BLM

Conservation and Management of Whitebark Pine Ecosystems

on Bureau of Land Management Lands in the Western United States

Technical Reference 6711-1

August 2016

Prepared by:

Dana L. Perkins, Ph.D., Forest Ecologist, Bureau of Land Management, Idaho

Robert E. Means, State Forester, Bureau of Land Management, Wyoming

Alexia C. Cochrane, Vegetation Ecologist, Cochrane Consulting (Bureau of Land Management, Idaho, retired)

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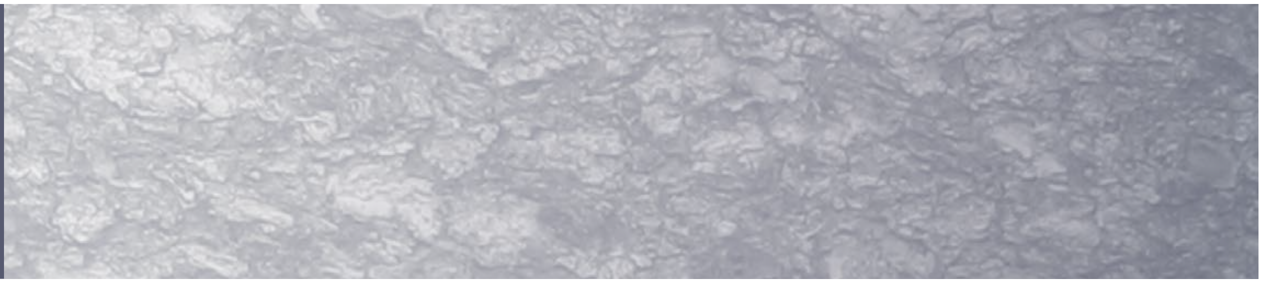
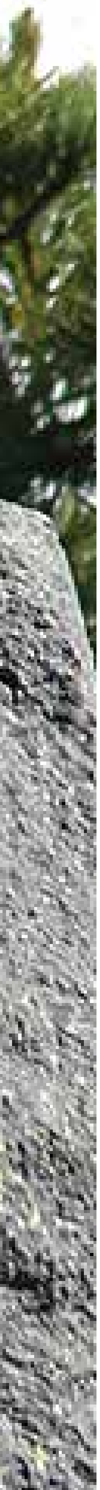
In Memoriam

Dedicated to Robert E. Means (10/1/1953 – 5/26/2015), whose passion for forests and love of learning inspired all who worked with him. He was a man of highest integrity with the compassion, wisdom, courage, and understanding to do his best, to do the right thing, and to make a difference. He succeeded.





Acknowledgments

We are grateful to the authors of three important strategies for whitebark pine restoration, for much of this reference is reproduced from their documents: "A Range-Wide Restoration Strategy for Whitebark Pine (*Pinus albicaulis*)" (Keane et al. 2012), "Whitebark Pine Strategy for the Greater Yellowstone Area" (Greater Yellowstone Coordinating Committee - Whitebark Pine Subcommittee 2011), and "Whitebark Pine Restoration Strategy for the Pacific Northwest Region 2009–2013" (Aubry et al. 2008). We are also grateful for reviews and editorial suggestions from Christy Cleaver, Bob Keane, Mary Francis Mahalovich, Kelly McCloskey, Connie Millar, Anna Schoettle, and Diana Tomback. We also send a huge thanks to Brian Weihausen for preparing maps and GIS modeling and to Mike DeArmond for his inspiring vision of healthy whitebark pine forests. A heartfelt thanks goes to National Operations Center employees Nancy Esworthy (editor) and Ethel Coontz (visual information specialist) for their excellent suggestions, which greatly improved this publication.

We are especially grateful to Kathy Radigan, senior forester in BLM's Division of Forest, Rangeland, Riparian, and Plant Conservation, Washington Office, who retired in January 2016 after 30 years of federal service. Not only did Kathy's support and passion for our public lands lead the national BLM forestry program forward, but her vision and guidance inspired and made possible the creation of this document as a valuable resource for conserving and managing whitebark pine ecosystems.

