United States
Department of
Agriculture

Forest Service

R1-06-28

August 2006

Whitebark Pine in Peril

A Case for Restoration

John W. Schwandt

USDA Forest Service
Forest Health Protection

Whitebark Pine in Peril: A Case for Restoration

John W. Schwandt
USDA Forest Service
Forest Health Protection

PREFACE

The purpose of this paper is to:

1) provide a range-wide assessment of whitebark pine health,
2) describe range-wide restoration strategies for conserving and restoring whitebark pine,
3) provide a brief managers guide for selecting restoration strategies, and
4) describe information needs and challenges to restoration.

The National Forest Management Act of 1976 and the Healthy Forest Restoration Act of 2003 provide the statutory and regulatory support for developing restoration strategies to conserve, maintain, and restore whitebark pine on federal lands. Whitebark pine restoration also complements the National Fire Plan, National Invasives Species Strategy and Western Bark Beetle Reports by maintaining or restoring health and stability in ecosystems threatened by invasive species, fire, and bark beetles.

Development and implementation of whitebark pine restoration strategies may also provide useful information for application to other high elevation white pine species, such as foxtail, limber, and bristlecone pines, that face similar conditions.

For additional copies of this publication, contact:

John W. Schwandt
USDA Forest Service, FHP
Coeur d'Alene, Idaho
(208) 765-7415
jschwandt@fs.fed.us

This publication is also available at:
www.fs.fed.us/r1-r4/spf/fhp/publications

CONTENTS

EXECUTIVE SUMMARY

The Role of Whitebark Pine

Whitebark pine is a keystone species of high elevation ecosystems throughout western North America. It is often the only tree species capable of surviving in harsh subalpine areas, and is crucial in stabilizing soil and moisture, and creating habitats that support a wide diversity of plants and animals. The large seeds are a primary food source for many animals including grizzly bears and the Clark's nutcracker which is the main seed dispersal agent. Over 90 percent of whitebark pine occurs in remote roadless areas, wilderness, or national parks where 300- to 500-year-old gnarled relics define high elevation vistas and provide much of the character of the alpine experience.

The Threat of White Pine Blister Rust

The inadvertent introduction of white pine blister rust from Europe in 1910 has resulted in severe losses in nearly all of our native five-needled pines. It has now spread to these fragile whitebark pine ecosystems where it has dramatically disrupted natural regeneration. Whitebark pine is no longer able to recover from natural disturbances such as wild fires and as a result, it has already disappeared from up to 98 percent of parts of its historic range. The urgency of the situation has recently increased due to outbreaks of mountain pine beetle which may kill trees that harbor natural resistance to blister rust. Without direct intervention, the prognosis is bleak.

The Goals of Conservation and Restoration

The ultimate goals of conservation and restoration are to protect and enhance existing populations, provide appropriate regeneration opportunities and increase the proportion of trees with natural resistance that will survive in the presence of white pine blister rust. Successful restoration will require a range-wide coordinated multi-agency effort with a long-term commitment.

Proposed Solutions

Successful range-wide restoration strategies will provide support to regional and site-specific strategies and will include the following:

- conduct rust surveys and monitoring to determine site conditions and prioritize restoration strategies
- preserve gene pools by collecting and storing seed or pollen from isolated populations of whitebark pine
- identify and test trees for natural resistance to white pine blister rust
- plant blister rust-resistant seed or seedlings in appropriate areas
- use silvicultural methods such as fire to reduce competing vegetation and create planting sites
- encourage natural regeneration especially where mature trees are at risk
- treat blister rust-resistant trees to prevent bark beetle attacks

Information Needs

- determine frequency of natural resistance across the range of whitebark pine
- identify resistance mechanisms, their heritability, frequency, and distribution
- further examine genetic variability in both the rust and whitebark pine populations
- develop guidelines for growing, testing, and regenerating seedlings at high elevations
- examine rust epidemiology and variation of infection to develop hazard rating models
- further examine relationships with nutcrackers, bark beetles, fire, and climate

Challenges to Success

- implement conservation strategies for isolated stands
- develop ways to expand fire use to create regeneration opportunities
- find ways to accelerate germination, seedling growth, cone production, and testing for resistance
- develop and implement strategies in remote or wilderness areas
- identify, test, and protect blister rust-resistant trees, and deploy blister rust-resistant seed or seedlings

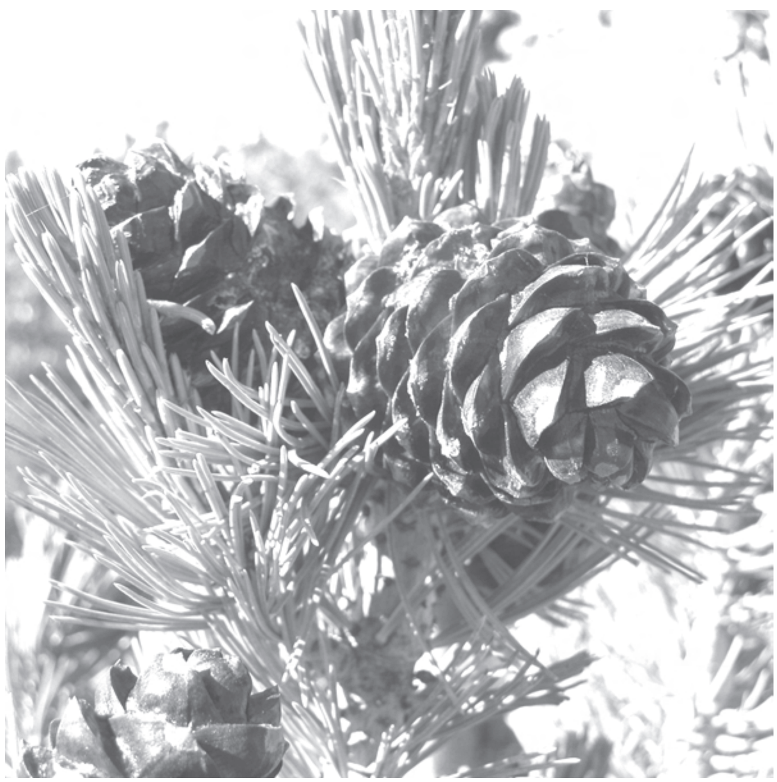


Photo: John Schwandt, USFS

Whitebark Pine in North America

DISTRIBUTION

The natural range of whitebark pine is one of the largest among conifers in North America, extending from the northern Rockies in Canada to the Sierra Nevada of California (Fig. 1: Little 1971). However, throughout its range, it only occurs in subalpine habitats, often near tree line (Fig. 2). As a result, its occurrence in this broad geographic area is limited to the two major mountain ranges in the west: between 900 and 2200 m elevation from the Cascades south to the Sierra Nevada and from about 1600 m to 2300 m in the Rocky Mountains from Alberta and British Columbia south to western Wyoming (Ogilvie 1990).

