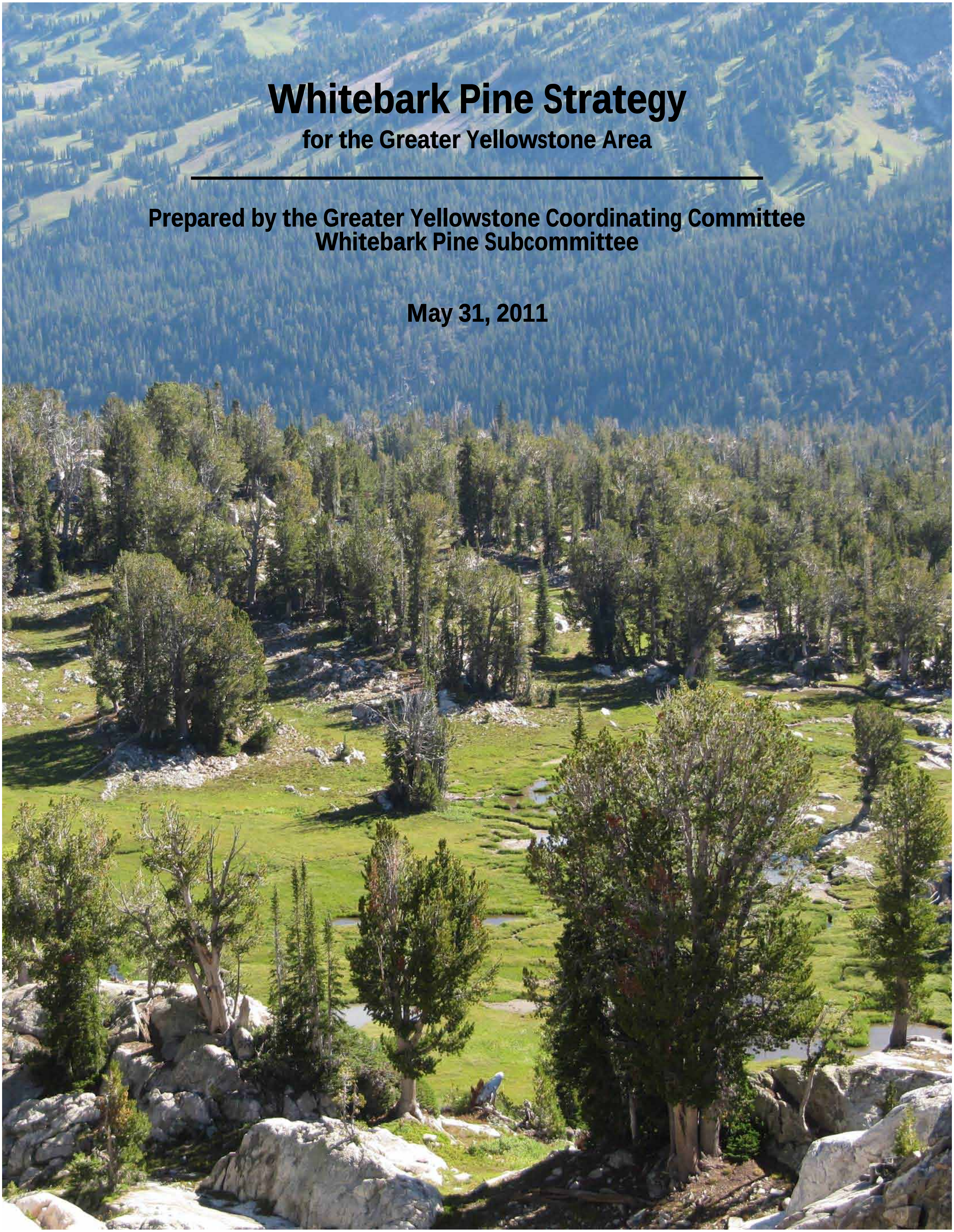
Whitebark Pine Strategy

for the Greater Yellowstone Area

Prepared by the Greater Yellowstone Coordinating Committee
Whitebark Pine Subcommittee

May 31, 2011



Whitebark Pine Strategy
for the Greater Yellowstone Area

Prepared by the Greater Yellowstone Coordinating Committee
Whitebark Pine Subcommittee

May 31, 2011

Suggested citation:
Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee. 2011. Whitebark Pine Strategy for the Greater Yellowstone Area. 41 p.

Cover photo: Whitebark pine, Grand Teton National Park. Photo by Nancy Bockino.

Executive Summary

As a foundation species of high elevation ecosystems in the greater Yellowstone area (GYA), whitebark pine (*Pinus albicaulis*) defines ecosystem structure, function, and process by providing snow capture and retention and carbon storage, increasing biodiversity, and serving as a food source for wildlife. Throughout its range, whitebark pine is currently at significant risk from both the nonnative white pine blister rust (*Cronartium ribicola)* and the native mountain pine beetle (*Dendroctonus ponderosae*). Climate change effects, including warmer temperatures and altered precipitation patterns, increase the reproductive rate and survival of mountain pine beetle and impact dispersal of white pine blister rust spores. Overstory mortality from these agents is unprecedented in many areas of the GYA, resulting in the need for a proactive approach to whitebark management that links federal administrative units throughout the GYA. In order to protect healthy whitebark pine and restore whitebark pine in areas with extensive overstory mortality, appropriate management actions must be coordinated, consistent, efficient, and science-based.

In response to the current situation in whitebark ecosystems, the Greater Yellowstone Coordinating Committee's Whitebark Pine Subcommittee, which has worked successfully across boundaries since its inception in 2000, developed this Whitebark Pine Strategy to promote the persistence of whitebark pine over time and space in the GYA by: (1) documenting the current condition of whitebark pine in the GYA; (2) establishing criteria to prioritize areas for management action; (3) identifying techniques and guidelines to protect and restore whitebark pine; and (4) facilitating communication and distribution of this information. This strategy is intended to enable land management units to maximize the use of their limited resources to maintain the presence of whitebark pine in the GYA.

This Whitebark Pine Strategy for the GYA is a living document that will be regularly updated to reflect changes in ecosystem conditions, advances in the understanding of whitebark pine ecosystems and management techniques, and improvements in the technology available to characterize and map whitebark pine. In addition, reviews by other resource staff such as fire managers, wildlife biologists, interpreters, and recreation specialists will provide the basis for integration of this strategy within individual management units as well as across the GYA. The Whitebark Pine Strategy f contains four sections.

Section 1. Introduction, Purpose and Need, and Strategic Objectives

Details the strategic objectives developed for assessing and conserving whitebark pine ecosystem condition in the GYA and describes the Whitebark Pine Subcommittee and their work to date, which aims to:

- Ensure natural regeneration and genetic diversity through protection of cone-bearing whitebark pine.
- Maintain and restore the role of whitebark pine in ecosystem function.
- Augment natural regeneration through strategic planting.
- Promote population resilience through genetic conservation and planting of rust resistant seedlings.
- Promote fire planning and use that protects high value whitebark pine and provides for long-term restoration.
- Work collaboratively across administrative boundaries to implement the strategy for the GYA.

Section 2. Methods

Describes the assessment and prioritization of whitebark stands in the GYA by the Whitebark Pine Subcommittee, which has

- Sponsored work to map and characterize whitebark pine stands across the GYA.
- Support long-term monitoring to track status and health trends of whitebark pine.
- Developed ecological criteria to determine each stand's priority for restoration and protection.
- Enabled further prioritization among stands by considering logistical factors such as land status and distance from roads or other access.

Section 3. Site Selection, Management Strategies, and Action Plan
Describes how whitebark stands within the GYA will be selected for management actions and addresses considerations for resistance, resiliency, and adaptive management relative to climate change. A three-year action plan based on current restoration and protection efforts and priorities is also presented.

Section 4. Tools for Protection and Restoration of Whitebark Pine Stands
Describes potential tools and techniques for protecting and/or restoring whitebark pine stands.

PROTECTION	RESTORATION
· Apply verbenone and carbaryl to prevent mortality due to mountain pine beetle. · Prune to remove blister rust infection and/or improve fire resistance. · Prevent loss of high value whitebark pine trees from fire. · Natural regeneration.	· Whitebark pine seed orchard. · Participation in whitebark pine genetic conservation program. · Collect whitebark pine seeds and cones. · Plant whitebark pine seedlings and seeds. · Guidelines and limitations for fire in whitebark pine stands. · Creation of nutcracker openings. · Thinning. · Natural regeneration.

Contents

Section 1. Purpose and Need, the Whitebark Pine Subcommittee, and Strategic Objectives

Purpose and Need

Whitebark pine is a critical component of high elevation ecosystems and is declining range-wide, including substantial overstory losses in the greater Yellowstone area (GYA). The purpose of this Whitebark Pine Strategy is to promote the continued presence of functioning whitebark pine ecosystems in the GYA by establishing management objectives and techniques, coordinating management efforts, and prioritizing remaining whitebark pine sites for protection and for restoration in areas where impacts from loss are likely the greatest.

Whitebark pine (*Pinus albicaulis*) is one of only six conifer species that commonly occur in the GYA. It is a five-needled pine with a limited range in the mountains of western North America. Whitebark pine is found on 10% or 2.5 million acres of the 24-million-acre GYA, in pure stands on harsh, high-elevation sites and in mixed conifer stands just below the timberline. Most of these stands are on land managed by the US Forest Service (USFS) or the National Park Service (NPS). Whitebark pine exhibits influence on ecosystem processes at multiple scales and serves as both a keystone and foundation species throughout the western United States and Canada. A keystone species is one which has an ecological role disproportionately large relative to its abundance, and a foundation species is one that defines ecosystem structure, function, and process (Tomback et al. 2001). As a foundation species, whitebark pine is often the initial colonizer on sites with difficult growing conditions due to high snow loads, poor soil development, and short growing seasons. Once established, it ameliorates site conditions, enabling other plant species to colonize (Callaway 1998). Whitebark pine regulates soil development, carbon storage, and capture and retention of snow, thus increasing the quantity and duration of summer runoff. This protracted melt provides water to feed streams and riparian communities longer into the growing season as well as a consistent flow to downstream water users (Arno and Hoff 1990). The whitebark pine's large, protein-rich seeds are an important food source for birds, squirrels, black and grizzly bears, and other mammals (Lorenz et al. 2008; Tomback et al. 2001).

Wide-spread loss of whitebark pine has occurred throughout its range due to extensive mortality from mountain pine beetle (*Dendroctonus ponderosae*) activity that began in approximately 1999 and due to damage from white pine blister rust (*Cronartium ribicola*; Logan et al. 2010). Concern for whitebark pine is increasing as mortality becomes evident across the GYA and as the effects of climate change are better understood (Bentz et al. 2010). Whitebark pine is highly vulnerable to infection by blister rust, with approximately 26% of the GYA population showing genetic resistance to the rust (Hoff et al. 2001; Kinloch 2003; Mahalovich et al. 2006). Blister rust reduces whitebark's ability to reproduce by killing cone-bearing branches, seedlings, and eventually mature trees (Tomback et al. 1995). Whitebark pine is also highly susceptible to infestation by the mountain pine beetle (Six and Adams 2007; Bockino 2008; Logan and Powell 2004). In addition, potential changes in habitat availability and competitive relationships with other forest tree species will influence the species' abundance and distribution. On some sites, the replacement of whitebark pine by other tree species may be facilitated if warmer temperatures accompanied by adequate moisture enable other tree species to survive in areas previously dominated by the cold-adapted whitebark pine.

The changing climate in the northern Rockies (Mote et al. 2005; Westerling et al. 2006) influences the survival and proliferation of both pathogenic agents impacting whitebark pine. Conventional wisdom held that whitebark pine ecosystems were simply too cold for bark beetles. However, the intensification of bark beetles within their historical range and expansion into high elevation ecosystems over the past decade is unprecedented and attributable to uncharacteristic temperature and precipitation patterns associated with a warming climate (Logan et al. 2010; Logan and Powell 2001; Bentz and Mullins 1999). The role of climate change in driving blister rust incidence and severity is less understood. High humidity and warm weather provide better conditions for blister rust, but cold and dry conditions have not limited its spread to higher elevations in the GYA where it has been present since at least 1945 (Kendall and Keane 2001; Newcomb 2003). The magnitude of these impacts has placed whitebark pine in a precarious situation. Interpretation of 2007 satellite imagery by the US Department of Agriculture Remote Sensing Applications Center indicated over 40% of whitebark stands in the GYA contained some level of canopy mortality (Goetz et al. 2009). Data from the 2008 Forest Health Protection aerial survey in the GYA found beetle activity in more than 50% of whitebark stands. Most recently, during the summer of 2009, aerial evaluation at a sub-watershed level documented the spatial extent and severity of whitebark pine damage from mountain pine beetle outbreaks across the entire GYA. Data from this project indicates that over 50% of whitebark stands in the GYA have already suffered high to complete mortality of overstory trees and 95% of forest stands containing whitebark pine have measurable mountain pine beetle activity (MacFarlane et al. 2009). Blister rust is wide-spread and continuing to increase in incidence and severity. Infection rates in monitored GYA plots average 20% (GYWPMWG) and range from 0% to 84% (Schwartz et al. 2007; Bockino 2008; Bockino and McCloskey 2010). The magnitude of whitebark pine loss in the GYA is consistent with rates for surrounding regions. In the northern Rocky Mountains mortality is as high as 90% (Gibson et al. 2008) and interior Columbia Basin whitebark populations have declined by at least 45% (Keane and Kendall 2001).

The deterioration of whitebark pine stand conditions across its range are widely recognized and in 2009 whitebark pine was petitioned for listing under the Endangered Species Act. In July 2010, the US Fish and Wildlife Service announced that petition warranted further investigation. The assessment is expected to be completed in summer 2011.

The Greater Yellowstone Coordinating Committee Whitebark Pine Subcommittee

With the mission to "work together to help ensure the long-term viability and function of whitebark pine in the Greater Yellowstone Area," the Whitebark Pine Subcommittee is composed of representatives from each of the six national forests and two national parks that are members of the Greater Yellowstone Coordinating Committee (GYCC). The group has worked successfully across unit boundaries and differences in agency culture to address a series of issues. When the subcommittee was established in 2000, the mapping of whitebark pine in the GYA was limited; blister rust were not consistently monitored; and mountain pine beetle activity was low. Several efforts to address the need for a GYA-wide map culminated in the *2010 Whitebark Pine Distribution and Condition Assessment for the Greater Yellowstone* (GYCCWBPSC 2010), which includes map attributes with common definitions across unit boundaries. It uses the most recent mapping available for each unit, whether produced from air photo interpretation, Landsat image analysis, or other vegetation mapping techniques.