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Abstract

Whitebark pine (*Pinus albicaulis* Engelm.), an important component of western high-elevation forests, has been declining in both the United States and Canada from the combined effects of the exotic disease white pine blister rust (caused by the pathogen *Cronartium ribicola*), mountain pine beetle (*Dendroctonus ponderosae*) outbreaks, altered fire regimes, and climate change. These combined threats have led to the recent listing of whitebark pine as a high-priority Candidate Species under the Endangered Species Act.

This reference presents general guidelines for planning, implementing, and evaluating whitebark pine conservation and management activities on lands administered by the Bureau of Land Management. It is adapted from three important strategies:

- "A Range-Wide Restoration Strategy for Whitebark Pine (*Pinus albicaulis*)" (Keane et al. 2012)
- "Whitebark Pine Strategy for the Greater Yellowstone Area" (Greater Yellowstone Coordinating Committee - Whitebark Pine Subcommittee 2011)
- "Whitebark Pine Restoration Strategy for the Pacific Northwest Region 2009–2013" (Aubry et al. 2008)

Key Words: *Pinus albicaulis,* ecosystem conservation, white pine blister rust, mountain pine beetle, climate change, high elevation

August 2016

Executive Summary

Whitebark pine (*Pinus albicaulis*) forests are declining across most of their range in western North America because of the combined effects of the exotic pathogen *Cronartium ribicola,* which infects five-needle white pines and causes the disease white pine blister rust; mountain pine beetle (*Dendroctonus ponderosae*) outbreaks; altered fire regimes; and effects from climate change. These threats have led to the recent listing of whitebark pine as a high-priority Candidate Species under the Endangered Species Act (Federal Register 2011). Until the status of whitebark pine can be addressed by the U.S. Fish & Wildlife Service, the Bureau of Land Management (BLM) is managing it as a special status species, guided by BLM Manual 6840, "Special Status Species Management."

The loss of this high-elevation tree species has serious consequences for subalpine ecosystems. Whitebark pine is considered both a keystone species for promoting community biodiversity and a foundation species for promoting community stability. The large, nutritious seeds are an important food for Clark's nutcrackers (*Nucifraga columbiana,* which is the primary seed disperser of whitebark pine seed) as well as for grizzly bears (*Ursus arctos horribilis*) and black bears (*Ursus americanus*), and many bird and small mammal species. Whitebark pine is often the first conifer to colonize high-elevation sites following ecosystem disturbances such as wildfire, and it facilitates establishment of other conifers and vegetation by ameliorating harsh environmental conditions, thus acting as a nurse tree. Whitebark pines stabilize rocky soils and reduce soil erosion. Their canopies shade snowpack, regulating snowmelt and thus regulating downstream runoff.

Because whitebark pine occurs primarily on national forests or lands administered by the National Park Service in "core areas" (i.e., higher elevations), most of the existing field research and management has occurred on these lands. The BLM manages an estimated 1%–2% of populations in the species' entire range. This is a small but important portion, because the BLM's whitebark pine populations border the major core areas, and also exist on the range margins, in isolated stands, and at lower elevations. Areas accessible by roads are being inventoried and mapped on BLM lands in Idaho, Montana, and Wyoming. Whitebark pine populations have generally not been mapped in California, Nevada, Oregon, and Washington, where they occur less frequently. Mapping efforts and inventories will be used to prioritize conservation actions using adaptive management (discussed in Section 3, Conservation Actions).

The BLM's conservation objectives for whitebark pine are:

1) Protect and maintain the genetic diversity of whitebark pine
2) Increase white pine blister rust resistance in future whitebark pine populations
3) Document conditions of current and potential whitebark pine habitats
4) Protect potential or known rust-resistant seed sources
5) Use silvicultural practices, including prescribed fire, to restore and maintain populations

This reference details the BLM's contribution to the conservation of whitebark pine, which includes shared seed and tree production facilities and shared expertise with other federal agencies and private partners. Conservation and restoration activities include seed collection, protection from mountain pine beetles, use of wildland fire, protection of high-value trees from fire, density management, and assisted and natural regeneration efforts. Research activities include progeny testing for rust resistance, cold hardiness, and drought tolerance and molecular analysis for genetic structure.