About 98 percent of the range of whitebark pine in the United States is on public lands, including national parks, wilderness areas, national forests, Indian reservations, and state lands (Tomback and Achuff 2006). Whitebark pine communities are found in twenty-five national forests in the northern Rocky Mountains and in all but one of the western national parks, where they are major attractions and help define the high mountain recreational experience.

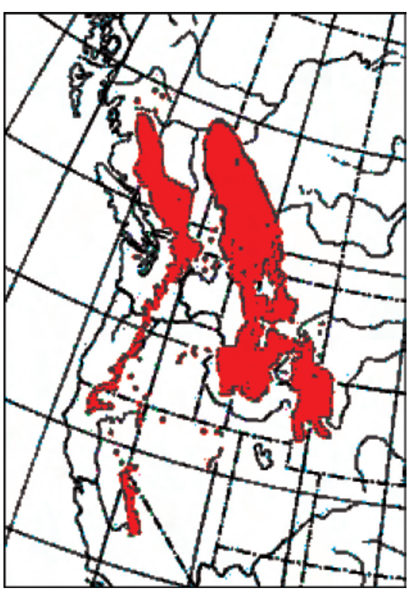


Figure 1. Distribution of Whitebark pine in North America.

Photo: Sandra Kegley, USFS

Figure 2. Whitebark pine, the keystone species of high elevations.

ECOLOGY AND BIOLOGY

Whitebark pine is one of nine species of five-needled pines native to North America. This group includes eastern, western, and southwestern white pines as well as whitebark, foxtail, sugar, limber, and the long-lived Great Basin and Rocky Mountain bristlecone pines. All of these species are susceptible to white pine blister rust, an exotic fungal disease that was accidentally introduced into both coasts of North America around the turn of the twentieth century. European nurseries commonly grew white pine seed from North America to produce seedlings that were then shipped back with the undetected hitchhiker. White pine blister rust infects needles of pines from spores produced on its alternate host (usually a wild currant or gooseberry shrub) and then grows down the branches and into the stem, killing branches as it grows. Each spring "blisters" of yellow spores erupt through the bark (Fig. 3), and spores may then travel long distances on prevailing winds before landing on the alternate host.

Figure 3. White pine blister rust sporulating on a small branch.

Whitebark pine occurs as both a climax species at tree line as well as an early successional species and it contributes far more to these high elevation ecosystems than might be predicted solely based on its biomass or abundance. Therefore, whitebark pine is often called a keystone species because it is the pillar of alpine ecosystems, which depend on whitebark pine for their stability, diversity, and very existence (Primick 2006). It is the first successional step in turning disturbed inhospitable sites into thriving communities with diverse populations of plants and animals, from soil microorganisms to grizzly bears. Whitebark pine helps stabilize soil and acts to accumulate snow and retard spring runoff, thus reducing flooding and improving water quality at lower elevations (Farnes 1990).

In the most extreme sites whitebark pine will be limited to short, weather-beaten shrubs termed "krummholz" (Fig. 4), but at lower elevations, it may grow as widely spaced individuals or as clumps in protected areas and even entire stands, contributing to diversity and stability in many other ecosystems (Rebertus 1991). On favorable sites, whitebark pine can live more than a thousand years, reaching over 100 feet in height and several feet in diameter (Arno and Hoff 1989). Further down-slope, whitebark pine is gradually out-competed by more shade-tolerant conifers, such as spruce and subalpine fir.

Figure 4. Weather-beaten whitebark may be the only tree species capable of occupying harsh sites.

Whitebark pine has very large seeds, which cannot be wind-disseminated like other pine species. Instead, it relies almost exclusively on Clark's nutcrackers for seed dispersal. The Clark's nutcracker is a large jay-like bird (Fig. 5) that has a specially developed bill for extracting seeds from cones and a special pouch in its throat used for seed transport that can hold over 100 seeds (Tomback 2001). Although most

Figure 5. Whitebark pine relies on the Clark's nutcracker for seed dispersal.

of the seed is cached within a few kilometers, nutcrackers may carry the seed up to 20 km looking for good sites to cache seeds. In the Rocky Mountains, nutcrackers help regenerate burned areas as they prefer to cache seed in recent burns. In a good cone crop year, a single nutcracker may cache 35,000–80,000 seeds and will return to retrieve up to 50 percent of them. However, when cone crops are poor, nutcrackers may eat all the seed or may simply move to other areas, severely limiting the possibility of natural regeneration (Lanner and Vander Wall 1980).

Because whitebark pine seeds have high nutrition value, they are also favorite foods for other animals, such as squirrels and the endangered grizzly bear. Squirrels will harvest large amounts of cones into storage areas called "middens," where they can feed on seed during the long winters. However, grizzly bears also have found that these middens can provide them with a great source of nutrients. Studies around Yellowstone National Park found during years of abundant cone crops that grizzly bears forage almost exclusively on whitebark pine seeds and as a result have higher reproduction rates (Matteson et al. 2001). Bears also tend to stay in the high-elevation whitebark zone resulting in dramatically fewer grizzly bear-human encounters.

Historically in the Rocky Mountains most mature whitebark pine were killed by fires, mountain pine beetle, or were slowly outcompeted by other species. In their coastal range, fires were not as important, but the effects of mountain pine beetles and competing vegetation were quite similar (Siderius and Murray 2004). Mountain pine beetle is a native insect that exhibits periodic outbreaks in lodgepole pine, sugar pine, and western white pine as well as whitebark pine. Sentinels of old dead "gray ghosts" from beetle outbreaks dating back to the 1930s can still be found on many isolated ridges (Fig. 6) (Perkins and Sweetnam 1996).

Photo: John Schwandt, USFS

Figure 6. A stand of dead whitebark pine—"gray ghosts"—in a high-elevation landscape.

CURRENT HEALTH ASSESSMENT

Whitebark pine is now rapidly declining through most of its range, and it has disappeared entirely in some isolated locations (Kendall and Keane 1993). These losses initiated listing of whitebark pine as a species at risk in Canada (Wilson and Stuart-Smith 2002), and it was listed as a species of concern in western Washington by the U.S. Fish and Wildlife Service in 2004. This dramatic decline is due to a combination of several factors, including:

1. white pine blister rust,
2. wildfires and competing vegetation, which may be the result of fire suppression,
3. outbreaks of mountain pine beetle, and
4. changing climatic effects.