Recognizing that the increased incidence of white pine blister rust threatened the health of whitebark pine in the GYA, the Whitebark Pine Subcommittee collaborated with the US Geologic Survey (USGS) and the NPS to form the Greater Yellowstone Whitebark Pine Monitoring Working Group (GYWPMWG). In 2001, the NPS Greater Yellowstone Monitoring Network (GRYN) in partnership with the GYWPMWG developed the *Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem* to monitor blister rust severity and distribution in the GYA. A total of 176 monitoring sites in 150 stands were established and each site was to be remeasured every four years. However, in response to dramatic increases in mountain pine beetle-caused mortality, sites have been read every two years since 2007 to document beetle-caused mortality. This is a long-term monitoring program that will continue to assess the health, status, and population dynamics of whitebark pine in the GYA indefinitely.

By 2004, some areas of the GYA were experiencing significant whitebark pine mortality and the Whitebark Pine Subcommittee began to address the need for management of the species. At about the same time, the USFS Tree Improvement Program established protocols for testing phenotypically blister rust resistant whitebark pine as part of a whitebark pine genetic restoration program for the Intermountain West (Mahalovich and Dickerson 2004). Initially, phenotypically rust resistant trees were identified in areas within six GYA forests with high blister rust infection rates. Since 2006, cones from these "plus" or "superior" trees, which have been treated to protect them from mountain pine beetle, have been harvested. In 2006, Grand Teton and Yellowstone national parks joined the program, identifying and harvesting cones from 16 additional trees. By 2008, the minimum number of tree families required for the Greater Yellowstone/Grand Teton seed zone had been collected. The USFS Tree Improvement Program initiated propagation of seeds from the Greater Yellowstone/Grand Teton whitebark pine seed zone in 2008 to begin blister rust screenings. Seedlings were innoculated in 2010. The initial results of these screenings will be available in July 2011; final results will be available in December 2013. A representative sample of survivors from the blister rust screening will be established at the Little Bear orchard site on the Gallatin National Forest in 2014.

Each unit in the GYA also collects cones from phenotypically rust resistant trees to provide for more immediate operational and restoration needs. GYCC funds and successful competition for limited USFS whitebark pine restoration funds have enabled the subcommittee to collect a large number of cones representing a varied gene pool across the range of whitebark pine in the GYA. A portion of cone collection focuses on sites of known blister rust resistance, cold hardiness, and growth rate as identified in a 1999 seed source study (Maholovich et al. 2006).

In 2006, the Whitebark Pine Subcommittee developed the GYA Decision Guidelines for Whitebark Pine Restoration, which evolved into the current Whitebark Pine Strategy for the GYA. The change in name reflects the recognition that protecting existing live whitebark pine is integral to maintaining functioning whitebark pine ecosystems and is as important as more traditional restoration techniques such as seedling propagation and outplanting. Development of the Whitebark Pine Strategy has led to the following interim products:

- The *2009 GYA Whitebark Pine Distribution Map* (GYCCWBPSC 2009, completed by Bockino, Whitley, and Mellander, a USFS and NPS cooperative effort).
- An annotated bibliography of whitebark pine literature, updated annually (Bockino 2010) posted at: http://fedgycc.org/WhitebarkPinePublicationsandArticles.htm.
- A change detection analysis by the USFS Remote Sensing Applications Center that identified change in whitebark pine canopy condition from 2000 to 2007 (Goetz et al. 2009).
- The *2010 Whitebark Pine Distribution and Condition Assessment for the Greater Yellowstone* (GYCCWBPSC 2010, completed by Bockino and Macfarlane as a USFS and NPS cooperative effort), which includes:
  - an update to the 2009 Whitebark Pine Distribution Map, and
  - a spatially explicit dataset that combines multiple data sources to create an ecologically-based score indicating each whitebark pine stand's need for protection and restoration activities.

Strategic Objectives for Whitebark Pine Management

Whitebark pine occurs in stands and patches where it is dominant as well as sites where it is part of a mixed forest, most frequently with Engelmann spruce or subalpine fir, but also with lodgepole and Douglas fir. Whitebark pine grows as full height trees and as krummholtz where continued exposure to harsh wind, cold temperatures, and short growing seasons cause the trees to grow in short, dense mats (Arno and Weaver 1990). As one of the few high elevation tree species in the GYA, whitebark pine provides numerous ecosystem services with significant and complex ecosystem effects (Tomback et al. 2001).

The strategic objectives of this strategy document are:

A. Provide a basis for collaboration among the federal land management agencies in the GYA to promote effective conservation of whitebark pine across administrative boundaries.

- **Under the guidance of the Whitebark Pine Subcommittee, coordinate the prioritization of restoration and protection sites for whitebark pine in the GYA.**
- **Promote consistent whitebark pine management goals, objectives, strategies, and guidelines.**
- **Support long-term monitoring through the use of the GYWPMWG monitoring protocol.**
- **Promote consistency of the Whitebark Pine Strategy for the GYA with the Management Guide to Whitebark Pine Forests of the Northern Rocky Mountains (Keane and Parsons 2010).**

- **Coordinate funding requests and projects to maximize limited financial and personnel resources.**
- **Ensure that the most recent research is incorporated into whitebark pine management actions.**

Whitebark pine ecosystem function and the current decline in the GYA is a landscape-level issue. For example, the protection of live whitebark pine on one administrative unit can provide a seed-source to neighboring units. The Whitebark Pine Subcommittee also promotes collaboration across the GYA by working with other groups that address whitebark pine issues. For example, the committee coordinates information-sharing events with the Whitebark Pine Ecosystem Foundation.

B. Protect the remaining cone-bearing whitebark pine throughout the GYA.

- **Protect mature and cone-bearing trees from insect and disease-induced mortality.**
- **Promote genetic diversity and conservation through protection of spatially distributed mature whitebark pine trees.**
- **Promote the protection of cone-bearing trees through coordination with fire management and recreation management staff.**
- **Increase knowledge of the ecosystem services provided by mature whitebark pine.**

Whitebark pine losses due to the mountain pine beetle are extensive and increasing. Interpretation of 2007 satellite imagery by the USDA Remote Sensing Applications Center indicated that more than 40% of whitebark pine stands contained some level of canopy mortality (Goetz et al. 2009). Data from the 2008 Forest Health Protection aerial survey in the GYA found beetle activity in more than 50% of whitebark pine stands. Most recently, the *Landscape Assessment of Whitebark Pine in the GYA*, a classification of overstory mortality based on aerial surveys, indicated that more than 50% of whitebark pine stands in the GYA have already suffered high to complete mortality of mature trees and 95% of forest stands containing whitebark pine have measurable mountain pine beetle activity (MacFarlane et al. 2009). All of this data has been incorporated into this Whitebark Pine Strategy for the GYA.

Mortality from white pine blister rust primarily occurs in smaller diameter trees and seedlings, but rust incidence is widespread and its severity is increasing. In the GYA, rust infection rates are spatially variable and as high as 84% (Schwartz et al. 2007; Bockino 2008; Bockino and McCloskey 2010); rates in monitored plots average 20% in the GYA overall (GYWPMWG) and 43% in Grand Teton National Park (Bockino and McCloskey 2010). In mature trees with blister rust infection, cone production is reduced due to branch and upper bole mortality. While the condition of the overstory can be assessed through aerial surveys and remote imagery, understory conditions must be monitored through ground-based surveys. Ground-based regeneration surveys are underway. Although preliminary data indicate that understory whitebark pine are present in many stands (Fothergill 2010; Larson and Kipfumueller 2010; Bockino, in preparation), it is not known if this understory will survive to cone-bearing age or release in response to canopy loss. These data also show that some whitebark pine forests that burned between 1946 and 1988 do not have substantial whitebark pine regeneration. Long-term monitoring of whitebark pine using existing monitoring plots and protocol will capture trends in understory populations over time. Protection of the remaining cone-bearing whitebark pine is critical so that there is sufficient seed to regenerate disturbed areas.

C. Maintain and restore the role of whitebark pine in ecosystem function.

- **Protect whitebark pine growing on harsh, exposed sites.**
- **Reduce forest fuels in and down slope from whitebark pine stands.**
- **Plant whitebark pine to increase biodiversity, anticipating vegetation response to climate change.**
- **Emphasize maintaining and restoring whitebark pine stands inside the grizzly bear Primary Conservation Area/Recovery Zone and in other areas occupied by grizzly bears.**

A long-lived, slow-growing tree species, whitebark pine establishes on a wide range of sites. Whitebark pine withstands high winds, cold temperatures, heavy snowpack, and drought (Arno and Weaver 1990). It is relatively shade intolerant and colonizes open areas with poor soil development. The influence of whitebark pine on ecosystem function is likely greatest where whitebark pine is dominant. In mixed stands, its role in snow capture and retention, soil development, and species diversity may be less crucial as it can be carried out by other tree species.

In the GYA whitebark pine seeds are an important food source for grizzly bears, black bears, and many other mammal and bird species (Lorenz et al. 2008). Grizzly bears obtain the whitebark pine seeds by digging up cones hoarded by squirrels in middens. The impact of whitebark pine cone production on a variety of life history and demographic parameters for grizzly bears in the GYA is well documented (Mattson and Reinhart 1994). Whitebark pine cone production influences rates of movement, diet, number of mortalities, distribution of bears, probability of survival, and fecundity (Schwartz et al. 2006; Haroldson et al. 2006; Mattson 2001). During years without high cone production, conflict between bears and humans tends to be higher.

D. Ensure whitebark pine regeneration and genetic variability through natural and assisted regeneration.

- **Protect remaining mature seed source trees to ensure propagule availability.**
- **Consider impacts to whitebark pine stands and regeneration when designing and managing resource benefit and prescribed fires.**
- **Reduce fuels near and in areas of extensive natural regeneration and restoration investments.**
- **Collect seed from rust-resistant individuals for outplanting.**
- **Provide rust-resistant seed stock through the establishment and maintenance of the GYA whitebark pine seed orchard, including monitoring of characteristics, genetics, and performance.**
- **Augment natural regeneration through strategic planting.**
- **Support research and monitoring to further our understanding of regeneration dynamics.**

Whitebark pine is a “masting” species—the annual cone crop abundance varies such that in some years more seeds are produced than are consumed by foragers, leaving some available for germination. In other years seed foragers and dispersers find sparse or non-existent seed crops. Large cone crops are most commonly produced every three years and can be synchronous across large areas. In 2009, for example, more than 70% of the GYA experienced a large cone crop.

The primary disperser of whitebark pine seeds is the Clark’s nutcracker. The relationship between the two species is often described as a co-evolved mutualism (Tomback and Linhart 1990); however, the pine may be more dependent on the nutcracker than the bird is on the tree. Nutcrackers are known to consume the seeds of several other tree species present in the GYA, both during the winter and in low seed years. Clark’s nutcracker harvests seeds in the fall and carries them in its sublingual pouch before caching them in a variety of locations for future retrieval and feeding. Whitebark pine seedlings are often found in clumps representing seed caches that the nutcracker did not retrieve. The sharp bill of the Clark’s nutcracker scores the seeds it caches, nicking the thick seed coat, allowing moisture to penetrate into the seed and promoting germination (Tomback 1978).

While nutcrackers are a beneficial seed disperser, they consume more seeds than they leave behind, and have been observed to cache seeds more than 10 kilometers from the source tree, storing them nearer their home range and nesting sites. As whitebark pine seeds become scarce on the landscape due to tree mortality and blister rust infection, the nutcracker’s role may become that of seed predator more than of seed disperser. The nutcrackers and red squirrels both harvest seeds rapidly in late summer and fall. Red squirrels gnaw cones from the branches and then retrieve them on the ground, stashing them in middens. At the time of seed ripening in August and early September, whitebark pine stands are alive with the sounds of birds and squirrels actively engaged in gathering seeds. Black bears also harvest cones by climbing into the trees and retrieving them, while grizzly bears commonly obtain seeds by raiding squirrel middens (Lanner 1996).

Analysis of nutcracker distribution and foraging behavior indicates that when cone supplies become too scarce in an area, the birds relocate to productive sites, even if those sites do not contain whitebark pine. The exact level of seed production required to maintain a nutcracker population is not clear, but is related to variables such as the cone productivity of other nearby tree species, distance to healthy stands, and topography (Barringer

2010). Evidence indicates that there is probably a threshold of whitebark pine seed production that supports nutcracker use of a stand; if this threshold is not met, the likelihood of seeds from that stand being dispersed and germinating is greatly reduced (McKinney et al. 2009; McKinney 2007).

Protection refers to intentional management actions to prevent mortality in particular whitebark pine trees or stands of trees. Actions include the use of a pesticide (carbaryl) and a synthetic pheromone (verbenone). Their use is intended to protect both the genetic variability of whitebark pine and its ecosystem functions, particularly in high elevations stands where whitebark pine is the dominant tree, provides wildlife habitat, and plays an important role in hydrologic function, carbon storage, and soil maintenance and development.

E. Promote fire planning and use that protects high-value whitebark pine resources and provides for long-term whitebark pine restoration.

- **Promote interaction between fire managers and the Whitebark Pine Subcommittee to identify locations where fire may be beneficial or detrimental to whitebark pine.**
- **Develop site-specific whitebark pine/fire management goals, objectives, and guidelines, and incorporate them into fire management plans.**
- **Promote fire as a natural element in whitebark pine forests when fuel loading and stand structure will support low to moderate fire.**
- **Identify sites that will benefit from post-fire planting.**

Fire is a dominant disturbance element in the forested ecosystems of the northern Rocky Mountains. It is suggested that unplanned ignitions will grow larger and occur more often as climate change continues to alter temperature and precipitation patterns (Westerling et al. 2006). It is recognized that in some forests climatic conditions and, to a lesser extent, fire suppression have resulted in structure and composition that may be uncharacteristic of historical conditions. It is important that planning for fire for resource benefit and prescribed fire incorporate site-specific goals, objectives, and management considerations that will foster the persistence of whitebark pine on the landscape.