This reference should be used in combination with three important strategies:

- "A Range-Wide Restoration Strategy for Whitebark Pine (*Pinus albicaulis*)" (Keane et al. 2012). Hereafter referred to as "Range-Wide Strategy," it contains detailed autecological and synecological information about whitebark pine and range-wide applications of guiding principles, and actions for restoration.
- "Whitebark Pine Strategy for the Greater Yellowstone Area" (Greater Yellowstone Coordinating Committee - Whitebark Pine Subcommittee 2011). Hereafter referred to as "GYA Strategy," it includes comprehensive action plans of past, current, and future restoration actions for the six national forests and two national parks that comprise the Greater Yellowstone Area.
- "Whitebark Pine Restoration Strategy for the Pacific Northwest Region 2009–2013" (Aubry et al. 2008). Hereafter referred to as "PNW Strategy," it prioritizes areas for treatment and identifies current conditions, access, and proposed actions in Oregon and Washington.

Introduction

Whitebark pine (*Pinus albicaulis* Engelm.) forests are declining throughout their range in western North America because of the combined effects of four primary threats. These are 1) the nonnative invasive pathogen *Cronartium ribicola*, which causes the disease white pine blister rust in five-needle white pines (e.g., Keane and Arno 1993; Maloney et al. 2012; Schoettle and Sniezko 2007), 2) native mountain pine beetle (*Dendroctonus ponderosae* Hopkins [Coleoptera: Curculionidae, Scolytinae]) outbreaks (e.g., Furniss and Carolin 1977; Bentz et al. 2010; Keane et al. 2012; Meddens, Hicke, and Ferguson 2012) (Figure 1.1), 3) altered fire regimes (Keane 2001), and 4) effects of climate change (Romme and Turner 1991; Schrag, Bunn, and Graumlich 2007; Creeden, Hicke, and Buotte 2014; Maloney 2014). These combined threats have led to the recent listing of whitebark pine as a Candidate Species under

Figure 1.1 Whitebark pine mortality from a mountain pine beetle outbreak in 2005. BLM-Idaho, Challis Field Office.

the Endangered Species Act (Federal Register 2011). Whitebark pine is found on Bureau of Land Management (BLM) lands in California, Idaho, Montana, Nevada, Oregon, Washington, and Wyoming. Until the U.S. Fish & Wildlife Service (USFWS) makes a final determination on whitebark pine, the BLM is managing it as a special status species—guided by BLM Manual 6840, "Special Status Species Management"—in Idaho, Montana, and Wyoming, those states where it occurs most frequently.

Loss of this high-elevation tree species poses serious consequences for subalpine ecosystems, both in terms of the effects on biodiversity and in losses of valuable ecosystem processes and functions (Tomback, Arno, and Keane 2001a; Tomback and Achuff 2010). Whitebark pine's large, nutritious seeds are an important food for Clark's nutcrackers (*Nucifraga columbiana*, the primary seed disperser of whitebark pine seed), for grizzly bears (*Ursus arctos horribilis*), and for black bears (*Ursus americanus*), and many bird and small mammal species (Tomback 1978, 1982; Hutchins and Lanner 1982; Hutchins 1994; Mattson, Kendall, and Reinhart 2001; Robbins et al. 2006; Lorenz, Aubry, and Shoal 2008). It is often the first pine to colonize cold, windswept, high-elevation sites following disturbances such as wildfire, and it facilitates establishment of other conifers and vegetation by ameliorating harsh environmental conditions, thus acting as a nurse tree (Callaway 1998; Callaway, Sala, and Keane 1998; Tomback et al. 2014). Whitebark pines stabilize rocky soils and reduce soil erosion. Their canopies shade snowpack, which helps regulate snowmelt and downstream runoff (Farnes 1990). The loss of whitebark pine can also affect fire regimes as well as recreational and aesthetic experiences (Keane et al. 2002; McCool and Freimund 2001; Tomback and Achuff 2010).