Blister Rust Effects

The introduction of white pine blister rust greatly altered the historical regeneration pathway of whitebark pine. This disease kills small trees quickly and in areas with high levels of blister rust infection, most natural regeneration never survives to cone-bearing age. In mixed stands, this mortality greatly hastens succession as whitebark pine is replaced by other competing species. In areas with high levels of blister rust infection, most natural regeneration never survives to cone-bearing age. Large trees are killed much more slowly, but blister rust can also kill major portions of the crown (Fig. 7), thus eliminating most cone production and having a ripple effect on regeneration potential and the animals that depend on these seeds for food.

There has not been a thorough survey throughout the entire range of whitebark pine, but individual surveys are finding blister rust continues to show up in areas where conditions were once thought to be too extreme for it. With few exceptions, blister rust has now spread throughout the entire range of whitebark pine. Hardest-hit areas are generally in the northern Rockies, where infection levels are often over 70 percent (Table 1). However, disease incidence may vary widely from place to place and between large trees and small trees at the same site.


Photo: John Schwandt, USFS

Figure 7. Branch and topkill by blister rust can limit cone production.

Fire Effects

Historically, fires have removed competing coniferous vegetation and created seedbeds for whitebark pine regeneration. However, fire suppression during the last 60 to 80 years may have contributed to stand conversion to other species that out-compete whitebark pine (Arno 2001). Natural ignitions in some alpine areas have been suppressed for fear that fires might run down slopes into more valuable timber or urban areas. Fires initiated on lower slopes in commercial timber stands have also been extinguished before they could reach the higher elevation whitebark stands. Before fire suppression in the Inland West, the average whitebark pine stand burned every 50 to 300 years (Arno 2001). Even with prescribed and natural fires that have been allowed to burn in wilderness areas in the last 25 years, less than 1 percent of whitebark pine sites have burned during that period.

Table 1. Percentage of live trees with blister rust infection on plots/transects from recent surveys.

Geographic Region - # reports - Reference	Range of Infection	Mean
British Columbia (rangewide) (Campbell & Antos 2000)	0 - 100%	50.0%
British Columbia (rangewide) (Zeglan 2002)	11 - 52.5%	38.0%
Northern Rocky Mountains (U.S., Canada) (Smith et al. 2006)	0-100%	43.6%
Selkirk Mountains, northern Idaho-5 stands (Kegley et al. 2004)	57-81%	70.0%
Colville NF, NE Washington -2 reports (Ward et al. 2006)	23-44%	41.4%
Greater Yellowstone Ecosystem (GYWPMWG 2005)	0-100%	25.0%
Intermountain West (Id, Nev, Wy, Ca) (Smith and Hoffman 2000)	0-100%	35.0%
Blue Mountains, NE Oregon (Ward et al. 2006)	0-100%	64.0%
Coast Range; Olympic Mtns., Wa - 2 reports (Ward et al. 2006)	4-49%	19.0%
Western Cascades; Wa/Or – 6 reports (Ward et al. 2006)	0-100%	32.3%
Eastern Cascades; Wa/Or – 13 reports (Ward et al. 2006)	0-90%	32.3%
Coastal Mountains, southwest Oregon (Goheen et al. 2002)	0 - 100%	52.0 %
California—statewide (Maloney and Dunlap 2006)	0-71%	11.7%

Fire suppression may also lead to increased fuels, which result in more intense fires that are more difficult to control. Isolated populations of whitebark pine have been eliminated by wildfires that burned all potential seed sources within the range of nutcrackers (Tom DeSpain pers. comm.).

Mountain Pine Beetle Effects

Although mountain pine beetle (MPB) is a native insect that historically recycled mature whitebark pine, an aerial survey of some recent outbreaks recorded over a million dead trees in 2005 (Fig. 8), and some of the few remaining whitebark pine stands are at high risk (Fig. 9) (Logan and Powell 2001). Because mountain pine beetle may be killing trees with natural blister rust resistance, there is increased urgency to implement restoration strategies to reduce losses and save at least some of the whitebark pine from beetle attack.

Climate Effects

Whitebark pine is extremely long-lived and is capable of surviving extreme environments, but it may not be able to adapt to changing climates. Recent warming trends may also play a role in displacing whitebark pine as competing vegetation invades more

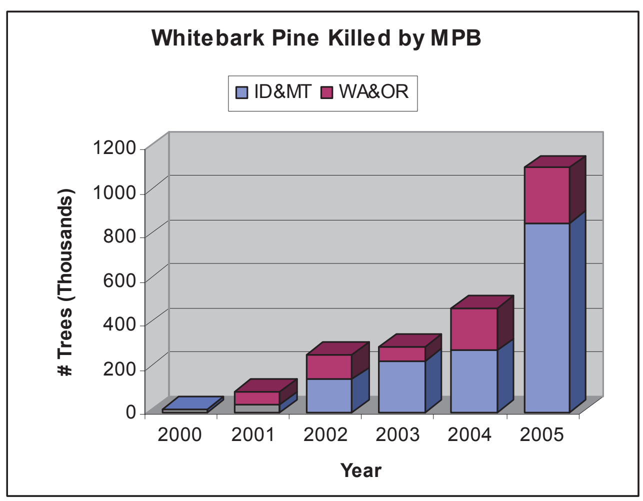


Figure 8. Whitebark pine mortality recorded during annual aerial surveys in Idaho, Montana, Washington, and Oregon.

Figure 9. Mountain pine mortality from mountain pine beetle in Yellowstone National Park.

of the natural range of whitebark (Bartlien et al. 1997). In addition, the long growth and maturation period of whitebark pine puts it at an adaptive disadvantage as it may not be able to respond to climate changes as rapidly as competitors that reproduce more frequently and at younger ages.

A warmer and moister weather pattern may also favor white pine blister rust by producing frequent "wave years" of conditions that promote massive numbers of infections (Koteen 2002). Warmer weather may also favor mountain pine beetle, and recent outbreaks have been more intense due to several mild winters that allowed more of the bark beetle population to survive (Logan and Powell 2001).

WHAT CAN BE DONE?

Because blister rust has spread nearly range-wide and is steadily increasing in severity, we must act now to develop and implement restoration strategies to maintain whitebark pine ecosystems. The goals of restoration and conservation are to be proactive in protecting and enhancing existing whitebark pine populations, as well as restoring populations where they have been lost.

The ultimate goal is to increase the proportion of trees with natural blister rust resistance that will survive in the presence of white pine blister rust. This will require strategies to evaluate current whitebark health, conserve isolated gene pools, promote natural rust resistance, reduce competing vegetation, enhance natural regeneration opportunities, and minimize bark beetle losses.