The historical role of fire in GYA whitebark pine stands and in maintaining viable whitebark pine ecosystems is unclear. Though it has been suggested that fire suppression is linked to a decline in some whitebark pine forests in the past century, the current stand conditions in the GYA are such that fire may prove detrimental in many stands. In addition, the high degree of variability among whitebark pine stand structures and fire dynamics throughout its distribution indicates an equally variable role of fire (Larson 2009; Walsh 2007). In some stands, the likely role of fire would be to decrease competition from other tree species, particularly sub-alpine fir, while creating forest openings where nutcrackers may cache whitebark pine seeds. Due to reduced seed production in blister rust infected trees and the loss of mature cone-bearing trees to mountain pine beetle, the likelihood of successful natural seedling establishment in fire-produced openings is reduced. Keane and Parsons (2010) long advocates of the use of fire to produce opportunities for “natural regeneration” in whitebark pine, have stated that managers must be prepared to plant whitebark pine seedlings in burned whitebark pine stands. This recognition that the likelihood of natural regeneration following fire has been greatly reduced is indicative of the condition of whitebark pine in the GYA and throughout its range (Klutsch et al. 2009; Bockino, in preparation).

The extensive loss of whitebark pine has made protecting individual trees and stands from fire an important management strategy. The parent or “plus” trees of the seedlings being grown from the GYA seed zone have been identified as phenotypically resistant to white pine blister rust and will likely provide valuable genetic material in the future. GYA fire managers have been notified of the locations of these trees so that they can be considered for fire protection. Similarly, healthy whitebark pine stands with high cone production are genetic reservoirs for future regeneration. As whitebark pine cone availability has vastly decreased on the landscape, the importance of each cone-bearing tree and stand increases (Barringer 2010; McKinney et al. 2009). The affect of fire on these sites to the overall health of the whitebark pine in the GYA should be considered in fire management decisions when practical. Management actions may be used on some sites to allow or encourage fire while still protecting high value whitebark pine through pre-fire thinning and movement of fuels away from whitebark pine boles.

Section 2. Methods

One premise behind this strategy is that existing whitebark pine forest conditions in the GYA should guide management actions and site prioritization at stand and landscape levels. This recognizes that actions taken or not taken in one part of the GYA could affect conditions in other parts.

Considerations and prioritization of management actions are GYA-wide. They are based primarily on the condition assessment described below, secondarily on the ecosystem values connected with particular sites, and thirdly on logistic feasibility. Maps are provided that show whitebark pine condition, ecosystem considerations, and land status, e.g., forest, park, wilderness, or roadless area.

Whitebark Pine Map

The GYCC Whitebark Subcommittee defined attributes for a whitebark pine map of the GYA that included a classification of whitebark pine cover types, size class, and canopy class that is consistent across all units. The classification formed the basis for the creation of the *2009 GYA Whitebark Pine Distribution Map* (completed by Bockino, Whitley, and Mellander, a USFS and NPS cooperative effort). The map was built on two previous efforts that used different primary sources: one based on Landsat imagery and the other on a 1985-based vegetation map. The 2009 map incorporated the most current vegetation maps available from each unit. Source data varied among administrative units, including different attributes, spatial resolution, and year of data collection. These varying data were examined for their commonality and reclassified to create a consistent whitebark pine layer with common attributes.

In April 2010, further data analysis resulted in improvements to the 2009 map. These analyses incorporated new National Agriculture Imagery Program (NAIP) imagery, elevation-based “ecozones,” findings from the 2009 Landscape Assessment System project (Macfarlane et al. 2009), and historical fire perimeter data. The result is the most accurate and current spatial dataset available on the extent of whitebark pine in the GYA, the *2010 Whitebark Pine Distribution and Condition Assessment in the Greater Yellowstone* (completed by Bockino and Macfarlane as a USFS and NPS cooperative effort). The map shows whether the stand is whitebark pine dominant (at least 60% of the tree cover is whitebark pine) or mixed (<60% of tree cover is whitebark pine), total canopy cover, whether the stands are mature (seed-producing) or immature (non-seed-producing), stand-level mortality, and prioritization status (described below). Table 1 lists the acres of whitebark pine on each of the GYCC administrative units.

Table 1. GYA whitebark pine distribution and acreage by administrative unit as of December 2010, % whitebark pine (WBP) refers to the percent of the unit's total acreage that is occupied by whitebark pine, % GYA whitebark pine refers to the % of total GYA whitebark acres that occur in this administrative unit.

GYA WHITEBARK PINE DISTRIBUTION						
Administrative Unit	**Total Land Area (acres)**	**WBP Acres**	**% Unit WBP**	**% Total GYA WBP by Unit**	**Dominant Stands (acres)**	**Mixed Stands (acres)**
Beaverhead-Deerlodge	967,703	150,626	15.6%	6.0%	**89,999**	**60,626**
Bridger-Teton	3,465,130	534,845	15.4%	21.2%	**269,570**	**265,273**
Caribou-Targhee	1,867,720	72,341	3.9%	2.9%	**50,266**	**22,074**
Custer	525,317	146,249	27.8%	5.8%	**66,454**	**79,792**
Gallatin	2,225,194	656,936	29.5%	26%	**303,724**	**353,210**
Grand Teton	333,327	28,500	8.6%	1.1%	**9,726**	**18,775**
Shoshone	2,468,072	624,825	25.3%	24.7%	**217,270**	**407,553**
Yellowstone	2,197,953	314,000	14.3%	12.4%	**307,588**	**6,410**
GYA Total	**14,099,767**	**2,528,322**	**17.9%**	**100%**	**1,314,597**	**1,213,713**

Whitebark Pine Stand-Level Condition Assessment

A stand condition assessment was completed for the whitebark pine mapped in the *2010 Whitebark Pine Distribution in the GYA*. The analysis used spatial data on canopy damage and stand structure to assign an ecologically-based score to each whitebark pine stand in regard to its priority for protection and restoration. The Whitebark Pine Subcommittee selected two variables (canopy damage and stand structure) based on their accuracy and GYA-wide coverage. Input data for the condition assessment of each stand includes numerical rankings of categories within the following attributes (Table 2):

- The **c*anopy damage*** score is based on (1) Landsat imagery, from which is derived conifer canopy change from 2000 to 2007; (2) the Landscape Assessment System report on mountain pine beetle-caused mortality in mature whitebark pine in the GYA; and (3) the framework of attributes defined by the subcommittee in 2009.
- The ***stand structure*** score is based on two attributes from the 2010 Whitebark Pine Distribution Map: relative canopy cover (open, moderate, or closed) and stand type: dominant (>60% relative canopy cover whitebark pine) or mixed (<60% relative canopy cover whitebark pine).

Canopy damage and stand structure scores for each polygon were mathematically combined to estimate the stand's ***overall current stand condition score*** to determine its priority for protection and restoration activities. This combined stand condition score ranges from 0 to 9 (Table 2; Figures 1 and 2).

Whitebark pine's pivotal role in maintaining high elevation ecosystem function is likely greatest in stands where it is the dominant forest species. In these stands whitebark pine is the main component, creating a forested habitat and providing associated ecosystem services. Loss of these whitebark pine stands will result in changes to hydrology, wildlife habitat, soil development, plant community composition, and other ecosystem services. In mixed stands other forest species may be able to provide some of these services. The ecosystem function value of whitebark pine stands is incorporated into stand prioritization through a data query for whitebark pine dominant stands with low mortality (Figures 3 and 4).

Whitebark pine polygons with the highest relative abundance of healthy, cone-bearing trees receive a high score for protection, while stands with high mortality and low cone production receive a high score for restoration. A stand with some mortality and some surviving mature trees could be a relatively high priority for both protection and restoration. Due to variability in stand condition and assessment variables, a stand may receive a high priority rating for protection and low for restoration or vice versa.

Tables 3, 4, and 5 contain the total number of acres with high stand condition scores (7 to 9) for protection or restoration and the number of acres by GYA administrative unit.

Ground verification was necessary to:

- determine and verify conditions that cannot be seen from the air, such as the presence or absence of whitebark pine regeneration, understory trees, and the degree of blister rust infection of live trees.
- identify conditions that have changed in the past year, including mortality and mountain pine beetle infestation.
- check the accuracy of the Whitebark Pine Condition Assessment, which could be modified if warranted.

Field surveys were conducted in 2010 to verify the conditions in stands designated high priority for restoration or protection. Preliminary summary data is currently available, and data analysis for ground verification efforts during 2010 will be completed in summer 2011.

Table 2. Scoring system for stand condition assessments to determine priority for protection and restoration.

Whitebark Pine Stand-level Condition Assessment		
	Protect	**Restore**
Canopy Damage Score (Integration of: Landscape Assessment 2009, RSAC Landsat Imagery Canopy Change 2000–07, Condition Assessment 2009)		
A. Very low canopy damage; current mountain pine beetle activity none to very low (LAS 0–0.9)	**5**	**0**
B. Low canopy damage; current mountain pine beetle activity low (LAS 1.0–2.0)	**4**	**0**
C. Moderate canopy damage; current mountain pine beetle activity moderate (LAS 2.1–3.0; RSAC 20–39)	**3**	**2**
D. High canopy damage; current mountain pine beetle activity low (LAS 5.0–5.5; no RSAC equivalent)	**3**	**4**
E. High canopy damage; current mountain pine beetle activity very high (LAS 3.1–4.9; RSAC 20–39)	**2**	**4**
F. Canopy loss to fire (RSAC 0–4; 79–100)	**1**	**4**
G. Very high canopy damage; current mountain pine beetle activity very low (LAS 5.6–6.0; no RSAC equivalent)	**1**	**5**
Stand Structure Score (stand type and canopy cover)		
A. WBPD stand and closed/moderate canopy cover	**4**	**4**
B. WBPD stand and open canopy cover	**3**	**3**
C. WBPMX stand and closed/moderate canopy cover	**2**	**2**
D. WBPMX stand and open canopy cover	**1**	**1**
E. Burned stands	**0**	**0**
Overall Current Stand Condition Score (canopy damage and stand structure)	**1–9**	**0–9**

Additional Data to Refine Prioritization

In addition to the above assessment, the following variables in site prioritization are provided as spatial overlay files, rather than being integrated into the overall stand condition score.

Grizzly Bear Habitat

The value of whitebark pine as grizzly bear habitat is determined through an analysis of stand type (dominant or mixed) and location relative to the Primary Conservation Area (PCA) and areas identified as occupied grizzly bear habitat (IGBST 2009) (Table 6). Grizzly bears are a highly valued wildlife species in the GYA and human-related mortality is undesirable. The goal of the grizzly bear conservation strategy is to manage grizzly bear habitat within the PCA to sustain a recovered Yellowstone grizzly bear population. As the role of whitebark pine in providing an important food for grizzly bears has long been recognized in the GYA, whitebark pine is considered part of grizzly bear habitat. This spatial layer was not assigned restore or protect values, as to allow for site-specific assessments.

Access and Land Status

The amount of funding, time, and energy needed to complete a project is dictated in large part by road and trail access to each whitebark pine stand. Cone caging and collection, protection with verbenone pouches, and other low impact operations would not be as impaired by difficulty of access as would other activities such as thinning, prescribed fire, or planting tree seedlings. Information to evaluate the ease of access is available in roads and trails datasets.

Differentiation among land status designations is a critical component in accurately prioritizing whitebark pine for management actions. Areas of mapped whitebark pine were classified by land status using these designations, which can be used to assess the challenge of implementing management actions:

- Wilderness areas, which include designated and recommended Wilderness Areas and Wilderness Study Areas.
- Research Natural Areas and designated, proposed, and recommended Wilderness areas.
- Inventoried roadless areas and non-wilderness national park areas.
- Other areas within national forests and national parks.

All management within wilderness areas must preserve wilderness character as directed by the Wilderness Act of 1964. A key aspect of wilderness is that it is an “area where the earth and its community of life are untrammeled by man” and the area “generally appears to have been affected primarily by the forces of nature”. The word “untrammeled” was carefully chosen to convey that wilderness should be a place that is not controlled or manipulated by humans, where humans display restraint so the area is self-willed. However, wilderness is also defined to be a place “which is protected and managed so as to preserve its natural conditions.” In accordance with the Wilderness Act, the Forest Service Manual for Management of Forest Cover and Management of Insect and Diseases (FSM 2323.5, 2323.54, and 2324.1) states:

- Manage forest cover to retain the primeval character of the environment and allow natural ecological processes to operate freely.
- Allow, wherever possible, the natural process of healing in handling disturbed communities. Consider structural or vegetative assistance only as a last resort.
- Allow reforestation only if a loss of the wilderness resource, due to human influence, has occurred and there is no reasonable expectation of natural reforestation.
- Allow indigenous insect and plant diseases to play, as nearly as possible, their natural ecological role within wilderness. Do not control insect or plant disease outbreaks unless it is necessary to prevent unacceptable damage to resources on adjacent lands or an unnatural loss to the wilderness resource due to exotic pests.
- Protect the scientific value of observing the effect of insects and diseases on ecosystems and identifying genetically resistant plant species.
- When control of insects or disease is necessary in National Forest wilderness, it shall be carried out by measures that have the least adverse impact on the wilderness resource and are compatible with wilderness management objectives. Special care must be taken with the use of chemicals inside wilderness because of possible effects on the total biological complex. Consider other alternatives to chemical use in the environmental analysis.

Section 4c of the Wilderness Act (Prohibition of Certain Uses) does not specifically prohibit actions proposed by the Whitebark Pine Strategy as long as there is no use of motorized equipment or mechanical transport. Cutting standing trees is only permitted when necessary for administrative use such as for maintaining trail systems. Within the USFS, proposed use of chemicals requires Regional Forester approval. When considering any action or suite of actions in Wilderness, a Minimum Requirement Analysis is used to answer two key questions (1) is the action necessary, and if so, (2) what is the minimum activity. Step 1 entails four key questions:

1. Is alteration clearly due to human influence (i.e., climate change, blister rust)?
2. Is there no reasonable expectation of natural restoration?
3. Is there a reasonable expectation that the restoration will be successful?
4. Can the restoration objective be accomplished outside of a wilderness area?

Both the USFS and NPS policies address the kind and extent of management activities that can occur in wilderness areas and Research Natural Areas. These areas also require more extensive National Environmental Policy Act scoping and documentation than do other national forest and national park areas. Therefore, these areas, which would present greater logistical challenges, were ranked lower than inventoried roadless areas (IRAs) and other forest and park areas. However, wilderness can and should play a prominent role through long-term monitoring to advance scientific learning regarding the effects of climate change and the effectiveness of restoration treatments at the landscape level.