Recent condition assessments and research publications have focused on upper subalpine and alpine treeline areas of the U.S. Forest Service (USFS) and National Park Service (NPS) lands, where whitebark pines primarily occur. The ecology, threats, and strategies to restore whitebark pine have been documented in peer-reviewed publications and in publications by the USFS research stations, including "Silvics of Whitebark Pine (*Pinus albicaulis*)" (Arno and Hoff 1989); (*Pinus albicaulis*) Engelm. (Arno and Hoff 1990, in "Whitebark Pine: Silvics of North America"); and, more recently, "A Range-Wide Restoration Strategy for Whitebark Pine (*Pinus albicaulis*)" (Keane et al. 2012). A comprehensive volume, "Whitebark Pine Communities: Ecology and Restoration" (Tomback, Arno, and Keane 2001b), also reviews and highlights autecological and synecological information.

In the last few years restoration strategies and condition assessments have continued to be published for different geographic regions of the West. The following are essential for BLM resource specialists:

1) "Whitebark Pine Restoration Strategy for the Pacific Northwest Region 2009–2013" (Aubry et al. 2008)
2) "Options for the Management of White Pine Blister Rust in the Rocky Mountain Region" (Burns et al. 2008)
3) "Mountain Pine Beetle Impacts in High-Elevation Five-Needle Pines: Current Trends and Challenges" (Gibson et al. 2008)
4) "The Future of High-Elevation, Five-Needle White Pines in Western North America" (Keane et al. 2011)
5) "Management Guide to Ecosystem Restoration Treatments: Whitebark Pine Forests of the Northern Rocky Mountains, U.S.A." (Keane and Parsons 2010b)
6) "A Range-Wide Restoration Strategy for Whitebark Pine (*Pinus albicaulis*)" (Keane et al. 2012)
7) "Whitebark Pine in Peril: A Case for Restoration" (Schwandt 2006)
8) "Land Managers Guide to Whitebark Pine Restoration in the Pacific Northwest Region 2009–2013" (Shoal, Ohlson, and Aubry 2008)
9) "Status of Whitebark Pine in the Greater Yellowstone Ecosystem: A Step-Trend Analysis Comparing 2004–2007 to 2008–2011" (Shanahan et al. 2014)
10) "Whitebark Pine in Washington and Oregon: A Synthesis of Current Studies and Historical Data" (Ward, Shoal, and Aubry 2006b)
11) "Whitebark Pine Conservation for the Canadian Rocky Mountain National Parks" (Wilson and Stuart-Smith 2002)
12) "Whitebark Pine Strategy for the Greater Yellowstone Area" (Greater Yellowstone Coordinating Committee - Whitebark Pine Subcommittee 2011)

13) Federal Register 2011; Endangered and threatened wildlife and plants; 12-month finding on a petition to list *Pinus albicaulis* as endangered or threatened with critical habitat: A proposed rule by the U.S. Fish and Wildlife Service on 7/19/2011

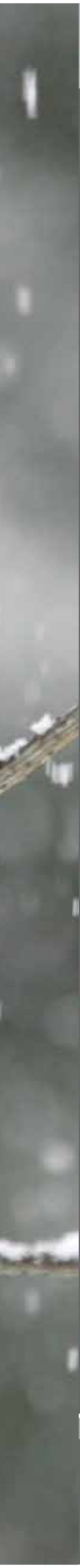
Less information is available on the condition of the lower treeline systems and isolated mountain ranges that occur on BLM-administered lands. These whitebark pine communities, hereafter called "range margin" habitats, are semi-arid, and often border mountain big sagebrush (*Artemisia tridentata* subsp. *vaseyana*) and Douglas-fir (*Pseudotsuga menziesii*) community types. They function as seed sources between continuous populations in the northern and central Rocky Mountains. They also serve as a seed source for dispersal between distinct mountain ranges. Their locations on both upper and lower treeline and in semi-arid climate systems could be affected by climate change (Romme and Turner 1991; Bower and Aitken 2008; Schrag, Bunn, and Graumlich 2007).