Implementation of restoration strategies will require close cooperation of scientists and mangers from multiple agencies and departments as well as broad public support. The importance of whitebark pine restoration needs to be emphasized in management plans by all state and federal agencies, and field projects that meet multiple resource needs should be a high priority.

The following is a list of conservation and restoration strategies that can be employed, and this is followed by a manager's guide that can be used to help select the best actions for particular sets of circumstances.

ASSESS FOREST HEALTH

A range-wide health assessment will help document current conditions and may be used as a basis for regional or local strategies.

To properly assess forest health conditions, we must conduct periodic surveys and establish permanent plots to accurately map occurrence and monitor the spread and intensification of blister rust and track mountain pine beetle populations. A national database has been created to maintain and consolidate this information and may contribute to developing rust hazard models (Lockman and DeNitto 2006).

CONSERVE GENETIC DIVERSITY

Isolated populations of whitebark pine can be protected from possible extinction by collecting and archiving seed (Fig. 10) and pollen and by grafting selected trees at nurseries. In this way, the gene pool can be retained even if stands are lost to wildfire or other disturbances.

Photo: John Schwandt, USFS

Figure 10. Cones must be protected from predation so seeds can fully ripen before collecting for testing and restoration.

HARNESS NATURAL RESISTANCE

There is little hope of preventing blister rust from spreading throughout the range of whitebark pine. Therefore, the most important strategies will help whitebark pine to survive in the presence of blister rust. Although rare, natural blister rust resistance has been found in sugar pine and western white pine; early tests of whitebark pine using similar methodology at Forest Service nurseries in Oregon and Idaho have found evidence (Fig. 11) that natural resistance to blister rust also occurs in whitebark pine (Richard Sniezko, pers. comm.). However, once a tree has been identified as a candidate for possible blister rust resistance, it may take 7-10 years to test it, assuming that we have the resources to find such trees in what are often very remote and isolated areas.

Photo: Richard Sneizko, USFS

Figure 11. Seedlings showing different levels of resistance to blister rust.

The best chance of finding the rare trees with natural blister rust resistance is in areas with the highest levels of blister rust infection (generally over 90 percent), where blister rust will likely have infected most of the susceptible trees and resistant trees will be easy to identify. Seed from all uninfected trees should be tested for blister rust resistance and could also be used to restock nearby sites where resistant trees cannot be found.

A proactive strategy is finding trees with blister rust resistance in areas with lower levels of infection is even though they will be harder to detect. This strategy successfully found some blister rust resistance in a population of healthy southwestern white pine, and is also being tested with bristlecone pine, so it may have potential with whitebark pine in areas with low infection levels.

Once blister rust-resistant trees or seedlings are identified, they can be grown in seed orchards to produce seed that could be used for restoration purposes. However, current needs will have to focus on collecting seed from 'plus' (potentially resistant) trees because orchards of new trees may not produce significant cone crops for 50 years or more (Arno and Hoff 1989, Bower 2006).

Although whitebark pine has broad tolerance for planting within its range, to maintain genetic diversity, several seed transfer zones have been developed (Mahalovich and Hoff 2000, Bower 2006), and it is important to find blister rust resistance in each zone.

Reduce Competing Vegetation

In areas with existing mature whitebark pine, coordinated projects with wildlife biologists seeking to improve browse by burning or cutting competing coniferous vegetation will also improve whitebark pine health as well as enhance opportunities for natural regeneration.

Burning areas without whitebark pine but where there is an adequate whitebark pine seed source nearby may be the best way to promote whitebark pine regeneration through seed-caching by nutcrackers. Coordination with fuels specialists can encourage prescriptive fire to help prevent buildup of catastrophic fuels as well as create seed beds (Fig. 12).

Even with a very aggressive planting program, only a small percentage of the range can be planted at a time, but a wildfire can create thousands of acres of sites that can be naturally planted by nutcrackers if an unburned seed source is within a few kilometers.

Photo: John Schwandt, USFS

Figure 12. Prescribed low-intensity fires can be used to reduce competing vegetation and create favorable regeneration sites.

Enhance Natural Selection

Natural selection for blister rust resistance will be strongest in the younger trees, resulting in high mortality, yet survivors will likely have some level of genetic rust resistance. By increasing natural regeneration, we can improve the probability of having trees with natural blister rust resistance.

However, natural selection alone will not guarantee restoration of whitebark pine stands because of the low frequency of blister rust resistance and because other disturbances will remove resistant trees. Increasing natural regeneration is especially important in areas where cone-bearing trees are at risk or very scattered because natural regeneration will not occur if nutcrackers cannot find enough cone-bearing trees (McKinney and Tomback 2006).

Prevent Bark Beetle Losses

Mountain pine beetle attacks in lodgepole pine have been reduced by thinning stands to improve their vigor, but this treatment is of little value in most whitebark pine stands, which largely consist of scattered individuals. However, scientists have discovered the chemical messenger (pheromone) used by mountain pine beetle to signal when a tree is full of beetles and are currently testing it to protect trees from bark beetle attacks. Early results are generally favorable, although additional tests will be needed to improve success (Kegley and Gibson 2004). Treating entire populations or stands of whitebark pine may not be realistic, but it may be of great use in protecting individual high-value trees in recreation sites or trees identified as blister rust-resistant. Bark beetle outbreaks typically last about five years, so treatment may only be necessary during years of high beetle populations.

A MANAGER'S GUIDE TO SELECTING WHITEBARK PINE RESTORATION STRATEGIES

The strategies discussed above can be summarized into logical scenarios to help managers prioritize and select their options for specific areas. Restoration plans and site-specific restoration strategies are currently being developed by interdisciplinary teams in Idaho and Montana; Washington, Oregon, and California; and Canada. However, the following generalities will pertain to nearly all plans. To help prioritize stands for intervention and select the appropriate restoration strategies, each potential site should first be assessed for the following:

- stand conditions:
  - the size and density of whitebark pine
    - presence of mature (cone-bearing) whitebark pine
    - presence of a cone crop
    - presence of whitebark pine regeneration
  - size and density of competing vegetation
- whitebark pine health
  - level of blister rust infection
  - level of mountain pine beetle activity
- site access and ownership, or management objectives that may influence management options (such as designated wilderness)

With this basic information in mind, one of the following general scenarios may be appropriate.