Management options in IRAs are less restrictive than in designated wilderness, but more restrictive than in other USFS and park areas. For example, fire and planting would be acceptable tools in IRAs, whereas mechanical treatments like thinning are at the discretion of the Secretary of Agriculture. Activities in other areas are governed by their respective management plans. In these areas, the restoration of whitebark pine habitat would generally be acceptable using a variety of tools, and likely consistent with existing management plans and compliance documents.

Genetic Diversity and White Pine Blister Rust Resistance

As further data become available on the distribution of genetic diversity in whitebark pine of the GYA, these data can be incorporated into the prioritization of stands for protection. Likewise, when the distribution of blister rust resistance is known, specific sites with live trees and high resistance may be identified for increased protection as well as additional seed, pollen, and scion collection to support the Little Bear seed orchard. These data are not presently available as an overlay; however, they will be tracked over time and included as a data layer when they become available.

Whitebark Pine Stands with High Priority for Protection

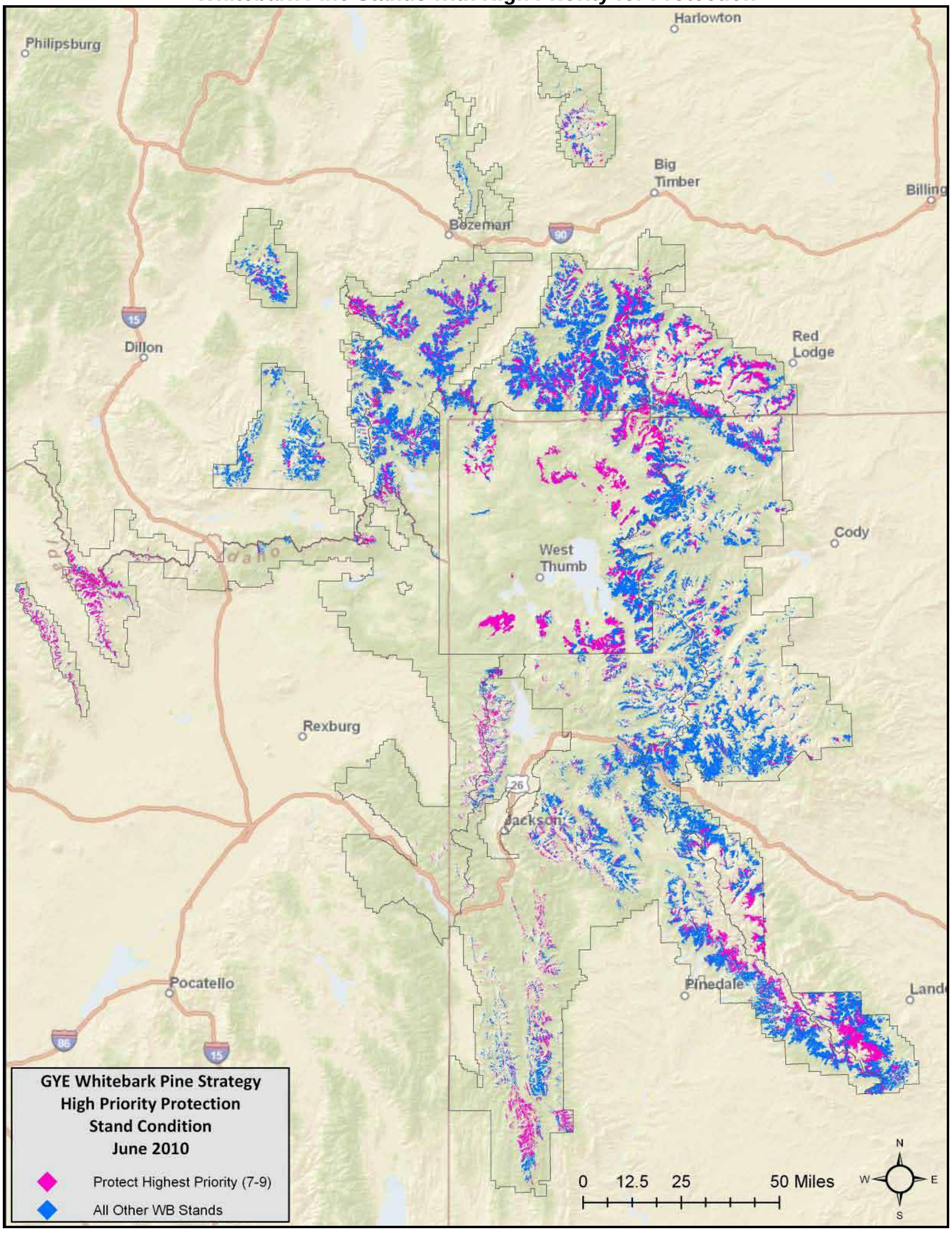


Figure 1. Stands with the highest protection score for overall stand condition are pink; all other stands are blue. All whitebark pine stands are represented on this map.

Whitebark Pine Stands with High Priority for Restoration

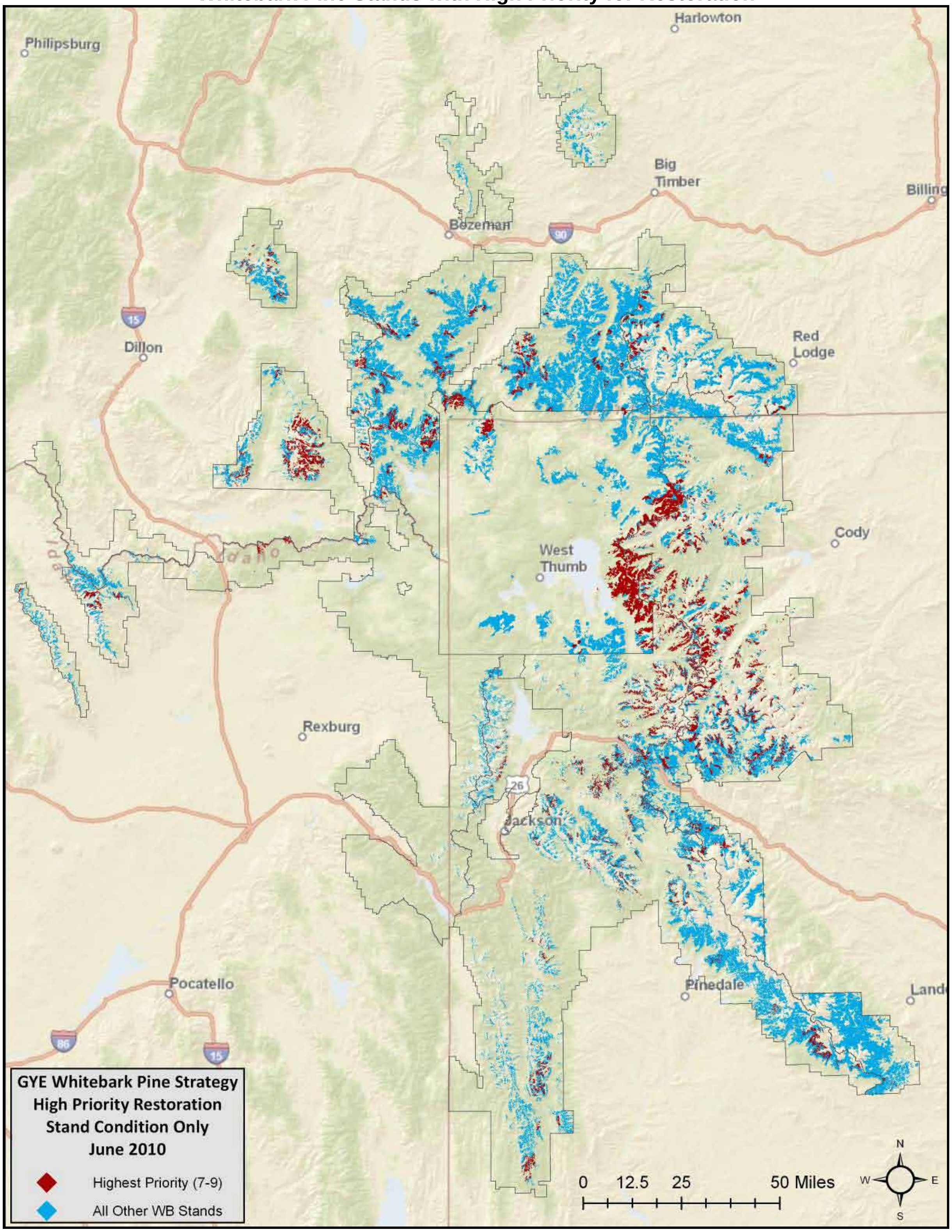


Figure 2. Stands with high restoration score for overall stand condition are red; all other stands are blue. All whitebark pine stands are represented on this map.

Whitebark Pine Stands with High Priority for Protection that Intersect Stands with High Ecosystem Function Value

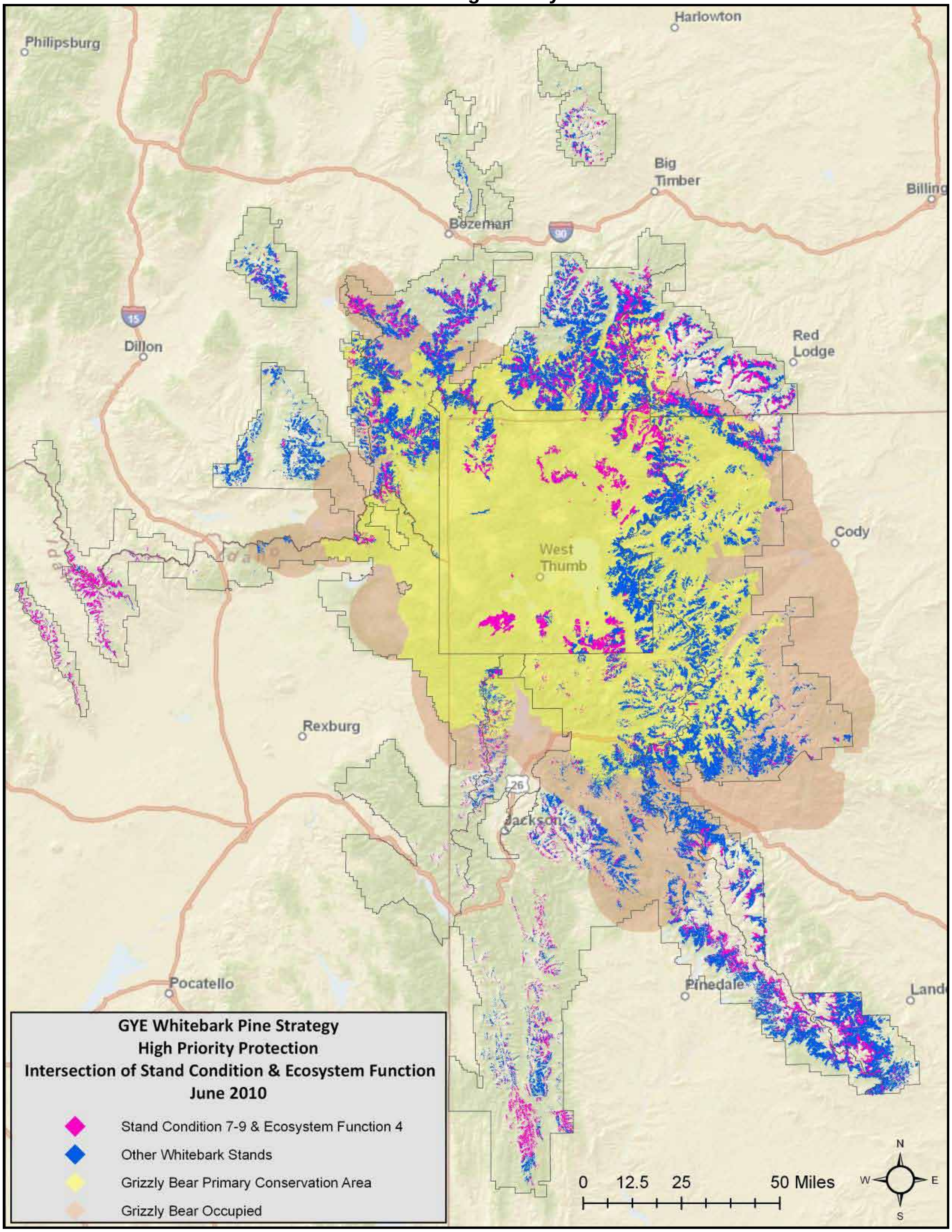


Figure 3. Stands in pink have high protection scores for both stand condition and ecosystem function. High ecosystem function depicted on this map is defined as stands dominated by whitebark pine with low overstory mortality. All other whitebark pine stands are in blue. The grizzly bear PCA and occupied areas are also depicted. All whitebark pine stands are represented.

