasible.
Accessibility	Prioritize areas with easiest access by road.
Previous management investments	Prioritize sites where cone collection or other whitebark pine management activities have already taken place.
Stand size	In general, treat larger stands first.

Restoration scenarios

Here are a few hypothetical but entirely likely scenarios.

Scenario 1

Conditions: A large, high-intensity wildfire recently burned through several thousand acres of subalpine habitat that contained a number of mature, cone-bearing whitebark pine stands. There is a moderate level of mountain pine beetle activity in the surrounding vicinity—mostly in lodgepole pine but also in some of the whitebark pine. Although no formal surveys have been conducted to assess blister rust levels, CVS/FIA and ecology plot data, as well as informal observations by district personnel, indicate that before the fire, white pine blister rust was present on at least ten percent of the live whitebark pines in the area. For some of the existing whitebark pine stands, the recent fire was a stand-replacing event. Other stands experienced lower severity burns, which killed most of the small-diameter whitebark pine trees and charred many of the older trees. Only one stand completely escaped the fire. Before the fire, no single stand was farther than 30 km (18 mi) from at least one other cone-bearing stand; now there are several gaps in this seed-dispersal continuity. The overall area is relatively rugged, although there is good trail system along the ridges, and most of the whitebark pine stands are within 5 km (3 mi) of a drivable road.

Implications: Whitebark pine regeneration potential in the burned area has been reduced by the combined impacts of the fire, blister rust, and mountain pine beetle. Large-diameter whitebark pine trees that were damaged but not killed by the fire are at an increased risk of being killed by mountain pine beetle within a few years, further diminishing the local seed source. Those stands that are now outside of realistic nutcracker-caching distance from a seed source are unlikely to experience any significant whitebark pine regeneration in the near future. Blister rust levels are low to moderate, indicating that prevailing climatic conditions are probably keeping the disease somewhat in check. This being the case, it will be difficult to identify potentially rust-resistant individual trees in the field.

Actions: An general strategy for this area would be to protect the remaining whitebark pine seed source and supplement natural regeneration by planting whitebark pine seedlings. All the burned stands are candidates for planting, particularly those stands farthest from the residual whitebark pine seed sources. Planting prescriptions should take into account that some of the seedlings will probably succumb to blister rust. Whitebark pine trees of cone-bearing size that survived the fire should be considered for cone collection to augment any existing seed collections already in storage. Stand-level verbenone treatment might protect the unburned stand from mountain pine beetle, and individual tree-level treatment might protect surviving large-diameter trees in the burned stands.

Scenario 2

Conditions: A small, geographically isolated whitebark pine stand lies within 2 km (1.25 mi) of a state highway. There is a popular ski resort nearby that is open year-round for skiing, hiking, dining, and general tourism. Historically, this area experienced stand-replacing fires on an average interval of 90 years, and fires of lesser severity about every 35 years. For many decades, all fires in the vicinity have been suppressed; now subalpine fir is out-competing the whitebark pine. There is currently no mountain pine beetle activity in the area. A recent survey found that 42 percent of the living whitebark pine trees in the stand were infected by white pine blister rust. Whitebark pine cone crops are dwindling because of competition from subalpine fir and topkill due to blister rust. Whitebark pine regeneration is extremely sparse—most living whitebark pines are 23 cm (9 in) or larger in dbh.

Implications: In the continued absence of disturbance, this stand will continue to decline. Given the close proximity of the wildland-urban interface, it is unlikely that fire would be allowed to burn here. There is no immediate concern about mountain pine beetle, although with its predominance of large-diameter trees the stand would be highly vulnerable if mountain pine beetle activity in the vicinity were to increase. Blister rust incidence is high enough that potentially rust-resistant individual trees may be identifiable in the field.