SCENARIO #1: MATURE WHITEBARK PINE ARE PRESENT

The goal will be to maintain or improve the stand vigor and encourage more natural regeneration by selective girdling, thinning, and prescribed burning of competing vegetation as necessary (Figure 13):

- If blister rust infection levels are low (<50 percent), stands should be monitored and natural regeneration should be encouraged, especially if mortality from mountain pine beetle is high.
- If blister rust infection levels are high (>90 percent), search for trees with no blister rust infection that may carry rust resistance and collect seed for resistance testing and restoration. If mortality from mountain pine beetle is high, it is critical to protect 'plus' (resistant-appearing) trees from attack (Fig. 14), and seed collection should be a very high priority.
- If blister rust levels are low to moderate, it may not be possible to select potentially resistant trees, but:
  - If mortality from mountain pine beetle is high, collect seeds for blister rust resistance testing and restoration. Encourage natural regeneration to provide a larger population for natural selection to act upon.
  - If mountain pine beetle populations are low, encourage more natural regeneration and monitor the stand for changes in rust or beetle populations.

Photo: John Schwandt, USFS

Figure 13. Controlling competion by other species through cutting or girdling to improve the vigor of whitebark pine (left).

Photo: John Schwandt, USFS

Figure 14. Pouches of pheromones can be used to prevent bark beetle attacks.

Scenario #2: Mature whitebark pine are absent from the stand but present nearby

This may frequently be the case after a fire or other disturbance has killed the mature whitebark pine. The goal will be to create sites for natural regeneration or planting nursery stock.

- Treat the site to attract nutcrackers to cache seed, burning competing vegetation if necessary (Fig. 15).
  - If blister rust infection levels are high, look for 'plus' trees nearby to obtain seed for planting.

Scenario #3. Mature whitebark pine are absent but some natural regeneration is present

This may occur in areas where most mature trees have been killed by mountain pine beetle or blister rust. The goal will be to maintain the stand by managing competing vegetation, if necessary, and to monitor it for blister rust levels. (Mountain pine beetle is not a concern in small trees.)

- If blister rust infection levels are high (Fig. 16), look for 'plus' trees nearby to obtain seed to augment natural regeneration.

Scenario #4: Whitebark pine-suitable site but no whitebark pine of any size are present in the stand or nearby

The goal will be to treat competing vegetation to create planting sites. If these sites are beyond the range of nutcrackers, they can only be restored by planting (Fig. 17).

- If trees with blister rust resistance have been identified for this area, they should be used to regenerate the site.

Photo: John Schwandt, USFS

Figure 15. (Left) Low-intensity prescribed fire to remove competing vegetation and create attractive sites for nutcrackers to cache seeds.

Photo: John Schwandt, USFS

Figure 16. (Right) In areas with high blister rust hazard, most small trees are rapidly killed.

Photo: John Schwandt, USFS

Figure 17. Whitebark pine seedlings will be grown 2-3 years before they can be outplanted.

INFORMATION NEEDS

There are still many unanswered questions regarding whitebark pine restoration requiring practical information that can be used to prioritize stands for restoration based on potential ecosystem impacts.

What is the frequency and genetic basis for white pine blister rust resistance?

If we knew the frequency of blister rust resistance in an area, we could determine how much regeneration would be needed for natural selection to be successful. Preliminary tests have shown that blister rust resistance does occur in whitebark pine, but we need to know if this is due to multiple resistance mechanisms, whether these mechanisms are controlled by one or many genes, the extent of their hereditability, and their geographic distribution of blister rust resistance across the range of whitebark pine.

Further examination of the genetic variation in populations of both whitebark pine and the rust fungus would be very beneficial in helping refine seed transfer zones and identifying potential for new virulent races of the rust.

How can we accelerate testing and growing processes and address remoteness of sites?

Testing trees for blister rust resistance and growing seedlings are very time consuming processes and shortcuts such as grafting cone-bearing branches and treating seed to improve germination should be investigated. Whitebark pine seed generally take at least two years to germinate, but germination may be enhanced by scarifying the seed or treating it with warm water before planting. The logistics of restoring whitebark pine to remote areas may be simplified by planting seed rather than seedlings. One small seed planting test (Fig. 18) was established in 2005

Photo: John Schwandt, USFS

Figure 18. Pilot test to compare seed treatments for germination and protection from rodents.

(Schwandt unpublished), and preliminary results indicate seed treatments may increase germination rates the first year, but additional tests are needed across the range of whitebark pine and monitoring survival of seedlings will also be important.

How do we define and model factors affecting infection?

Most surveys have found wide variation in rust infection levels, and if we understood the source of this variation, we could develop hazard rating models to help predict potential for infection on different sites. Hazard rating models will have to include the alternate hosts. We know that infections on whitebark pine come from spores produced on the alternate hosts (Fig. 19), but very little is known about the role of alternate hosts in these high-elevation ecosystems or if infections on whitebark are coming from local or distance sources.

Figure 19. Ribes, an alternate host in the life cycle of blister rust.

How is fire best used for restoration?

We know that fire can create large areas of potential seed beds, but we need a better understanding of fire behavior, its effects on alternate hosts, and how to safely use prescribed and wildland fires in these high elevations to reduce competing vegetation and create seed beds that will attract nutcrackers.

What is the role of nutcrackers in declining stands?

The relationships between whitebark pine and nutcrackers are only partially understood. For example, we do not know what level of cone crop is necessary to have successful caching by nutcrackers and at what threshold they will simply move on.

How can we reduce mountain pine beetle impacts?

We have some preliminary information that indicates mountain pine beetles may prefer trees with blister rust at low population levels, but once they reach outbreak levels, beetles may actually prefer trees without rust (including rust-resistant trees) (Kegley and Schwandt 2004). However, these relationships need further examination across the range of whitebark pine. Additional testing of anti-aggregant pheromones are needed to better refine their use and efficacy under varying field conditions.

How rapidly do whitebark pine decline?

Additional permanent plots need to be established to monitor changes in rust infection levels or intensity, mortality, bark beetle populations, and document effects of potential climate change on whitebark pine ecosystems. Data from these plots needs to be added to a common database for sharing and analysis.

CHALLENGES

There are significant challenges to implementing whitebark pine restoration strategies. Some are biological or physical in nature—the remote location of whitebark pine and its slow biological 'clock'—while other challenges are administrative or simply a challenge in allocating resources.

A primary challenge is to implement restoration strategies in at least some isolated whitebark pine populations in each seed transfer zone before they are lost. Entire stands can be lost from wildfires overnight, and mountain pine beetle can kill most of the mature whitebark in a few years over wide areas. Other whitebark pine stands are slowly being lost due to a combination of blister rust and competition from other species that are normally held in check by low-intensity fires. If all whitebark are eliminated within the caching range of Clark's nutcrackers (about 20 km), that piece of the whitebark range is lost unless it is replanted with nursery stock. If seed have not been collected from these areas, a small part of the gene pool may be lost forever.