Whitebark Pine Stands with High Priority for Restoration that Intersect Stands with High Ecosystem Function Value

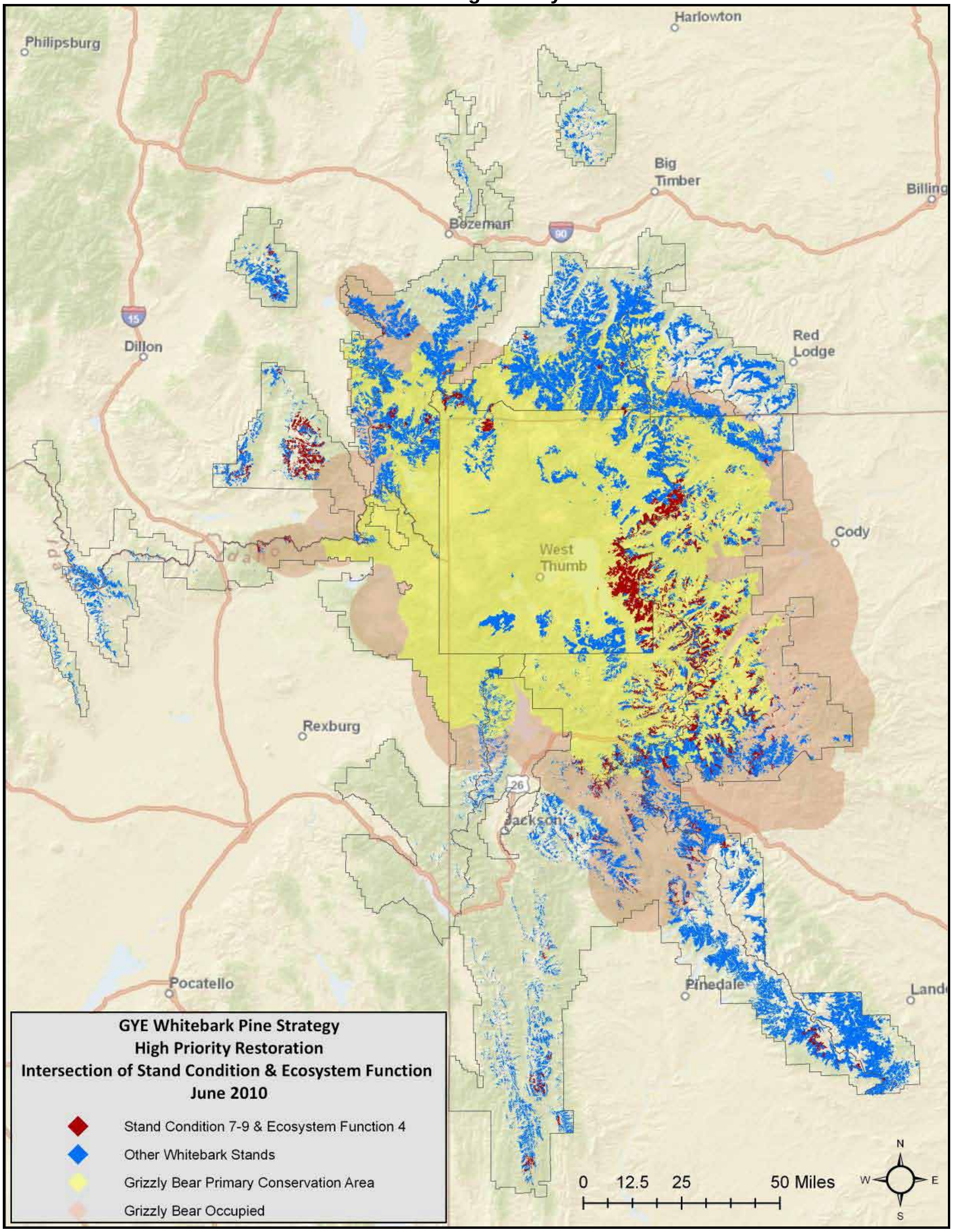


Figure 4. Stands in red have high restoration scores for both stand condition and ecosystem function. High ecosystem function depicted on this map is defined as stands dominated by whitebark pine with low overstory mortality. All other whitebark pine stands are in blue. The grizzly bear PCA and occupied areas are also depicted. All whitebark pine stands are represented.

Table 3. Total GYA acres o whitebark pine in each management category.

TOTAL ACRES WITH STAND CONDITION SCORES 7–9	
Protect	**Restore**
770,607	496,789

Table 4. Acres of whitebark pine by GYA administrative unit and with stand protection scores 7 to 9, and acres of whitebark pine with scores 7 to 9 as a percentage of all whitebark pine acres within that unit.

WHITEBARK PINE STANDS WITH HIGH PROTECTION PRIORITY							
Park/Forest	**Total Acres**	**Acres WBP**	**Stand Condition Score**			**Total 7–9**	**% of all WBP**
			7	**8**	**9**		
Beaverhead-Deerlodge	967,703	150,626	21,298	3,537	1,664	26,499	18%
Bridger-Teton	3,465,130	534,845	91,242	50,996	4,228	146,466	27%
Caribou-Targhee	1,867,720	72,341	26,812	22,071	4,489	53,372	74%
Custer	525,317	146,249	27,091	37,597	10,067	74,755	51%
Gallatin	2,225,194	656,936	135,992	48,100	363	184,455	28%
Grand Teton	333,327	28,500	5,981	4,857	1,889	12,725	45%
Shoshone	2,468,072	624,825	74,226	29,000	14,157	117,383	19%
Yellowstone	2,197,953	314,000	122,272	32,574	106	154,952	49%
GYA Total	**14,050,416**	**2,528,322**	**504,914**	**228,732**	**36,961**	**770,607**	**30%**

Table 5. Acres of whitebark pine by GYA administrative unit and with stand restoration scores 7 to 9, and acres of whitebark pine with scores 7 to 9 as a percentage of all whitebark pine acres within that unit.

WHITEBARK PINE STANDS WITH HIGH RESTORATION PRIORITY							
Park/Forest	**Total Acres**	**Acres WBP**	**Stand Condition Score**			**Total 7–9**	**% of all WBP**
			7	**8**	**9**		
Beaverhead-Deerlodge	967,703	150,626	22,313	22,665	851	45,829	30.4%
Bridger-Teton	3,465,130	534,845	17,205	94,867	7,559	119,631	22.4%
Caribou-Targhee	1,867,720	72,341	478	998	622	2,098	2.9%
Custer	525,317	146,249	13,360	263	0	13,623	9.3%
Gallatin	2,225,194	656,936	20,107	29,780	0	49,887	7.6%
Grand Teton	333,327	28,500	109	429	0	548	1.9%
Shoshone	2,468,072	624,825	40,016	91,824	21,346	153,186	24.5%
Yellowstone	2,197,953	314,000	45,210	54,437	12,340	111,987	35.7%
GYA Total	**14,050,416**	**2,528,322**	**158,798**	**295,273**	**42,718**	**496,789**	**19.6%**

Table 6. Data sets available as overlays for stand prioritization. The grizzly bear habitat attribute is embedded in the *2010 Whitebark Pine Distribution and Condition Assessment Map* and can be evaluated with a data query.

Available Overlays for Further Stand Prioritization
I. Grizzly Bear Habitat (Stand type and spatial proximity to Primary Conservation Area [PCA] and current occupied areas)
ü Whitebark pine dominant stand within PCA
ü Whitebark pine mixed stand within PCA
ü Whitebark pine dominant stand outside of PCA but in occupied grizzly bear habitat
ü Whitebark pine mixed stand outside of PCA but in occupied grizzly bear habitat
ü Other whitebark pine stands, including burned stands
II. Land Status
ü Wilderness areas, including designated and recommended Wilderness Areas and Wilderness Study Areas
ü Research Natural Areas
ü Inventoried roadless areas; national park areas that are not wilderness
ü All other national forest and national park areas
III. Access: Compiled Roads and Trails and as Separate Locally Available Datasets
IV. GYA-wide Compiled Plus Tree and 110-seed Source Locations

Section 3. Site Selection, Management Strategies, and Action Plan

Site Selection

Members of the Whitebark Pine Subcommittee and USFS and NPS managers will consider the priority rating of whitebark pine stands and landscapes when selecting sites for protection and restoration activities. They agree to direct funding opportunities, proposals, and National Environmental Protection Act (NEPA) compliance to address high priority areas based on stand condition and ecosystem values throughout the GYA. This approach recognizes that actions that take place on any jurisdiction may affect the long-term status of whitebark pine throughout the GYA. Protection and restoration maps will be updated annually to reflect management activities that have taken place, changes in whitebark pine condition, and new information or research inputs.

Proposals for actions in whitebark pine will be reviewed by the Whitebark Pine Subcommittee when requested. Although it is not a funding or approving body, the group may be asked to recommend or rank proposals relative to others. Discussion of sites, management techniques, and monitoring plans are usually discussed at fall or spring Whitebark Pine Subcommittee meetings and results are presented at the fall meeting, which serves as an annual research and information meeting.

Other considerations in site selection, not included in condition assessment:

Previous investments—Sites with previous restoration investments or for which seed has been collected and are available for planting might be rated higher.

Connectivity—Because of the limited dispersal distance of Clark’s nutcrackers, sites connected to a large expanse of other whitebark pine might receive higher consideration than areas that are isolated.

National Environmental Policy Act complexity—Projects where NEPA compliance for whitebark pine restoration is covered as a part of a larger restoration project or where NEPA could be accomplished with a categorical exclusion might receive higher consideration than sites where NEPA compliance would be very complex and likely require an environmental impact statement.

Natural restoration potential—Areas where natural ignition is not permitted due to regulatory constraints or where natural fire would be unlikely due to high risks might be ranked higher than areas where either prescribed fire or natural ignition is permitted and is a potentially viable option for restoration.

Likelihood of sufficient funding and manpower—Projects where there is a high likelihood of partnerships that leverage funds or where there are volunteers and grant funding is likely might rate higher than a situation where the land management agency is limited to appropriated funds.

Likelihood of success—Projects where existing research and monitoring supports successful restoration might be ranked higher than projects using techniques that do not have the support of research or monitoring and where there is fair to high risk that the project may not accomplish the stated objectives.

Climate Change

Uncharacteristic precipitation and temperature patterns could impact whitebark pine and whitebark pine restoration by:

- Increasing mountain pine beetle and other insect activity.
- Resulting in temperature and moisture conditions that favor blister rust transmission or other pathogens such as root disease.

- Causing changes in seasonality and precipitation that affect the regeneration niche of whitebark pine and drought stress, growth, and survivorship of mature or juvenile trees.
- Altering fire intensity, size, and season length (Westerling et al. 2006).

As these climate change impacts are better understood, they will affect which management tools are selected at specific sites. For example, climate change may impact which seeds are grown to be planted in a particular site and may eventually alter whitebark pine seed transfer guidelines.

Climate science is currently moving toward regional scaling of climate models and maps to reflect potential climate change outcomes. As scaled regional models or more detailed predictive mapping become available, this information will be incorporated into the annual work plan and future revisions of the Whitebark Pine Strategy.

To take into consideration the uncertainty associated with changing climate, vegetation management strategies can incorporate one or more of the following approaches:

Increase resistance—manage ecosystems to resist changes resulting from climate change.

- Promote a mosaic of age and stand types at the stand and landscape levels.
- Promote genetic diversity through protection of remaining whitebark pine and ensuring genetic variability in planting stock.
- Use carbaryl or verbenone to increase the resistance of individual whitebark pine trees to mountain pine beetles. Carbaryl treatments are preferred when feasible due to significantly greater efficacy.
- Protect, plant, or thin to encourage multiple size and age cohorts.
- Protect and plant on sites where whitebark pine is most competitive.

Increase ecosystem resilience—manage ecosystems to maintain the ability of the system to absorb and rebound following a perturbation or disturbance.

- Promote genetic diversity to increase ecosystem resilience.
- Promote a mosaic of age and stand types at the landscape level.
- Ensure a wide spatial distribution of seed availability on the landscape as well as a genetically diverse seed bank ex situ.
- Where appropriate, thin forest vegetation to reduce drought stress resulting from increasingly warm temperatures associated with climate change.

Enable ecosystem responses to climate change—proactively accommodate change by facilitating ecosystems to respond as environmental conditions change.

- Consider future climatic conditions when selecting planting sites.
- Promote a mosaic of age and stand types at the landscape level.

Three-year GYCC Whitebark Pine Strategy Action Plan

The Whitebark Pine Strategy for the GYA: Three-year Action Plan			
Action	**Quantity**	**Description**	**Unit & Timeframe**
Protection: Reduce mountain pine beetle-caused mortality.	120 trees in blister-rust resistance trials.	Apply carbaryl and/or verbenone on annual basis.	All GYA units where rust trials occurs and high mountain pine beetle infestation persists (2011–2014).
Protection: Reduce mountain pine beetle-caused mortality.	300 acres additional cone-bearing trees total in several units, may increase in 2012.	Apply carbaryl and/or verbenone on annual basis.	Bridger-Teton National Forest, Gallatin National Forest, Shoshone National Forest, Grand Teton National Park, (2011–2013).
Protection of seed-bearing whitebark pine trees from fire.	Areas of remaining live whitebark pine throughout GYA.	Coordinate with fire managers to discourage fire in areas that act as seed reservoirs on a unit or watershed basis.	All units (2011–2014).
Pruning for fire protection.	25 acres.	Pruning.	Gallatin: Cooke City project 2011.
Thinning for fire protection.	120 acres.	Thinning.	Gallatin: Cooke City project 2011.
Restoration: Seed production on seed orchard.	Establish 5-acre orchard with 30–120 rust-resistant trees.	Provide rust resistant seedlings by 2025 for outplanting.	Gallatin National Forest “Little Bear”: Site prep 2011. First planting 2012.
Restoration: Planting.	Within 40,000 acres designated for planting projects.	Plant seedlings.	2011–2013 projects currently in place for: Caribou-Targhee, Bridger-Teton, Shoshone, and Gallatin. Other units will plant as projects are developed.
Restoration: Scion collection.	Collect 25–30 scion from 30–60 trees based on blister rust screening results.	Collect scion from identified rust resistant trees to provide seed for orchard stock.	2011–2013 work to be conducted throughout GYA by Grand Teton and Gallatin climbers.

The Whitebark Pine Strategy for the GYA: Three-year Action Plan, cont.			
Action	**Quantity**	**Description**	**Unit & Timeframe**
Restoration: Cone collection.	20 trees per year.	Maintain reservoir of genetic diversity through operational cone collections, contract and unit tree climbers.	All units: emphasize collections from known resistance in Caribou-Targhee, Shoshone, and Bridger-Teton, and new sites on Gallatin for additional genetic diversity (2011–2013).
Restoration: Sow and grow seedlings.	30,000 per year.	Grow seedlings from collected seed for out-planting.	All units: coordinate funding and timing.
Restoration: Create nutcracker openings.	20 openings.	Remove overstory.	Gallatin: Cooke City project 2011.
Restoration: Daylight understory to release regeneration.	5 sites.	Remove overstory.	Gallatin: Cooke City project 2011.
Long-term monitoring.	176 transects across the GYA includes wilderness and non-wilderness sites.	Support continued implementation of the GYWPMWG monitoring protocol.	Greater Yellowstone Network in partnership with GYWPMWG, Whitebark Pine Sub-Committee and units, ongoing.
Monitoring.	All sites where management actions are taken.	Record treatments and outcomes for further refinement of management techniques.	Gallatin: Cooke City Rx burns/plantings. Caribou-Targhee sites planted in 2010. Bridger-Teton National Forest: Grouse Mountain.
GIS-based mapping.	GYA-wide whitebark pine distribution.	Update whitebark condition, keep track of project areas and acreage, refine site prioritization.	Ongoing by Whitebark Pine Subcommittee.
Develop database including spatial and monitoring data.	GYA-wide database to incorporate and maintain availability of multiple types of data.	Develop and maintain database and guide to available whitebark pine data.	Subcommittee/unit staff in collaboration with Grand Teton and possibly GRYN as repository, ongoing.
Ski area whitebark pine protection.	600 trees.	Collaborate with ski areas to protect remaining whitebark pine.	Ongoing at Jackson Hole Mountain Resort and Grand Targhee.