This reference is for BLM land managers and resource specialists to use with the 13 references listed above for prioritizing, designing, and implementing successful whitebark pine conservation and management efforts, from individual trees for gene conservation to stand- and watershed-level treatments. Conservation includes both protection and restoration actions.

The BLM's conservation objectives for whitebark pine are:

1) Protect and maintain genetic diversity in whitebark pine
2) Increase resistance to white pine blister rust in future whitebark pine populations
3) Document conditions of current and potential whitebark pine habitats
4) Protect potential or known rust-resistant seed sources
5) Use silvicultural practices, including prescribed fire, to restore and maintain populations

Photo provided by the National Park Service, U.S.D.I., Public Domain



Section 1: Ecology

Systematics

Pines are gymnosperms, classified in the class Pinopsida, order Pinales, and division Coniferophyta (U.S. Department of Agriculture, Natural Resources Conservation Service 2015). Whitebark pine is further classified in the subgenus *Strobus*, the "white" or "soft" pines technically referred to as haploxylon pines for having one rather than two fibrovascular bundles per needle. Traditionally, whitebark pine was placed in section *Strobus* and subsection *Cembrae* (Little and Critchfield 1969; Price, Liston, and Strauss 1998). Recent genetic studies have suggested that *Cembrae* pines do not form a genetically distinct (monophyletic) group (Gernandt et al. 2005). These authors recommended merging two five-needle white pine subsections—*Strobi and Cembrae*—to form a new subsection, *Strobus,* within a new pine section, *Quinquefoliae.*

Whitebark pine is one of five species known worldwide as "stone pines" (*Pinus albicaulis, P. cembra, P. sibirica, P. pumila, and P. koraiensis*). They differ from all other pines in cone morphology. The cones of the stone pines are indehiscent, which means that the scales do not open when seeds are ripe, so the seeds are retained. The seeds are removed from cones by the three worldwide species of "nutcrackers" (genus *Nucifraga*) (Lanner 1982). The nutcracker–stone pine interactions are regarded as coevolved mutualisms, whereby the nutcrackers are the primary seed dispersers for the five stone pines (Tomback and Linhart 1990).

Distribution

Whitebark pine, along with several other five-needle white pines (*Pinus flexilis, P. longaeva, P. aristata,* and *P. balfouriana*), occurs at the highest elevations of western tree species (Arno and Hoff 1990; Tomback et al. 2011). Whitebark pine has the largest and northernmost distribution of all five-needle white pines (Tomback and Achuff 2010). At its northernmost latitudes in British Columbia (55°N), it occurs at elevations as low as 5,500 ft (1,680 m), and ranges to elevations above 10,000 ft (3,050 m) in Wyoming (42°N) and up to 12,000 ft (3,658 m) in California (36°N). Whitebark pine occurs primarily in upper subalpine forests and at treeline in the United States and Canada, including the northern Rocky Mountains, Great Basin, Sierra Nevada, and Cascades, and northern coastal ranges (Arno and Hoff 1990; McCaughey and Schmidt 2001) (Figure 1.2). Its distribution is split into two broad sections: western and eastern. The western coastal batholith and volcanic chain sections include the Sierra Nevada and Klamath mountains of California and Cascade Mountains of California, Oregon, Washington, and British Columbia, and also the Olympic Mountains of Washington and coastal ranges through the Bulkley Mountains of British Columbia. The eastern Rocky Mountain sections range from the Wyoming and Wind River ranges of western Wyoming, north through the Greater Yellowstone Area, Idaho, Montana, and north to about 55 degrees latitude in Alberta and British Columbia. Whitebark pine also grows in the Great Basin ranges of California, in western, northern, and eastern Nevada, and in the Blue and Wallowa mountains of northeastern Oregon, northeastern Washington, and southern British Columbia (Little and Critchfield 1969; Ogilvie 1990). Updated information for the range-wide distribution of whitebark pine, using a standard scale and minimum size polygon, is available on the Whitebark Pine Ecosystem Foundation website *(http://whitebarkfound.org/?p=772)*.