Actions: A restoration strategy for this stand would include cone collection, pruning blister rust-infected branches from high-value individual trees, thinning to reduce competition from subalpine fir, and post-thinning planting of whitebark pine seedlings. Seedling mortality due to blister rust may be high, so the planting prescription should include sufficient seedlings to compensate for losses. Burning slash piles will improve the area's visual quality and reduce fuels, also reducing potential for human caused ignitions in this high-use area. Cone collections should address all three cone collection purposes: gene conservation, operational collection, and blister rust resistance testing. Mountain pine beetle activity in the vicinity should be monitored; stand-level verbenone treatments could be implemented quickly if the potential for beetle infestation of this stand develops. The high visibility of this project area provides an opportunity for interpretive signs and public education about whitebark pine and subalpine ecosystems. It's likely that local volunteer groups could be recruited to plant seedlings and monitor their growth and survival.

Scenario 3

Conditions: Aerial insect and disease surveys show that mountain pine beetle activity is increasing rapidly in a dense lodgepole pine forest on a southwest-facing slope deep within a congressionally designated wilderness area. The lodgepole pine becomes mixed with whitebark pine in an increasingly open forest at higher elevations, and many of the large-diameter whitebark pine in this mixed stand also have been recently killed by mountain pine beetle. There is an approximately 150-ha (400-ac) low-density stand of whitebark pine dispersed throughout rocky subalpine habitat above the beetle-infested area. This stand has a diverse mix of age classes, from ankle-high seedlings to mature cone-bearing trees. Blister rust incidence in live whitebark pine in the area is low—about 6 percent. There are a number of old "grey ghost" whitebark pine snags in the stand, presumably a legacy of the widespread mountain pine beetle epidemics in the 1930s and 1940s. A late-season, lightning-ignited fire burned across an adjacent ridge 10 years ago, killing most of the trees along that ridge; whitebark pine is regenerating well in the burned area. The entire area is remote, accessible only by foot by way of a steep, 10-mile trail.

Implications: The current increase in mountain pine beetle activity both locally and region-wide and the fact that some whitebark pines in this particular area have already been attacked indicate that additional mortality of whitebark pine in this stand from mountain pine beetle can be expected in the near future. The old whitebark pine snags are evidence that this stand has survived mountain pine beetle outbreaks in the past. The stand is not significantly affected by blister rust, and there is little competing vegetation to hinder regeneration. The only immediate threat is the increasing activity of mountain pine beetle, but the stand's age-class diversity is high, and the younger cohorts in the stand are likely to survive a beetle epidemic; if most of the cone-bearing trees are killed, there may be a 10- to 20-year lull in local cone production while the younger trees mature.

Actions: No restoration action is currently indicated for this stand. Given the high level of resilience present in the current stand, verbenone treatment is probably unnecessary. Also, the stand's location within wilderness boundaries lowers its priority for restoration relative to similar stands outside of wilderness (Aubry et al. 2008). Cone collection is definitely an option, but the area's remoteness makes collecting cones logistically impractical, especially because there are other (and perhaps larger), more readily accessible cone-bearing stands in the conservation area. This wilderness stand provides an opportunity to monitor mountain pine beetle impacts in a relatively intact whitebark pine forest; natural regeneration and seedling survival after fire could be monitored along the adjacent burned ridge.

Case Studies

On-the-ground whitebark pine restoration is a relatively new practice for Pacific Northwest Region forests. Here are brief case studies of four projects—several plantings and two thinnings—that have been implemented on four different forests.

Case Study 1: Planting seedlings on the Colville National Forest, northeastern Washington

Several small out-plantings of whitebark pine seedlings have taken place in the Selkirk and Kettle Crest Mountains on the Colville National Forest in northeastern Washington. The projects described here were opportunistic plantings using excess seedlings from lots grown for testing purposes at either the Dorena GRC or the Coeur D'Alene Nursery.

Salmo Mountain

Approximately 150 seedlings were planted near the Salmo Mountain Lookout on the Colville National Forest in 2003. The seedlings— planted by two Forest Service employees and one volunteer—were scattered in protected microsites throughout an open stand of mixed whitebark pine and subalpine fir. Informal observations indicate that 4-year seedling survival is about 50 percent. The seedlings were very small when planted and, as a result of soil creep, some were even shorter after their first year. Survivors have grown only an inch or so in 4 years (DeSpain, pers. comm., 2008).