Section 4. Tools for Protection and Restoration of Whitebark Pine

PROTECTION TOOL: PREVENTING MORTALITY FROM MOUNTAIN PINE BEETLE WITH CARBARYL AND VERBENONE

Purpose of Treatment

- Protect identified plus trees, cone-producing trees, and trees exhibiting blister rust resistance.
- Reducing mountain pine beetle-caused mortality will be a crucial first step in the restoration process (Gibson et al. 2008).

Description of Treatment

- Anti-aggregation pheromones in verbenone help reduce attacks on susceptible trees. Limited effectiveness (50%–90%) for one year (Kegley et al. 2003; Kegley and Gibson 2007; Gillette et. al. 2006).
- Carbaryl is a preventive, registered insecticide spray to reduce attacks on susceptible trees. Provides good protection for 1–2 years.

Treatment Priorities

- Individual plus trees as identified in the GYA.
- Areas/trees identified with high blister rust resistance.
- Areas designated as high priority for protection with moderate beetle pressure, availability of live cone-bearing whitebark pine, and reasonable access.

Verbenone

Effectiveness being tested under varied conditions—estimated at 60% effective with annual application.

1. **Individual Tree Treatment**
   - Staple two pouches per tree from mid- to-late June (could be earlier, depending on when beetles fly).
   - Replace original two pouches with two new pouches by the end of July.
   - Number of pouches could differ depending on pouch size (see label directions).

2. **Stand-Level Treatment**
   - Pouches should be placed in a grid pattern, 35–50 pouches per acre (Bentz et al. 2005).

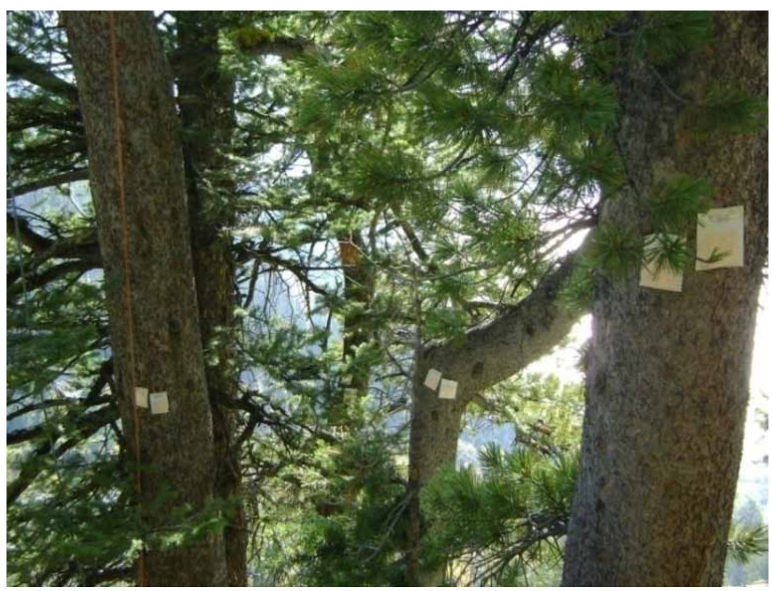
3. **Landscape Approach**
   - Aerial application verbenone flakes (Gillette et al. 2009).
   - May prove useful for rapid response to mountain pine beetle outbreaks following prolonged drought and wildfire when stands are especially vulnerable to attack.
   - May prove useful in larger landscapes, difficult-to-access areas, and protecting high elevation, remote stands of whitebark pine (Gillette et al. 2008).
   - This method has not been tested in whitebark pine, however could be considered if addition research and development demonstrates success in whitebark.

Carbaryl

High level of effectiveness—90% with annual or bi-annual application. Preferred when trees are readily accessible.

Individual Tree Treatment

- All bole surfaces must be sprayed to the point of runoff, including the root collar and exposed surface roots. Tree boles should be sprayed as high as possible up to a 4”–5" top diameter (Steed 2007).
- Trees protected against mountain pine beetle should be sprayed before beetles fly, usually by mid June. Given limited access to whitebark pine sites in spring prior to beetle flights, trees may be sprayed in the fall to provide protection for the next year.
- Carbaryl treatments must be formulated according to label directions; use only the prescribed 2% active ingredient.
- Application of 2% active ingredient provides nearly 100% protection of treated trees for up to two years; the chemical can overwinter one winter (Fettig et al. 2006).



Verbenone pouches in Grand Teton National Park.
NPS photo by Nancy Bockino.

PROTECTION TOOL: PRUNING TO REMOVE BLISTER RUST INFECTION AND IMPROVE FIRE RESISTANCE

Purpose of Treatment

- Prolong the life of existing trees.
- Remove the blister rust infection before it reaches the main stem.
- Protect high value trees (plus trees, high rust-resistant stands, stands with remaining cone-bearing trees) from blister rust and low-intensity ground fires.
- Remove ladder fuels, including lower branches under and around individual trees or dominant whitebark pine stands.
- Decrease fuels in or near whitebark pine trees/stands.
- Create a fuel-break at the edge of areas where fire is wanted or not wanted.

Treatment Priorities

- Plus trees, high rust resistance stands, stands with remaining cone-bearing trees.
- Healthy small-diameter trees that are well established, have only a few cankers, and are accessible for pruning.
- Trees with few cankers in stands with high blister rust.
- Isolated stands with few cone-bearing trees (important for genetic diversity).
- Trees with reasonably easy access.
- Areas of high aesthetic value.
- Areas that may be unique or have ecological or aesthetic value (e.g., campgrounds, ski areas) (Aubry et al. 2008).

Description of Treatments

1. Preventive Pruning (crown raising)

- Initiate preventive pruning when trees are 5'–10' tall to reduce risk of lethal infections.
- Remove small sprouts growing directly out of the bole (epicormic branches) that provide a direct infection course to the main stem.

2. Sanitation Pruning

- Prune cankers within 6"–24" of the main stem.
- Pruning is most effective on trees with only one stem canker within 6' of the ground and if <50% of bole circumference will be girdled by treatment (Burns et al. 2008).
- Cankers must be pruned or scribed at least 2"–3" beyond the visible canker margin to ensure complete canker removal. Lightly scrubbing a canker with water may help make the canker margins more visible (Burns et al. 2008).
- Pruning is easier in the spring when cankers are more visible (Schnepf and Schwandt 2006).
- Branch collar should be left on the tree to leave a smaller wound.
- When cutting branches larger than 1.5" in diameter, make an undercut to prevent bark from stripping as the branch is severed.
- Care should be taken to minimize damage to tree.
- Hand shears are adequate for trees less than ½-inch in diameter; use loppers or hand saws for larger branches; pole pruning saws are effective for pruning higher than 6'.
- See Schnepf and Schwandt 2006 and Burns et al. 2008.

3. "Fire Proofing"

- Remove slash and down material adjacent to whitebark pine.
- Remove 1,000-hour surface fuels to reduce fire severity and duration.

Branches infected with blister rust could be pruned.
NPS photo by Nancy Bockino.

PROTECTION TOOL: PREVENTING LOSS OF HIGH VALUE AND CONE-PRODUCING WHITEBARK PINE FROM WILDLAND OR PRESCRIBED FIRE

Purpose of Treatment

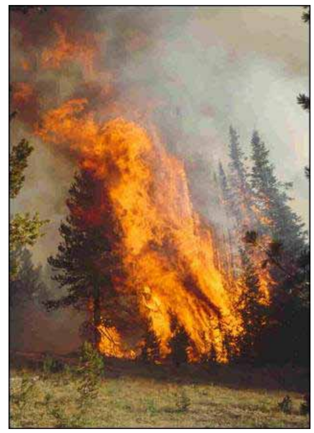
- Prevent fire-caused mortality of cone-bearing trees.
- Maintain range of whitebark pine genetic material on the landscape.

Treatment Priorities

- Individual plus trees as identified in the GYA.
- Areas/trees identified with high blister rust resistance.
- Areas designated as high priority for protection due to availability of live cone-bearing trees and reasonably easy access.

Description of Treatment

- Provide maps of plus trees and cone-bearing trees to fire management offices.
- Before the fire season begins, work with fire management offices to identify locations where fire may be beneficial or detrimental to whitebark pine management goals.
- Incorporate whitebark pine fire management needs into fire plans when they are being reviewed.
- Create strategic objective for use in the Wildland Fire Decision Support System fire management program.



Use fire planning to prevent fire-caused mortality of cone-bearing trees. USFS photo.

RESTORATION TOOL: WHITEBARK PINE SEED ORCHARD

Purpose of Treatment

- Produce improved seed for out-planting of blister rust resistant trees.
- Incorporate genetic considerations into a strategy to restore whitebark pine.

Whitebark pine seedlings ready for out-planting. USFS photo.

Description of Treatments

- Selection criteria—USFS, FSH 2409.26g, Chapter 700.
- Site visit required from Regional Geneticist, Dr. Mary F. Mahalovich.
- PIAL habitat type with some indication PIAL is nearby.
- Less than 15% slope to allow for operation of machinery.
- Source of water for irrigation (nearby creek, holding tank, drip system).
- Good drainage.
- Half-mile buffer from mature trees of the same species to prevent pollen contamination.
- Avoid sites with high winds, frost pockets, swales, or droughty soils.
- Avoid old agricultural sites to avoid compacted sites or introduced pests/pathogens.
- No residual overstory.
- Site preparation required—burning and removal of herbaceous/grass during start up.
- Fencing required.
- 100-foot buffer surrounding the orchard.
- Single ownership—not crossing administrative boundaries.
- Orchard-derived seeds and seedlings will be tested for performance, cold hardiness, blister rust resistance, growth, and genetic diversity.

Restoration Tool: Planting Whitebark pine seedlings and seeds

Purpose of Treatment

- Restore and/or regenerate whitebark pine where they have been reduced by natural and anthropogenic agents (e.g., mountain pine beetle, fire, blister rust).
- Assure the future of whitebark pine on the landscape.
- Provide seed sources for areas where local seeds have been diminished.

Treatment Priorities

Planting Seedlings

- Whitebark pine seed source has been reduced.
- Recent burned over whitebark pine stands.
- Heavy mortality from mountain pine beetle.
- Heavy mortality from blister rust.
- Lower age class diversity.
- Easy access.

Planting Seeds

- Remote areas where plantings of seedlings may not be feasible.
- Wilderness or other areas with poor access or management restrictions.

Post-fire replanting of whitebark pine seeds.
USFS photo by Elizabeth Davy.

Description of Treatments

1. Planting Seedlings

- Plan early; nursery grown seedlings are slow growing (typical of high elevation species). Two growing seasons are essential (McCaughey 2010).
- Seed availability shared across the GYA; strive to use seed collected from blister rust resistant trees (http://fsweb.moscow.rmrs.fs.fed.us/ftp/pub/treeimp/WBP/WBPSOUCERANNK111SOURCE).
- Anticipate mortality when determining need for trees per acre and long-term goal.
- Grouse whortleberry (*Vaccinium scoparium*) has a positive effect and *Carex* has a negative effect on the growth and survival of planted whitebark pine seedlings (Keane et al., in prep).
- Follow planting guidelines (McCaughey et al. 2010; Izlar 2007).
  - Plant large hardy seedlings with well-developed root systems. Follow through on long-term monitoring to track seedling survival.
  - Reduce overstory competition and increase light by allowing at least a 20" radius around the planted tree.
  - Try to plant in whitebark pine habitats. Don't plant in burned lodgepole pine habitat, since lodgepole pine will regenerate rapidly and out-compete the whitebark pine.
  - Reduce understory vegetation around planted trees to reduce competition for available soil moisture and nutrients.
  - Avoid planting in swales, frost pockets, or extremely windy sites.
  - Where cold hardiness may be an issue, follow seed transfer guidelines of planting no more than +/- 400 feet in elevation from the seed source (Mahalovich et al. 2006).
  - Essential to use microsites.
  - Provide shade and physical protection by planting near stumps, rocks, or other stationary objects.
  - Avoid planting near snags; they may fall, pulling out or damaging a seedling.
  - When determining spacing, adjust for the expected survival rate.
  - Plant when soil moisture is adequate; summer and fall plantings have been successful.
  - Follow seed transfer guidelines with respect to blister rust; do not plant seedlings/seeds derived from low whitebark pine blister rust areas into sites with high whitebark pine blister rust incidence (Mahalovich et al. 2006).
  - Bower and Aitken (2008) suggest that seed transfer guidelines in the presence of a changing climate should consider transfer with respect to latitude, temperature, and source population date of needle flush.

2. Planting Seeds

- There are no tested protocols for planting whitebark pine seeds. The above recommendations also apply to planting seeds.
- Seed pre-treatments of warm stratification and seed coat scarification appear to improve germination (Shoal et al. 2008).
- Challenges from test sites/areas of consideration (Shoal et al. 2008).
  - Rodent predation.
  - Seedling desiccation due to hot dry condition despite use of microsites.
  - Competition from vegetation..

RESTORATION TOOL: WHITEBARK PINE PERFORMANCE TEST AND IN SITU CLONE BANK

Purpose of Treatment

- Monitor durability of blister rust performance under field conditions.
- Monitor elite tree performance and stability of effective population size.
- Evaluate repeated natural inoculations against local blister rust spore populations.
- Validate Greater Yellowstone/Grand Teton breeding zone boundary.
- Validate existing seed orchard selections, rogue poorer performing entries to maintain/increase rust resistance gains in orchard population.
- Estimation of genetic parameters (heritability, phenotypic and genetic correlations, juvenile-mature correlations).
- Provision for a base population for advanced generation selections.

Whitebark pine performance test,
Lone Mountain Tree Improvement Area,
Idaho Panhandle National Forest
(survivors of the 110-seed source study).
USFS photo by M.F.Mahalovich.

Description of Treatments

- Selection criteria—USFS, FSH 2409.26f, Chapter 500
- Site visit required from Regional Geneticist, Dr. Mary F. Mahalovich.
- PIAL habit type with some indication PIAL is nearby
- Reasonably accessible to facilitate measurement
- Uniform site as possible with relative to soils, aspect, elevation, and slope.
- Large enough to accommodate the entire planting (15–20 acres).
- Area should not include large “non-plantable” areas.
- Standard site preparation practices should be followed
- Single ownership sites.
- Site representative of conditions where whitebark restoration is likely.
- Design and layout of a randomized complete block design, three replications, 10 seedlings per family per replication. 10’ x 10’ spacing. Includes treatment (plus and elite tree families) and control (woodsrun or unimproved) single-tree plots.
- Measurements: 1st year, survival; 3rd year and every 5th year thereafter, baseline (survival, height, and damaging agents).
- One annual quick check (samplingo,f 100 trees).
- Opportunistic measurements when insect, disease, or damaging agent/event exceeds 50% of test (minimum requirement to detect family differences).