Figure 1.2 Whitebark pine distribution map (Arno and Hoff 1989).

Whitebark pine on BLM-administered lands occurs primarily in Idaho, Montana, and Wyoming, and to a lesser extent in California, Nevada, Oregon, and Washington. The BLM's whitebark pine populations are often different than those on USFS and NPS lands because they include communities of trees at the lower-elevation range of whitebark pine. These include range margin habitats, disjunct populations, and geographically distinct mountain islands that serve as valuable seed sources for distant populations. Individual trees at lower treeline, and at high-elevation sagebrush-whitebark pine ecotones (~8,000–9,000 ft, 2,440–2,750m) on all federal ownerships may be especially drought resistant, and provide potential sources of genetic diversity (D.L. Perkins, pers. obs.). Because whitebark pine historically has not been a species of commercial interest, and comprises a small component of forests, the distribution of whitebark pine is largely unmapped on BLM lands. Acreage estimates based on USFS Forest Inventory and Analysis (FIA) data (*http://www.fia.fs.fed.us/*) and bioclimatic envelope models (Warwell, Rehfeldt, and Crookston 2007) vary from approximately 47,000 ac (USFS FIA) to greater than 145,000 ac (Warwell, Rehfeldt, and Crookston 2007; D.L. Perkins and B. Weihausen, unpublished data). See Table 1.

Description

Whitebark pine occurs on high-elevation sites characterized by rocky, poorly developed soils, cold temperatures, and snowy, windswept exposures (Arno and Hoff 1989). Whitebark pine occurs in three distinct community types: 1) trees that are dominant and self-replacing over time in climax communities, which are open stands on harsh, windswept sites, 2) flagged and krummholz (matlike growth) trees, growing either solitarily or in dense groups with other species (tree islands) in treeline communities, and 3) a minor to major seral species

Table 1. Estimated acreage of whitebark pine on BLM lands derived from Forest Inventory Analysis (USFS-FIA) data (second column); and a bioclimatic model (Warwell, Rehfeldt, and Crookston 2007), and *Atlas of United States Trees* (Little 1971) (third column).

State	Forest Inventory Analysis acres	Bioclimatic model acres (≥60% probability of occurrence)
Idaho	24,219	77,993
Montana	11,827	40,473
Wyoming	11,700	21,142
California	Not available	3,359
Nevada	Not available	1,894
Oregon	Not available	1,465
Washington	Not available	32
Total	**47,746**	**146,358**

Note: A 60% threshold for probability of occurrence from the bioclimatic model gave the most reliable estimates when verified with field data.

on productive sites with other conifers, such as subalpine fir (*Abies lasiocarpa*), lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmannii*), limber pine (*P. flexilis*) (Arno and Hoff 1990; Tomback, Arno, and Keane 2001b) (Figure 1.3).

Figure 1.3 Multiple age classes of whitebark pine, limber pine, and subalpine fir on Commissary Ridge. BLM-Wyoming, Kemmerer Field Office.

In climax communities, whitebark pine is a long-lived tree attaining ages of more than 1,000 years on exposed sites. Mature trees older than 400 years are common (Luckman, Jozsa, and Murphy 1984; Perkins and Swetnam 1996). It is slow-growing, investing in extensive root systems, and rarely grows faster than other conifers except on the most severe sites (Arno and Hoff 1990). Whitebark pine is considered shade-intolerant to moderately shade-tolerant (Minore 1979; Arno and Hoff 1990) and a poor competitor, which accounts for its successional status. On productive sites, it reaches heights of 22–65 ft (7–20 m).

Clark's nutcracker is the primary seed disperser for whitebark pine; the birds bury seeds several centimeters deep in soil or other substrate in caches of 1–15 seeds (Tomback 1978; Hutchins and Lanner 1982; Lorenz et al. 2011). Seeds that are not retrieved from these seed caches may germinate in place, leading to seedling establishment. As a consequence of multiple seeds in a cache, whitebark pine frequently occurs as a "tree cluster," which is a closely associated group of genetically

Figure 1.4 Three whitebark pines, each with multiple stems forming a tree clump. Multiple stems originate from seeds cached by Clark's nutcracker, the dispersal agent for whitebark pine.