Tom Despain, USFS

One of the whitebark pine seedlings planted on Salmo Mountain. The seedling tags were pinned to the ground near the planted seedlings to help with relocation for monitoring.

Another 100 to 150 seedlings were planted that year along the Kettle Crest near Sherman Mountain. First-year survival was about 70 percent. Soil creep is not as much of an issue here but, like the seedlings planted near Salmo Mountain, after several years these show little height growth (DeSpain, pers. comm., 2008).

Olson Peak

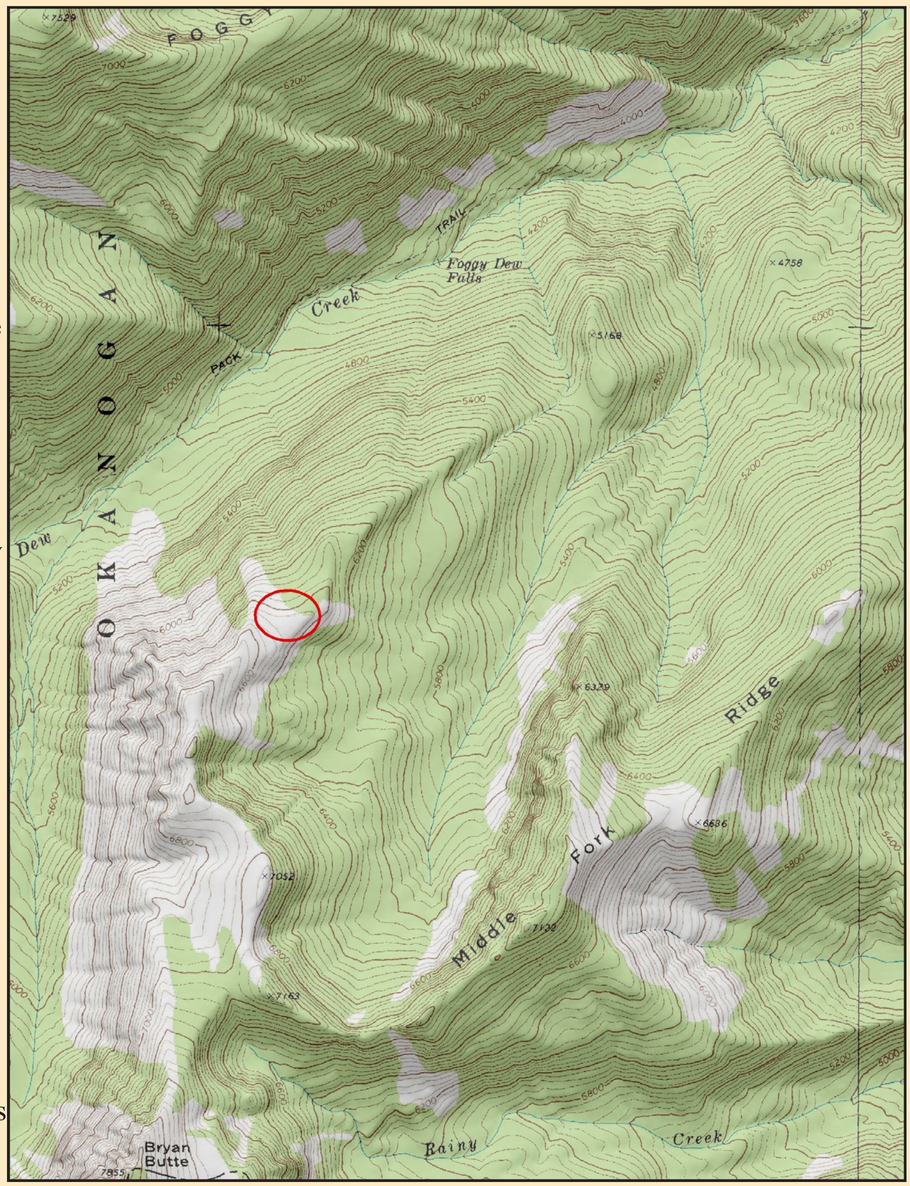
In 1997, a small experimental planting was established on Olson Peak, in an area that had burned in 1994. This site is at 1,700 m (5,600 ft) in elevation—some 120 to 150 m (400 to 500 ft) lower than the lower limit of whitebark pine in the Selkirk Range—so whitebark pine would probably occur only as an early seral pioneer species at this site. One hundred thirteen seedlings were planted on an 8-ft spacing, in three rows running up and down the slope. The trees were very small when planted, and some early mortality occurred when seedlings were covered by soil as a result of nearby animal activity. In 2006, 9 years after planting, survival was good at approximately 76 percent, and some saplings were over 1 m (40 in) tall (Haas, pers. comm., 2008).