RESTORATION TOOL: COLLECTING WHITEBARK PINE CONES AND SEEDS

Purpose of Treatment

- Collect seeds for planting, one of the main foundations for restoration. Seeds would be used for growing of seedling and out-planting.
- Promote rust resistance and decrease white pine blister rust in the GYA.

Description of Treatments

1. Climbing

- Trees are climbed twice, once for caging and once for collection.
- Cone collection contract needed.
- USFS requires formal training (FSH 6709.11 Health and Safety Handbook, 22.49 Tree Climbing).
- Tools: climbing with ropes and ladders; ground-based collection with tree-tong and cherry pickers (Murray 2007; FSH 2409.26f- Seed Handbook).
- Safety requirements (National Tree Climbing Guide 0167-2802-MTDC).

2. Cone Protection and Collection

- See FSH 2409.26f–USDA Seed Handbook and Whitebark Cone Collection Manual (Ward 2006).
- Avoid squirrel cache collections.
- Essential to cover cones with wire cages or hardwire cloth for protection from depredation/bird/squirrels/chipmunks in early summer.
- Seeds must be mature before collection; since cones are in cages, wait until the cones are almost falling apart to assure full maturity, usually after August 15.
- Tarps should be placed on the ground to catch any fallen seeds and prevent them from picking up any soil-borne diseases.
- Cones should be placed in clean nylon or burlap bags, collected in the tree, and then lowered to the ground to avoid damage to the seeds.
- Fill each bag no more than half full and tie within 3" of the top to allow air circulation.
- Operational collection: bulk the collection, collect from a minimum of 20 trees, and use two-bushel unlined burlap bags.
- Plus trees—use one bag per tree.
- Store cleaned, bagged cones in a dry, cool area; protect from direct sunlight, rain, wind, rodents, or other small mammals until transport to the nursery.

Treatment Priorities

- Phenotypic rust resistant trees and plus trees.
- Areas with high blister rust infection; immediately search for trees that exhibit rust resistance.
- Rust resistant areas as identified by M. Mahalovich.
- Accessible stands.

Left: Caged cones on the Bridger-Teton National Forest, 2009.
Right: A bag of whitebark pine cones.
NPS photos by Nancy Bockino.

RESTORATION TOOL: GUIDELINES AND LIMITATIONS FOR WILDLAND OR PRESCRIBED FIRE IN WHITEBARK PINE STANDS

Purpose of Treatment

- Return ecosystem processes to whitebark pine landscapes (Keane 2001).
- Newest work in GYA shows that fire *did not* drive PIAL recruitment and many high elevation stands do not have fuels to support large-scale fire (Larson 2009 and Walsh 2005).
- Mimic historical disturbance characteristics to facilitate whitebark pine regeneration and cone production (Keane et al. in prep).
- PIAL less abundant in old burns (Klutsch et al. 2008, Bockino in prep.).
- Create nutcracker openings and seed caching sites.
- Nutcrackers have been documented avoiding burned areas (Lorenz 2007).
- Use fire in lower elevations to create mosaic landscape to serve as fuel breaks and slow the intensity of fire before it reaches higher elevations (Shoal et al. 2008).
- Remove competing conifers.

Treatment Priorities

- Mixed species stands.
- Areas with limited access.
- Burning near areas with moderate to high levels of blister rust infection and mortality to protect possible rust-resistant trees. The surviving cone-bearing trees would likely contain rust-resistant genes (Keane et al., in prep).

Description of Treatments

- Avoid areas of mountain pine beetle activity. Areas with mountain pine beetle activity should be avoided for any fire treatments so as not to promote additional attacks.
- Exercise caution in areas of high whitebark pine mortality. Sufficient seed sources are critical to whitebark pine reestablishment.
- Use low intensity surface fires that will kill primarily subalpine fir in the understory and maybe a few in the overstory, but maintain the overstory mature whitebark pine.
- Promote fire as a natural element in whitebark pine forests when fuel loading and stand structure will support low to moderate fire.
- Mixed severity burns are fires of different intensities creating complex patterns of tree mortality; survival provides seed caching sites (Keane et al. 2001).
- Protect remaining seed-source trees from fire.

Whitebark pine cones.
NPS photo by Nancy Bockino.

RESTORATION TOOL: CREATION OF NUTCRACKER OPENINGS

Purpose of Treatment

- Encourage natural regeneration of whitebark pine through caching of seed by Clark's nutcracker.
- Increase genetic diversity through seed dispersal by nutcrackers (Krakowski et al. 2003).
- Decrease costs of regeneration.

Description of Treatments

- Mechanical treatments (Keane et al., in preparation).
  - Cut all non-whitebark pine trees below a threshold diameter to thin stand.
  - Create 1–30 acre openings to mimic patchy, mixed severity fires.
  - Cut all trees except whitebark pine.
  - Cut all subalpine fir trees to increase fuel loading for prescribed fire.
- Remove slash from mechanical treatment areas so nutcrackers have caching sites and to prevent *Ips* beetle infestations; this can be done mechanically or using prescribed fire.
- Stand replacing wildfire.
- Moderate severity wildland or prescribed fire.

Treatment Priorities

- Mixed conifer stands.
- Conifer stands adjacent to whitebark pine seed source.
- Stands with a high percentage of whitebark pine, which may be more valuable as a seed source and not good candidates to convert to nutcracker openings (Moody 2006).
- Open canopy whitebark pine stands may self replace and are not a high priority for creation of nutcracker openings (Moody 2006).

Keys to Treatment Success

- More natural regeneration in areas where seed source is nearby (Klutsch et al. 2008).
- For maximum caching opportunities, openings should be within 300' of an abundant seed source (Lorenz 2008).
- Seed dispersal is unlikely in areas greater than a half mile (1 km) from seed sources (Moody 2006)
- Nutcrackers cache seed in variety of open areas and closed canopies
- Nutcrackers seem to prefer openings less than 37 acres in size.
- Dense shrub or grass cover may inhibit successful whitebark pine germination.

Left: Clark's nutcracker. Photo by Allen Carroll.
Right: Clark's nutcracker gathering whitebark pine cones.
NPS photo by Nancy Bockino.

Protection and Restoration Tool: Natural regeneration

Purpose of Treatment

- Increase genetic diversity; seed dispersal by nutcrackers influences genetic patterns (Krakowski et al. 2003).
- Decrease costs of regeneration.

Description of Treatments

- Areas with less squirrel predation on seed caches such as higher elevations may have greater natural regeneration success (Lorenz 2008).
- Retain seed-producing trees in a variety of areas to ensure nutcrackers have a source of seeds to cache.
- Nutcrackers are the main seed dispersal mechanism and will cache seed in openings or closed canopies, steep slopes, needle litter, rocks, and tree trunks (Lorenz 2008).
- Regeneration is more successful when associated with *Vaccinium scoparium* (Tomback et al. 1993).
- Make sure there is enough seed cached in an area to regenerate; rodents will feed on the cached seeds.
- At least 20–50 cone-bearing trees per acre are needed to be considered a seed source (Keane et al. in prep); 120–280 cones/acre are needed to support a nutcracker (McKinney 2007).

Treatment Priorities

- Local extinctions can occur if stands of whitebark pine decline and seed sources are not close enough to provide adequate regeneration.
- 10 km is the maximum distance to expect nutcrackers to reestablish a whitebark pine stand.

Left: Natural regeneration.
Right: Whitebark pine seedling, Shoshone National Forest.
NPS photos by Nancy Bockino.

Restoration Tool: Thinning

Purpose of Treatment

- Reduce competition with shade-tolerant tree species.
- Release of seedlings and saplings in understory.
- Create nutcracker openings.
- Reduce susceptibility to mountain pine beetle.
- Decrease susceptibility to stand replacing fire.
- Simulate a mixed severity fire without the risk of burning.
- Fell trees to augment fire.

Description of Treatments

- Mechanical removal of trees competing with whitebark pine (e.g., lodgepole pine, subalpine fir, and Engelmann spruce) can be done in the overstory and/or understory of a mature stand with a commercial timber sale, stewardship agreement, service contract, or agency hired crews (force account).
- This could consist of cutting all non-whitebark pine trees below a threshold diameter. Remove slash if fire is a concern.
- Cut trees that compete with seedling/sapling/pole size trees to release their growth, potentially resulting in larger and more frequent cone crops.
- Clear-cut or clear-cut with reserves to simulate a stand-replacing fire and provide nutcracker caching sites. Remove all non-whitebark pine from an area; leave some down material for nutcracker caches or planting microsites.
- Cut some trees to leave down material in stands or across the landscape to provide nutcracker caching sites. Open canopy to provide caching sites.
- Thin stands to a basal area of 60 to 80 square feet to reduce susceptibility to mountain pine beetle. Stands with less than 45 square feet of basal area and a stand density index of less than 80 are less susceptible to mountain pine beetle attacks, as are trees less than 7" DBH (Perkins and Roberts 2003).
- Remove mountain pine beetle-infested trees prior to beetle flight to decrease numbers of beetles that can attack new green trees. This is effective in small, accessible stands to reduce beetle populations in an area (Carroll et al. 2006).
- Thin ladder fuels, especially subalpine fir and spruce, to reduce susceptibility to stand-replacing crown fire.
- If promoting nutcracker caching of seeds is a treatment goal, reduce slash concentrations to allow nutcracker access to the ground.
- Fell or slash non-whitebark pine trees to leave on the ground to enhance the fuel bed. Slash left on site will provide quickly drying fine fuel loadings so that the burn can be implemented under moist conditions and a prescribed fire will spread to more of a burn unit.
- Avoid burning any live whitebark pine as a result of slash burning.

Thinning and removing large trees.
USFS photo by Bob Keane.

Literature Cited

Arno S.F., and R.J. Hoff. 1990. Whitebark pine (*Pinus albicaulis* Engelm.). *In* R.M. Burns and B.H. Honkala , eds. Silvics of North America: 1. Conifers; 2. Hardwoods. *Agriculture Handbook* 654 (2). Washington, D.C., USDA Forest Service. 877 p.

Arno, S.F., and T. Weaver. 1990. Whitebark pine community types and their patterns on the landscape. *In* W.C. Schmidt and K.J. McDonald (eds.), Proceedings — Symposium on Whitebark Pine Ecosystems: Ecology and management of a high mountain resource, March 29–31, 1989, Bozeman, MT. USDA Forest Service GTR-INT-270. 118–130.

Aubry, C., D. Goheen, R. Shoal, T. Ohlson, T. Lorenz, A. Bower, C. Mehmel, and R.A. Sniezko. 2008. Whitebark pine restoration strategy for the Pacific Northwest Region, 2009–2013. Region 6 Report, USDA Forest Service, Pacific Northwest Region, Portland, OR.

Barringer, L. 2010. Determining the relationship between whitebark pine stand-level health and seed dispersal by Clark's nutcracker. M.S. Thesis. University Colorado Denver.

Bentz, B., J. Regniere, C. Fettig, M. Hansen, J. Hayes, J. Hicke, R. Kelsey, J. Negron, and S. Seybold. 2010. Climate change and bark beetles of the Western United States and Canada: direct and indirect effects. *BioScience* 60(8): 602–613.

Bentz, B.J., S. Kegley, K. Gibson, and R. Thier. 2005. A test of high-dose verbenone for stand-level protection of lodgepole and whitebark pine from mountain pine beetle (Coleoptera: Curculionidae; Scolytinae) attacks. *Journal of Economic Entomology* 98:1614–1621.

Bentz, B.J., and D.E. Mullins. 1999. Ecology of mountain pine beetle (Coleoptera: Scolytidae) cold-hardening in the Intermountain West. *Environmental Entomology* 28:577–587.

Bockino, N. *In preparation*. Whitebark pine regeneration density and spatial distribution in the Greater Yellowstone Ecosystem. Grand Teton National Park, Moose, WY.

Bockino, N., and K. McCloskey. 2010. Whitebark Pine Monitoring in Grand Teton National Park 2007–2010: White Pine Blister Rust and Mountain Pine Beetle. Grand Teton National Park Division of Science and Resource Management.

Bockino, N. 2009. Annotated bibliography for whitebark pine ecology: 2009 Additions. Grand Teton National Park. Moose, WY.

Bockino, N. 2008. Annotated bibliography for whitebark pine ecology. Grand Teton National Park. Moose, WY.

Bockino, N.K. 2008. Interactions of white pine blister rust, host species, and mountain pine beetle in whitebark pine ecosystems in the Greater Yellowstone. M.S. Thesis. University of Wyoming.

Bower, A.D., and S.N. Aitken. 2008. Ecological genetics and seed transfer guidelines for *Pinus albicaulis* (Pinaceae). *American Journal of Botany* 95:66–76.

Burns, K.S., A.W. Schoettle, W.R. Jacobi, and M.F. Mahalovich. 2008. Options for the management of white pine blister rust in the Rocky Mountain region. Report RMRS-GTR-206. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Callaway, R.M. 1998. Competition and facilitation on elevation gradients in subalpine forests of the northern Rocky Mountains, USA. *Oikos* 82:561–573.

Carroll, A L., T.L. Shore, and L. Safranyik. 2006. Chapter 6, Direct control: Theory and practice. Pages 155–172 *in* L. Safranyik and B. Wilson, eds. The mountain pine beetle: A synthesis of biology, management and impacts on lodgepole pine. Natural Resources Canada, Canadian Forest Service. Pacific Forestry Centre. Victoria, B.C. Canada.

Davis, D. 2005. National tree climbing guide: 2005 edition. Technical Report 0567-2819 MTDC. USDA Forest Service, Missoula Technology and Development Center. Missoula, MT. 88 p.

Fettig, C.J., K.K. Allen, R.R. Borys, J. Christopherson, C.P. Dabney, T. J. Eager, K.E. Gibson, E.G. Hebertson, D.F. Long, A.S. Munson, P.J. Shea, M.I. Smith, and M.I. Haverty. 2006. Effectiveness of bifenthrin (Onyx) and carbaryl (Sevin SL) for protecting individual, high-value conifers from bark beetle attack (Coleoptera: Curculionidae: Scolytinae) in the western United States.

Gibson, K., K. Skov, S. Kegley, C. Jorgensen, S. Smith, and J. Witcosky. 2008. Mountain pine beetle impacts in high-elevation five-needle pines: Current trends and challenges. Forest Health Protection Report R1-08-20. USDA Forest Service, Northern Region, Missoula, MT.