Figure 1.5 Male pollen cones (strobili) (upper left) and a mature, ovoid-shaped whitebark pine cone (lower right). Cones occur on the tips of branches.

distinct stems (Lanner 1980; Linhart and Tomback 1985; Furnier et al. 1987) (Figure 1.4). It also occurs as a single-stemmed form. The krummholz form that occurs at the highest elevations is long-lived, and reproduces by layering (King and Graumlich 1998). It is less common than the upright tree form on lower-elevation BLM lands.

Whitebark pine seeds may be cached near source trees or more rarely transported 20 mi (32 km) or farther across the landscape (Lorenz et al. 2011; Tomback 1978). Nutcrackers cache across a variety of terrain, primarily in their home areas, which range in size from 0.5 to 20 sq mi (1.4–52 sq km). They use many forest types, including ponderosa pine (*Pinus ponderosa*), mixed conifer, and whitebark pine habitats. Seed caches are generally close to source trees (Lorenz et al. 2011; Tomback 1978), but have also been reported in open areas (Norment 1991) and burned areas (Tomback, Sund, and Hoffman 1993; Tomback et al. 2001). In contrast with resident nutcrackers that have established home ranges, nutcrackers also occur as migrant populations, caching seeds in autumn and moving on to new locations (Lorenz et al. 2011). Because whitebark pine seeds are primarily dispersed by Clark's nutcracker, nutcracker behaviors and population dynamics are extremely important to whitebark pine conservation. More information on nutcracker-pine interactions can be found in the Range-Wide Strategy, pages 8–11, and on the interagency website *(http://ecoshare.info/projects/whitebark-pine/)*.

Whitebark pine is a monoecious species, with both male and female strobili located on the same tree (Arno and Hoff 1990). Female cones (strobili) are deep purple when immature, purple-brown when mature, elliptical in shape, and grow at the tips of branches, primarily in the upper crown (Figure 1.5) (Arno and Hoff 1989). Male pollen cones are pink when mature, fading to orange when dry, and are generally found in the lower crown (Figure 1.5). Needles occur in fascicles of five, are 1.2–2.8 in. (3–7 cm) long, and a deep-yellow green to dark-green color. Unripe cones are resinous and range in length from 2 to 3.5 in. (5–8 cm); they are sessile, usually occur in clusters of two to five, and remain on the tree unless dislodged by animals (Arno and Hoff 1989). Cones are ovoid, with scales that are thick distally and terminate in a blunt tip. Cones contain about 60 large, 0.28–0.43 in. (7–11 mm) long, wingless seeds (Forcella and Weaver 1980; Owens, Kittirat, and Mahalovich 2008; Weaver and Forcella

1986). Tomback (1982) in the eastern Sierra Nevada reported a mean of 45 filled seeds per cone, whereas Owens, Kittirat, and Mahalovich (2008) and Weaver and Forcella (1986) reported 66 and 75 seeds per cone, respectively, in the Rocky Mountains. Whitebark pine starts producing cones at 30–50 years of age, with sufficient canopy volume to have high cone production at about 125–250 years of age (Arno and Hoff 1989; Krugman and Jenkinson 1974). The frequency of synchronous abundant cone crop years, or masting events, varies regionally by climate and population level, from yearly to every 2–5 years in many areas, although a few cones are produced within a stand nearly every year (Arno and Hoff 1990; Crone, McIntire, and Brodie 2011; Krugman and Jenkinson 1974; Tomback, Arno, and Keane 2001b).