Case Study 2: 1992 Foggy Dew thinning treatment on the Okanogan National Forest, north-central Washington

The Foggy Dew project was a precommercial thinning treatment of one half of a 6-ha (15-ac) stand on the Okanogan National Forest, in the Sawtooth Ridge system north of Lake Chelan. The treatment took place in September 1992. The stand, located at 1,965 m (6,440 ft) in elevation on a northerly aspect, was approximately 40 years old at the time and was composed primarily (over 50 percent) of whitebark pine in the sapling to small pole size classes. Other species present in the stand were subalpine fir, Engelmann spruce, lodgepole pine, and subalpine larch.

The objective of the treatment was to manage whitebark pine silviculturally to produce cones as a wildlife food source. The stand management prescription called for a best tree thinning from below to an average of 1,112 trees per ha (450 trees per ac). This was not a restoration thinning intended to specifically remove competition from whitebark pine, but rather a stocking control thinning intended to reduce overall stand density while retaining some tree species diversity. Species in order of leave tree preference and stocking were whitebark pine (50 percent), Engelmann spruce (20 percent), subalpine fir (20 percent), and lodgepole pine/subalpine larch (10 percent). The unthinned stand was left to serve as a control. The prescription was fairly conservative, allowing for additional thinning in 20 to 40 years. A crew of five completed the treatment in 3 days.

This project has not been regularly monitored. The 2001 Rex Creek Fire came within several miles of the stand. Recent surveys in nearby stands have recorded blister rust rates of 14 to 57 percent (no blister rust was observed in the Foggy Dew stand itself at the time of the thinning treatment), and aerial insect and disease surveys indicate that mountain pine beetle activity in whitebark pine in the vicinity has increased considerably in the past 5 years. Permanently marked monitoring plots were established in both the thinned and unthinned portions of the stand. Revisiting this site to assess current conditions and the effect of the thinning treatment would be valuable.



Map of the Foggy Dew drainage. The thinning project area is circled in red.

Case Study 3: Whitebark pine restoration treatments in the Vinegar Hill Scenic Area, Umatilla National Forest, northeastern Oregon

The Vinegar Hill Scenic Area is located in the south-central portion of the Blue Mountains in northeastern Oregon. In 2003, a restoration project was implemented to reduce stand density and basal area levels of co-dominant and understory subalpine fir and other competing conifer species to promote whitebark pine growth and vigor. The project area contained three units totaling 33 ha (82 ac) of accessible stands with a predominance of whitebark pine. Competing subalpine fir, lodgepole pine, and other conifer species were removed by felling or girdling. No whitebark pines were cut, and some other conifers were left uncut, resulting in a mixed stand with a non-whitebark pine density (basal area) of less than 10 m^2 per ha (44 ft^2 per ac). The work was completed under a service contract at a cost of $1,927–$2,322 per ha ($780–$940 per ac) (Novotny et al. 2007).