Major declines are already occurring over large portions of whitebark pine range. A recent northern Idaho study found that whitebark pine is only occupying 4,000 acres of its historic range of 200,000 acres, a 98 percent decline (Figs. 20 and 21). These dramatic losses pose a daunting challenge to restoration efforts, and planting efforts to date have only covered a few hundred acres. However, we do not need to restore every acre. If blister rust-resistant whitebark pine are available, they will eventually produce cones that the nutcracker will use to plant additional blister rust-resistant trees if historical disturbances such as fire cycles create suitable planting opportunities. Therefore, the use of prescribed and wildland fires to create large

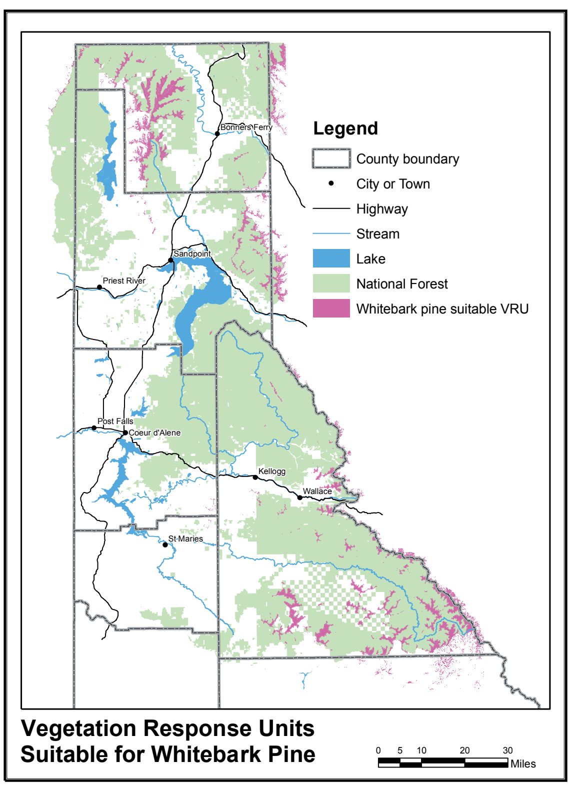
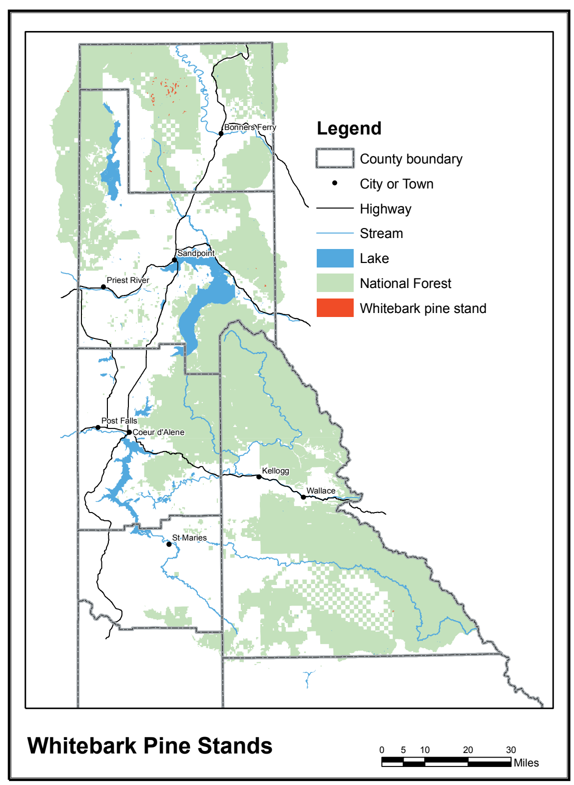


Figure 20. Historic area capable of supporting whitebark pine on all ownerships in northern Idaho and bordering forests.



Maps: Gregory Tensmeyer, USFS

Figure 21. Current distribution of whitebark pine on federal ownership in northern Idaho and bordering forests.

natural regeneration opportunities for caching by Clark's nutcrackers needs strong support. Burning opportunities in high elevations are often extremely limited, but methods to expand the fire window have been developed and need broader application.

The slow biological clock that worked well for a species that can occupy sites for many hundreds of years now makes restoration a challenge because it takes whitebark pine so long to grow and produce seed. This makes it important to investigate methods to shorten germination time and increase growth so that seedlings can be available more quickly for rust testing or reforestation. Because good cone crops only occur every few years, it is important to act quickly to protect and collect cones during a good cone year.

Because so much whitebark occurs in remote or wilderness areas, the logistics of locating and protecting blister rust-resistant trees from mountain pine beetle may be a challenge. Logistics of planting seedlings or implementing treatments such as thinning or girdling competing vegetation can also be a challenge. However, it maybe possible to plant seeds instead of seedlings and to use wildland fire to accomplish restoration goals in remote areas. It will be important to work with wilderness administrators to develop restoration strategies that can be conducted in accordance with wilderness guidelines. Wilderness areas already have wildland fire and invasive weed control programs in place, but the invasion of blister rust poses a much greater long-term threat to these ecosystems.

Some testing for blister rust resistance in whitebark pine is essential to determine the frequency of rust resistance genes across the range of whitebark pine. A complete breeding program would require a long-term commitment of resources, but it may be possible to create and protect local, *in situ* seed orchards of 'plus' trees as an alternative to offsite seed orchards.

CONCLUSIONS

This assessment has found that whitebark pine is clearly in peril across much of its range, and if steps are not taken to implement restoration strategies, we will continue to lose valuable ecosystem diversity and health in these fragile high-elevation sites. Blister rust will continue to expand and intensify throughout the entire range of whitebark pine, and the current outbreaks of mountain pine beetle will increase the urgency for action. However, we have biological evidence that restoration strategies can reverse this trend.

The general restoration concepts described here apply across the range of whitebark pine and provide guidelines for prioritizing restoration efforts under different stand conditions.

Surveys across the range of whitebark pine have found that rust infection levels vary widely, so restoration needs are not restricted to a single region or area. Therefore, it will be important to identify stands at greatest risk of extirpation and collect seed to test for blister rust resistance and reforestation.

Because whitebark pine is so important to all aspects of high-elevation ecosystems, it has attracted very broad interest and support for restoration. Therefore, it will be important to coordinate strategies with other resource managers to find areas of mutual interest and provide opportunities to combine resources. These concepts may also be of value in developing restoration strategies for other high elevation species that are also in jeopardy.

The biology of whitebark pine and the logistics of isolated populations present significant challenges but we have the technology and expertise to meet these challenges and create opportunities from them.