Gillette, N.E., N. Erbilgn, J.N. Webster, L. Pederson, S.R. Mori, J.D. Stein, D.R. Owen, K.M. Bischel, and D.L. Wood. 2009. Aerially applied verbenone-releasing laminated flakes protect *Pinus contorta* stands from attack by *Dendrotonus ponderosae* in California and Idaho. *Forest Ecology and Management* 257:1405–1412.

Goetz, W., P. Maus, and E. Nielson. 2009. Mapping whitebark pine canopy mortality in the Greater Yellowstone Area. RSAC-0104-RPT1. USDA Forest Service, Remote Sensing Application Center, Salt Lake City, UT. 9p.

(GYCCWBPSC) Greater Yellowstone Coordinating Committee, Whitebark Pine Subcommittee. 2009. Greater Yellowstone Ecosystem whitebark pine distribution map by N. Bockino, J. Whitley, and K. Mellander. Cooperation with USDA Forest Service and Grand Teton National Park.

GYCCWBPSC. 2010. 2010 whitebark pine distribution and condition assessment for the Greater Yellowstone by N. Bockino and W. Macfarlane. Cooperation with USDA Forest Service - Forest Health and Protection and Grand Teton National Park.

Greater Yellowstone Whitebark Pine Monitoring Working Group. 2007. Interagency Whitebark Pine Monitoring Protocol for the Greater Yellowstone Ecosystem, Version 1.00. Greater Yellowstone Coordinating Committee, Bozeman, MT.

Greater Yellowstone Whitebark Pine Monitoring Working Group. 2010. Monitoring whitebark pine in the Greater Yellowstone Ecosystem: 2009 Annual Report. Pages 63–71 in C.C. Schwartz, M.A. Haroldson, and K. West, eds., Yellowstone grizzly bear investigations: annual report of the Interagency Grizzly Bear Study Team, 2009. U.S. Geological Survey, Bozeman, Montana, USA.

Hoff, R.J., D.E. Ferguson, G.I. McDonald, and R.E. Keane. 2001. Strategies for managing whitebark pine in the presence of white pine blister rust. *In* D.F. Tomback, S.F. Arno, and R.E. Keane, eds. Whitebark pine communities. Island Press, Washington DC. 346-366.

Izlar, D.K. 2007. Assessment of whitebark pine seedlings survival for Rocky Mountain plantings. M.S. thesis. College of Forestry and Conservation, University of Montana, Missoula. 76 p.

Keane, R.E., and R. Parsons. 2010. A management guide to ecosystem restoration treatments: Whitebark pine forests of the Northern Rocky Mountains. General Technical Report RMRS-GTR-232, USDA Forest Service Rocky Mountain Research Station, Fort Collins, CO.

Keane, R.E., K.L. Gray, and L.J. Dickinson. 2006. Whitebark pine diameter growth response to removal of competition. USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory.

Keane, R.E., and S.F. Arno. 2001. Restoration concepts and techniques. Pages 367–400 *in* D. Tomback, S.F. Arno, and R.E. Keane, eds. Whitebark pine communities: Ecology and restoration. Washington, D.C.: Island Press.

Kegley, S., K. Gibson, J. Schwandt, and M. Marsden. 2003. A test of verbenone to protect individual whitebark pine from mountain pine beetle attack. Forest Health Protection Report 03-9. USDA Forest Service, Northern Region, Missoula, MT. 6 p.

Kegley, S.J., and K.E. Gibson. 2007. Using verbenone to protect whitebark pine from mountain pine beetle attack. Report 07-1. USDA Forest Service, Coeur d'Alene Field Office, ID.

Kendall, K.C., and R.E. Keane. 2001. Whitebark pine decline: Infection, mortality, and population trends. *In* Whitebark pine communities. D.F. Tomback, S.F. Arno, and R.E. Keane, eds. Island Press, Washington DC. pp. 221–242.

Klutsch, J.G., B.A. Goodrich, and W.R. Jacobi. 2008. Assessment of whitebark pine regeneration in burned areas of the Shoshone and Bridger-Teton National Forests and Wind River Reservation, Wyoming. Final report, USDA, Forest Health Protection.

Krakowski, J., S.N. Aitken, and Y.A. El-Kassaby. 2003. Inbreeding and conservation genetics in whitebark pine. *Conservation Genetics* 4:581–593.

Lanner, R.M. 1996. Made for each other, a symbiosis of birds and pines. Oxford University Press, New York, NY.

Larson, E., and K. Kipfumueller. 2010. Patterns in whitebark pine regeneration and their relationships to biophysical site characteristics in southwest Montana, central Idaho, and Oregon, USA. *Canadian Journal of Forest Research* 40:476–487.

Larson, E.R. 2009. Status and dynamics of whitebark pine (*Pinus albicaulis*) forests in southwest Montana, central Idaho, and Oregon, USA. Dissertation, University of Minnesota. 190 p.

Logan, J., W. Macfarlane, and L. Willcox. 2010. Whitebark pine vulnerability to climate-driven mountain pine beetle disturbance in the Greater Yellowstone. *Ecological Applications* 20(4):895–902.

Logan, J.A., and Powell, J.A. 2004. Modelling mountain pine beetle phenological response to temperature. *In* T.L. Shore, J.E. Brooks, and J.E. Stone, eds. Mountain Pine Beetle Symposium: Challenges and Solutions, October 30–31, 2003, Kelowna, British Columbia, Canada. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia, Information Report BC-X-399, 210–222.

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.

Lorenz, T.J., C. Aubry, and R. Shoal. 2008. A review of the literature on seed fate in whitebark pine and the life history traits of Clark's nutcracker and pine squirrels. USDA Forest Service, Pacific Northwest Research Station PNW-GTR-742.

Lorenz, T.J. 2007. Radio-tagging Clark's nutcrackers: Preliminary data from a study of habitat use in Washington state. Pages 169–172 *in* E.M. Goheen and R.A. Sniezko, technical coordinators. Whitebark Pine: A Pacific Coast Perspective. Conference, August 27–31, 2006, Ashland, OR. USDA Forest Service, Pacific Northwest Region, Portland, OR. R6-NR-FHP-2007-01.

Macfarlane W.W., J.A. Logan, and W.R Kern. 2009. Using the landscape assessment system (LAS) to assess mountain pine beetle-caused mortality of whitebark pine, Greater Yellowstone Ecosystem, 2009. Project report prepared for the Greater Yellowstone Coordinating Committee, Whitebark Pine Subcommittee, Jackson, Wyoming. 69 p.

Mahalovich, M.F., and R.J. Hoff. 2002. Whitebark pine operational cone collection instruction and seed transfer guidelines. Unpublished report.

Mahalovich, M.F., and G.A. Dickerson. 2004. Whitebark pine genetic restoration program for the Intermountain West (United States). Pages 181–187 *in* R.A. Sniezko, S. Samman, S.E. Schlarbaum, E. Scott, and H.B. Kriebel, eds. Breeding and genetic resources of five-needle pines: growth, adaptability and pest resistance. Conference, July 23–27, 2001, Medford, OR, USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO. RMRS-P-32.

Mahalovich, M.F., K.E. Burr, and D.L. Foushee. 2006. Whitebark pine germination, rust resistance, and cold hardiness among seed sources in the Inland Northwest: planting strategies for restoration. USDA Forest Service Proceedings, RMRS-P-43.

Mattson, D.J., and D.P. Reinhart. 1994. Bear use of whitebark pine seeds in North America. *In* W.C. Schmidt, F.K. Holtmeier, eds. Proceedings International workshop on subalpine stone pines and their environment: The status of my knowledge. USDA Forest Service, Intermountain Research Station, GTR-INT-309. Ogden, UT. 221-220.

Mattson D.J., K.C. Kendal, and D.P. Reinhart. 2001. Whitebark pine, grizzly bears, and red squirrels. Pages 121–134 *in* D. Tomback, S.F. Arno, and R.E. Keane, eds. Whitebark pine communities: Ecology and restoration. Washington, D.C.: Island Press.

Mattson, D.J., B.M. Blanchard, and R.R. Knight. 1991. Food habits of Yellowstone grizzly bears, 1977–1987. *Canadian Journal of Zoology* 69:1619–1629

McCaughey, W., G.L. Scott, and K.L. Izlar. *In press.* Revised whitebark pine planting guidelines. USDA Forest Service, Region 1, 2008, Western Journal of Applied Forestry.

McKinney, S.T. 2007. A predictive model of nutcracker seed dispersal in whitebark pine. Presentation at Whitebark pine Ecosystem Foundation Meeting. September 28–30, 2007, Lincoln, MT.

McKinney, S.T., C.E. Fiedler, and D.F. Tomback. 2009. Invasive pathogen threatens bird–pine mutualism: Implications for sustaining a high-elevation ecosystem. *Ecological Applications* 19(3):597–607

Moody, R.J. 2006. Post-fire regeneration and survival of whitebark pine (*Pinus albicaulis*). M.S. thesis, University of British Columbia.

Mote, P.W., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier. 2005. Declining mountain snowpack in western North America. *Bulletin of the American Meteorological Society*. 86: 39–49.

Murray, M.J. 2007. Cone collecting techniques for whitebark pine. *Western Journal of Applied Forestry* 22(3):153–155.

Newcomb, M. 2003. White pine blister rust, whitebark pine, and *Ribies* species in the Greater Yellowstone Area. M.S. Thesis. The University of Montana, Missoula, MT.

Perkins, D.L., and D.W. Roberts. 2003. Predictive models of whitebark pine mortality from mountain pine beetle. *Forest Ecology and Management* 174:495–510.

Schnepf, C.C., and J.W. Schwandt. 2006. Pruning western white pine, a vital tool for species restoration. Pacific Northwest Extension Publication PNW 584. University of Idaho, Oregon State University, Washington State University.

Schwartz C.C., M.A. Haroldson, and K. West 2007. Yellowstone grizzly bear investigations: annual report of the Interagency Grizzly Bear Study Team, 2006. Bozeman, MT, U.S. Geological Survey.

Schwartz, C.C., M.A. Haroldson, and G.C. White. 2006. Survival of cub and yearling grizzly bears in the greater Yellowstone ecosystem, 1983–2001. Pages 25–31 *in* C.C. Schwartz, M.A. Haroldson, G.C. White, R.B. Harris, S. Cherry, K.A. Keating, D. Moody, and C. Servheen, eds. Temporal, spatial and environmental influences on the demographics of grizzly bears in the greater Yellowstone ecosystem. *Wildlife Monographs* 161.

Shoal, R., T. Ohlson, and C. Aubry. 2008. Land managers guide to whitebark pine restoration in the Pacific Northwest region. September 2008. p 12–13.

Six, D.L.,. and J.C. Adams. 2007. Relationships between white pine blister rust and the selection of individual whitebark pine by the mountain pine beetle. *J. Ento. Sci*. 42: 345–353.

Steed, B. 2007. White paper on carbaryl written for Helena National Forest.

Tomback, D.F., S.F. Arno, and R.E. Keane. 2001. The compelling case for management intervention. *In* Whitebark pine communities. *Edited by* D.F. Tomback, S.F. Arno, and R.E. Keane. Island Press, Washington D.C. pp. 4–25.

Tomback, D.F, J.K. Clary, J. Koehler, R.J. Hoff, and S.F. Arno. 1995. The effects of blister rust on postfire regeneration of whitebark pine-the Sundance burn of northern Idaho (USA). *Conservation Biology* 9: 654–664.

Tomback, D.F., S.K. Sund, and L.A. Hoffman. 1993. Post-fire regeneration of *Pinus albicaulis*: Height-age relationships, age structure, and microsite characteristics. *Canadian Journal of Forest Research* 23(2): 113–119.

Tomback, D.F., and Y.B. Linhart. 1990. The evolution of bird-dispersed pines. *Evolutionary Ecology* 4:185–219.

Tomback, D.F. 1978. Foraging strategies of Clark's Nutcracker. *Living Bird* 16:123–161.

(USDA) U.S. Department of Agriculture Forest Service. 2009. Individual tree protection using carbaryl insecticide for western conifer-infesting bark beetles. Forest Health and Protection, Intermountain and Northern Regions.

USDA Forest Service. 2010. Tree Improvement Site, http://fsweb.moscow.rmrs.fs.fed.us/ftp/pub/treeimp/WBP.

USDA Forest Service. R1 Supplement, DRAFT FSH 2409.f, Seed Handbook.

USDA Forest Service. FSH 6709.11 Health and Safety Handbook, 22.49 Tree Climbing.

USDA Forest Service. FSM 2323.5. Management of Forest Cover.
USDA. Skills for Tree Improvement Training. 2003. Presentation on whitebark pine restoration, cone collection strategy by Mary Frances Mahalovich.
Walsh, J.R. 2005. Fire regimes and stand dynamics of whitebark pine (*Pinus albicaulis*) communities in the Greater Yellowstone Ecosystem. M.S. thesis, Colorado State University, Fort Collins.
Ward, K., R. Shoal, and C. Aubry. 2006. Whitebark pine cone collection manual. USDA Forest Service Pacific Northwest Region: Oregon and Washington.
Westerling, A.L, H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increases Western U.S. forest wildfire activity. *Science* 313.

Photo by Nancy Bockino.

Acknowledgements and Participants

The Greater Yellowstone Coordinating Committee
Whitebark Pine Subcommittee 2008–2011 Inclusive

Current Chair (2011):
Kelly McCloskey, Ecologist, Grand Teton National Park

Vice Chair:
Jodie Canfield, Wildlife Biologist, Gallatin National Forest

Members:
Jay Frederick, Beaverhead-Deerlodge National Forest
Ellen Jungck, Shoshone National Forest
Cathey Hardin, Caribou-Targhee National Forest
Cathie Jean, Greater Yellowstone Network
Nancy Bockino, Grand Teton National Park
Jeff Dibenedetto, Custer National Forest
Elizabeth Davy, Caribou-Targhee National Forest
Shannon Podruzny, USGS Interagency Grizzly Bear Study Team
Karl Buermeyer, Bridger-Teton National Forest
Dan Reinhart, Yellowstone National Park
Erin Shanahan, Greater Yellowstone Network

Cooperators:
Mary F. Mahalovich, USFS Regional Geneticist
Steve Munson, USDA Forest Health Protection
Wally Macfarlane, GEO/Graphics, Inc.
Kathryn Mellander, Grand Teton National Park