Project Specifications

- Live trees of competing species were cut or girdled within a 15-m (50-ft) radius of whitebark pines that were more than 5 m (16.5 ft) in height. A 6-m (20-ft) radius was used if whitebark pine tree height was less than 5 m (16.5 ft).
- Competing trees with a diameter at breast height (dbh) of 18 cm (7 in) or greater were girdled by two overlapping sawcuts below the lowest limb.
- If the tree to be removed was less than 18 cm (7 in) dbh, it was cut below the lowest live limb, bucked into manageable pieces, and hand-piled at the edge of the stand.
- Slash piles were restricted to no more than 2.5 m x 2.5 m x 2 m (8 ft x 8 ft x 6 ft) in size and were located at least 9 m (30 ft) from standing live trees or snags. The piles were burned in fall 2004.

Vince Novotny, USFS

Aerial view of a thinning project to reduce competition from subalpine fir—the red trees are subalpine firs that have been girdled.

Case Study 4: Planting whitebark pine seedlings on the Deschutes National Forest, south central Oregon

Approximately 700 whitebark pine seedlings have been planted into 15 sites on the Deschutes National Forest in Oregon in small-scale restoration projects implemented from 2003 to 2007. Most of these seedlings were planted on small, heavily trodden recreation sites located in whitebark habitat in and around the Three Sisters Wilderness. These plantings used 2-year-old container stock, grown in 10-cubic-in (164-ml) tubes by the Dorena GRC. Rocks and down wood were used to provide protective microsites.

Based on casual observations, seedling survival has been fairly high, with 3- and 4-year survivals at 70 percent. Pocket gophers have been the main damaging agent (Jensen, pers. comm., 2008).

Chris Jensen

Tree-planter-created microsites and newly planted whitebark pine seedlings on a small restoration project. This is a dual-objective project that both restores whitebark pine and rehabilitates a heavily used recreation site.

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Glossary

cache—In relation to seed dispersal by animals, refers to a discrete site selected by an animal for temporary cone or seed storage. Caches may contain one or many cones or seeds depending on the species of animal storing and the species of plant being stored; also the act of placing, hiding, or storing provisions in such a place.

co-evolved—Evolution involving successive changes in two or more ecologically interdependent species (for example, a plant and its pollinators) that affect their interactions.

***ex situ* gene conservation**—

Choice 1: Any conservation method that entails removal of individual plants or propagating material (seed, pollen, tissue) from its site of natural occurrence—that is, conservation "off-site" in gene banks as seed, tissue, or pollen; in plantations; or in other live collections, such as ex situ conservation stands.

Choice 2: Conservation of genetic resources that entails removal of individuals or reproductive material from its site of natural (original) occurrence; that is, conservation off site.

indehiscent—Not opening spontaneously at maturity to release seeds.

krummholz—A shrub-like or prostrate form of a high-elevation tree that has developed its low, bent shape because of frequent exposure to high winds.

management-ignited fire—A fire that is set and confined to a predetermined area and produces the fire behavior and fire characteristics required to attain planned fire treatment and/or resource management objectives.

mutualism—An interaction between two or more species where both species derive benefit. Mutualisms can be lifelong interactions involving close physical and biochemical contact (known as symbiosis) such as those between plants and mycorrhizal fungi; they can also be briefer, non-symbiotic interactions, such as those between flowering plants and pollinators or seed dispersers. Mutualisms may be optional (facultative) or obligatory.

prune—To cut off dead or surplus branches of (a tree or shrub).

scarification—To slit or soften the outer coat of (seeds) in order to speed germination.

stratification—The process of pretreating seeds to simulate natural conditions that a seed must endure before germination. Many seed species have what is called an embryonic dormancy and generally speaking will not sprout until this dormancy is broken.

subalpine—Of, relating to, or inhabiting high upland slopes and especially the zone just below the timberline.

sublingual pouch—A diverticulum or sack-like extension of the floor of the mouth under the tongue used by birds in the genus *Nucifraga* to carry seeds.

wildland fire use—The management of naturally ignited fires to achieve resource benefits, where fire is a major component of the ecosystem.

wildland-urban interface—Where houses meet or intermingle with wildland vegetation.

Land Managers Guide to Whitebark Pine Restoration in the Pacific Northwest Region

2009–2013

United States
Department of
Agriculture

Forest Service

Pacific Northwest
Region

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