Whitebark pine losses have not occurred overnight, so there is no doubt restoring whitebark pine will require long term implementation of restoration strategies. Whitebark pine is a sentinel species whose restoration is important to sustaining the diversity and health of high elevation ecosystems, and implementing range-wide restoration strategies represents a key step to reverse the current trends. If we can develop and maintain blister rust resistant whitebark pine populations in each seed transfer zone long enough, natural processes may eventually resume restoration.

LITERATURE CITED

Arno, S.F. 2001. Community types and natural disturbance processes. *In:* Tomback, D.F., Arno, S.F., Keane, R.E. (eds.), Whitebark Pine Communities: Ecology and Restoration. Island Press, Washington, D.C., U.S.A., pp. 74-88.

Arno, S.F. and R. J. Hoff. 1989. Silvics of Whitebark Pine (*Pinus albicaulis*). USDA Forest Service, Intermountain Reseach Station. General Technical Report INT-253. Ogden, Utah. 11 p.

Bartlein, P.J., C. Whitlock, and S. L. Shafer. 1997. Future climate in the Yellowstone National Park Region and its potential impact on vegetation. *Conservation Biology* 11:782-792.

Bower, A.D. 2006. Ecological genetics: Effects of inbreeding and white pine blister rust in genetic structure of whitebark pine (*Pinus albicaulis* Engl.) PhD. Dissertation, University of British Columbia.

Campbell, E.M. and J.A. Antos. 2000. Distribution and severity of white pine blister rust and mountain pine beetle on whitebark pine in British Columbia. *Canadian Journal of Forest Research* 30:1051-59.

DeSpain, Tom. 2006. Personal communication. Area Geneticist, USDA Forest Service Pacific Northwest Region 6, Colville NF, Colville, Washington.

Farnes, P.E. 1990. SNOTEL and snow course data: describing the hydrology of whitebark pine ecosystems. *In:* Proceedings—Symposium on Whitebark Pine Ecosystems: Ecology and Management of a High-mountain Resource. Schmidt, W.C. and K.J. McDonald (comps.), USDA Forest Service, General Technical Report INT-270, Intermountain Research Station, Ogden, Utah, pp. 302-304.

Goheen, E.M., D.J. Goheen, K. Marshall, R.S. Danchok, J.A. Petrick, and D.E. White. 2002. The status of whitebark pine along the Pacific Crest National Scenic Trail on the Umpqua National Forest. USDA Forest Service, Pacific Northwest Research Station Gen. Tech. Rep. PNW-GTR-530. Portland, Oregon. 21 p.

Greater Yellowstone Whitebark Pine Monitoring Working Group. 2006. Monitoring whitebark pine in the Greater Yellowstone Ecosystem: 2005 annual report. *In:* C.C. Schwartz, M.A. Haroldson, and K. West, (eds.), Yellowstone Grizzly Bear Investigations: Annual Report of the Interagency Grizzly Bear Study Team, 2005, pp. 73-80.

Kegley, S. and K. Gibson. 2004. Protecting whitebark pine trees from mountain pine beetle attack using verbenone. USDA Forest Service, Northern Region, Forest Health Protection, Report 04-8, Missoula, Montana.

Kegley, S., J. Schwandt, K. Gibson. 2004. Forest health assessments in selected stands in the Selkirk Mountains of northern Idaho. USDA Forest Service, R-1 FHP Report 04-5.

Kendall, K.C., and R.E. Keane 2001. Whitebark pine decline: infection, mortality, and population trends. *In:* Tomback, D.F., S.F. Arno, and R.E. Keane (eds.), Whitebark Pine Communities: Ecology and Restoration. Island Press, Washington, D.C., U.S.A., pp. 221-242.

Koteen, L. 2002. Climate change, whitebark pine, and grizzly bears in the Greater Yellowstone Ecosystem. *In:* Schneider, S.H., and T.L. Root, (eds.), Wildlife Responses to Climate Change: North American Case Studies. Island Press, Washington, D.C., U.S.A., pp. 343-414.

Lanner, R.M. and S.B. VanderWall. 1980. Dispersal of limber pine seed by Clark's nutcracker. *Journal of Forestry* 78:637-639

Little, E.L. 1971. Atlas of the United States Trees. Vol. 1: Conifers and Important Hardwoods. USDA Forest Service Misc. Pub No. 1146. Washington D.C.

Lockman, I.B. and G.A. DeNitto. 2006. Whitebark-Limber Pine Information System ver 1.0. USDA Forest Service, *www/fs/fed/us/r1-r4/spf/fhp*.

Logan, J. A. and J.A. Powell 2001. Ghost forests, global warming, and the mountain pine beetle (Coleoptera: Scolytidae). *American Entomologist* 47 (3):160-172.

Mahalovich, M.F. 2006. Personal communication. Regional Geneticist, Regions 1,2,3,4, USDA Forest Service, Rocky Mountain Research Station, Moscow, Idaho.

Mahalovich, M.F. and G.A. Dickerson. 2004. Whitebark Pine genetic restoration program for the Intermountain West (United States). *In:* Sniezko, R.A., S. Salmon, S. Schlarbaum, and H.B. Kriebel (eds.), Proceedings, Breeding and Genetic Resouces of Five-needle Pines: Growth, Adapatability and Pest Resistance, July 23-27, 2001. USDA Forest Service Rocky Mountain Research Service, Fort Collins, Colorado. RMRS-P-32, pp. 181-187.

Mahalovich, M.F. and R.J. Hoff. 2000. Whitebark pine operational cone collection instructions and seed transfer guidelines. *Nutcracker Notes* 11:10-13.

Maloney, P. and J. Dunlap 2006. White pine blister rust and whitebark pine ecosystems in California. *In:* Proceedings, Whitebark Pine: A Pacific Coast Perspective. August 28-31, 2006. Ashland, Oregon. (In press.)

Matteson, D.J., B.M. Blanchard, and R.R. Knight. 1992. Yellowstone grizzly bear mortality, human habituation, and whitebark pine seed crops. *Journal of Wildlife Management* 56:432-442.

Mattson, D.J., K.C. Kendall, and D.P. Reinhart. 2001. Whitebark pine, grizzly bears, and red squirrels. *In:* Tomback, D.F., S.F. Arno, and R.E. Keane (eds.), Whitebark Pine Communities: Ecology and Restoration. Island Press, Washington, D.C., U.S.A., pp. 121-136.

McKinney, S.T. and D. F. Tomback. 2006. The influence of white pine blister rust on seed dispersal in whitebark pine. (In press.)

Ogilvie, R.T. 1990. Distribution and ecology of whitebark pine in western Canada. *In:* Schmidt, W.C. and K.J. McDonald (compilers), Proceedings—Symposium on Whitebark Pine Ecosystems: Ecology and Management of a High-mountain Resource. USDA Forest Service, General Technical Report INT-270, Intermountain Research Station, Ogden, Utah, pp. 54-60.

Paine, R.T. 1966. Food web complexity and species diversity. *American Naturalist* 100:65-75.

Perkins, D.L. and T.W. Sweetnam. 1996. A dendrochronology assessment of whitebark pine in the Sawtooth-Salmon River region, Idaho. *Canadian Journal of Forest Research* 26:2123-2133.

Primick, R.B. 2006. Essentials of conservation biology. Fourth edition. Sinauer Assoc. Inc, publisher. Suderland, Massachusetts.

Rebertus, A.J., B.R. Burns, and T.T. Veblen. 1991. Stand dynamics of *Pinus flexilis*-dominated subalpine forests in the Colorado Front Range. *Journal of Vegetation Science* 2:445-458.

Schwandt, J. and S. Kegley. 2004. Mountain pine beetle, blister rust, and their interaction on whitebark pine at Trout Lake and Fisher Peak in northern Idaho from 2001-2003. USDA Forest Service, R-1 FHP Report 04-9.

Siderius, J. and M. Murray. 2004. An initial assessment of the fire histories of two whitebark pine sites in the Washington Cascades. *In:* Taylor, L. (ed.), Symposium Proceedings: Mixed Severity Fire Regimes: Ecology and Management. Washington State University, Pullman, Washington, pp. 137-147.

Smith, C. M., Wilson, B., Rasheed, S., Walker, R., Carolin, T., Dobson, B. 2006 (in press). Whitebark pine and blister rust in the Rocky Mountains of Canada and northern Montana. *Canadian Journal of Forest Research*.

Smith, J.P. and J.T. Hoffman. 2000. Status of white pine blister rust in the intermountain west. *Western North American Naturalist* 60 (2):165-179.

Sniezko, R.A. 2006. Personal communication. Center Geneticist, USDA Forest Service, Dorena Genetic Resource Center, Cottage Grove, Oregon.

Tomback, D.F. and P. Achuff. 2006. Blister rust and Western Forest Biodiversity: Ecology, Values, and Outlook for Five-needled White Pines. (MS.)

Tomback, D.F. 2001. Clark's nutcracker: agent of regeneration. *In:* Tomback, D.F., S.F. Arno, and R.E. Keane (eds.), Whitebark Pine Communities: Ecology and Restoration. Island Press, Washington, D.C.., pp. 89-104.

Ward, K., R. Shoal, and C. Aubry. 2006. Whitebark pine in Washington and Oregon: A synthesis of current studies and historical data. USDA Forest Service Pacific Northwest Region Pacific Northwest Albicaulis Project. February 2006. 22p.

Wilson, B.C. and G.J. Stuart-Smith. 2002. Whitebark Pine Conservation for the Canadian Rocky Mountain National Parks. KNP-01. Cordilleran Ecological Research, Winlaw, British Columbia, Canada.

Zack, Art. 2006. Personal communication. Forest Ecologist, USDA Forest Service, Northern Region, Idaho Panhandle National Forests, Coeur d'Alene, Idaho.

Zeglen, S. 2002. Whitebark pine and white pine blister rust in British Comumbia, Canada. *Canadian Journal of Forest Research* 32:1265-74.

ACKNOWLEDGEMENTS

The development of this document required the collaboration and unselfish sharing of data, photos and information from numerous individuals within the Forest Service, other land management agencies and universities. The following individuals were especially helpful with direction and document review: Carol Aubry, Anna Schoettle, Diana Tomback, Holly Kearns, and Kerry Britton. Funding for this effort was provided by the Washington Office, State and Private Forestry, Forest Health Protection. Funding for the preparation including formatting and layout by Mark Riffe, Information Technology Experts, was provided by the Forest Health Technology Enterprise Team, Fort Collins, Colorado.

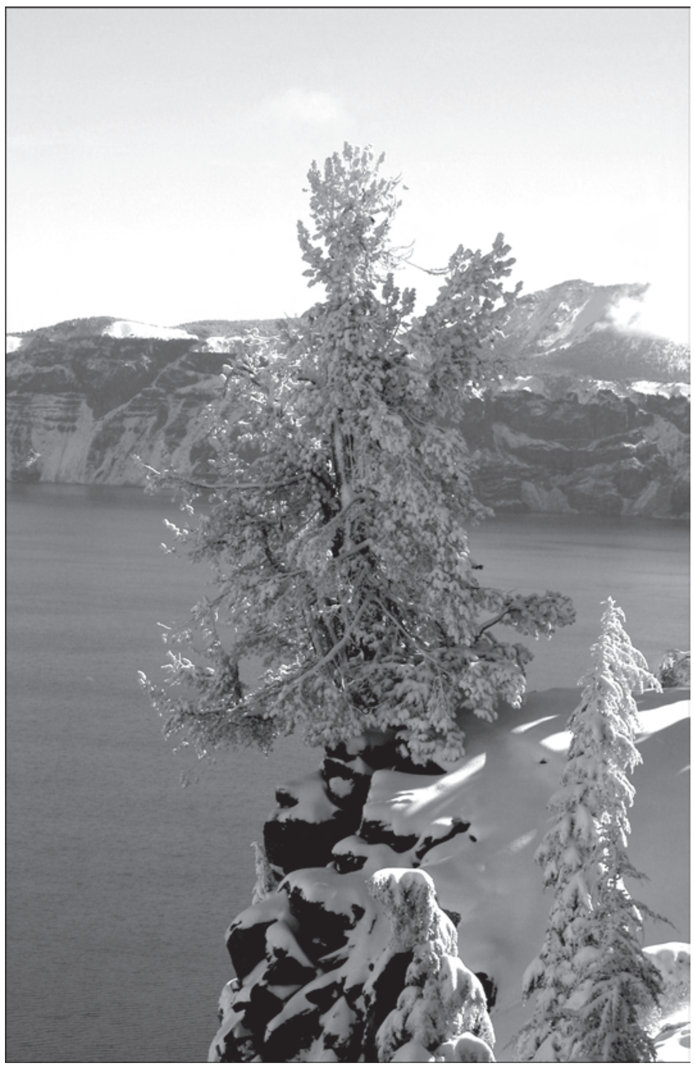


Photo: John Schwandt, USFS

Whitebark pine is a keystone species of high-elevation ecosystems throughout western North America. The introduction of white pine blister rust has led to dramatic declines in parts of its range, but implementation of restoration strategies can reverse this trend.

Photo:

Mature whitebark pine struggling for survival in a high-elevation ecosystem (John W. Schwandt, USFS).