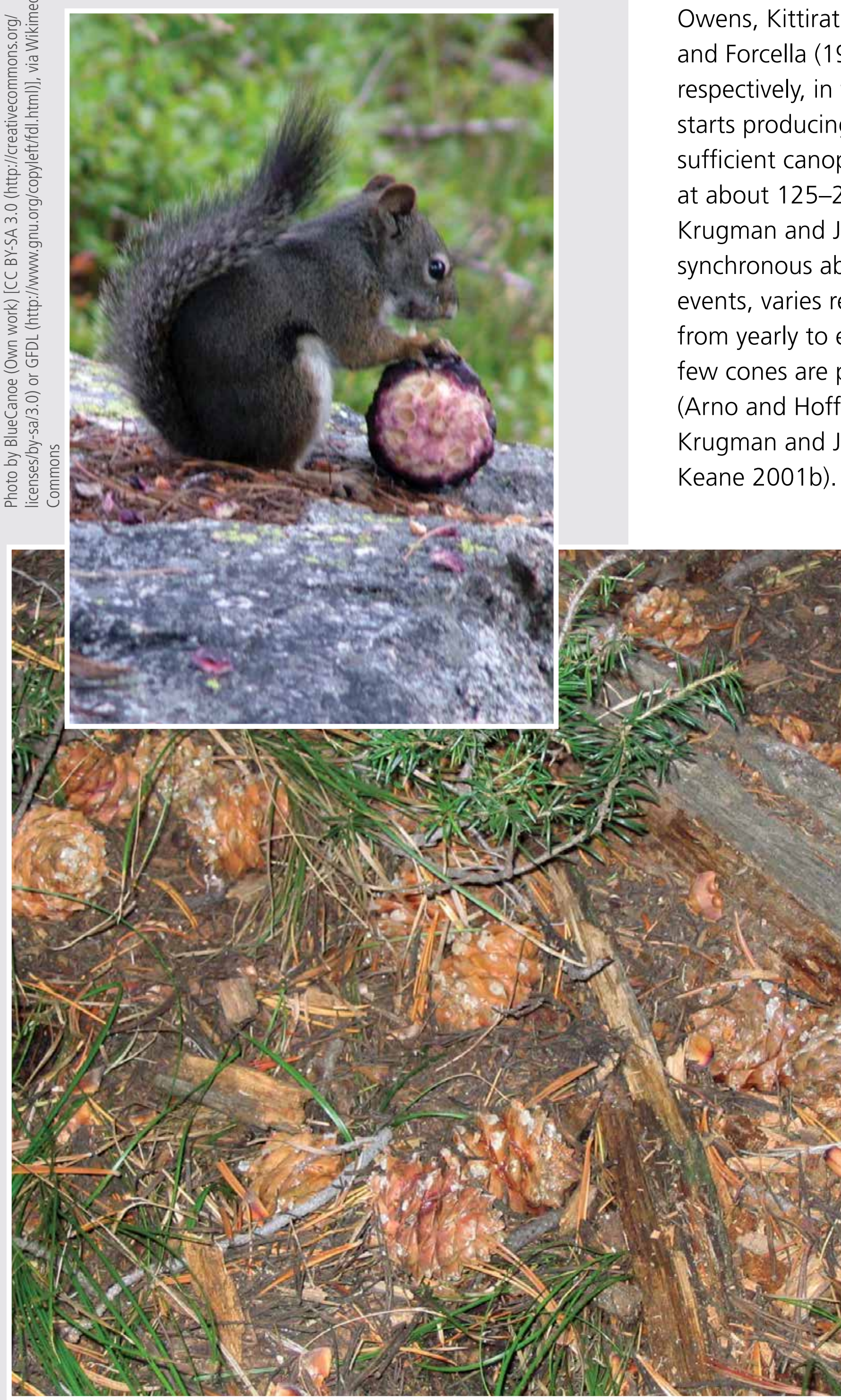


Figure 1.6 Whitebark pine cones stored in a pine squirrel midden on the ground are generally not a source of seed for regeneration.

Importance to Wildlife

Whitebark pines seeds are high in dietary fat, and numerous wildlife species, including the seed dispersal agent Clark's nutcracker, depend on them for a nutritious food source. Seeds are relatively large and contain from 28% (Robbins et al. 2006) to 52% fat, 21% carbohydrate, and 21% protein by weight (Lanner and Gilbert 1994). Their size and thick seed coat make whitebark pine seeds a high-quality, concentrated, and long-lasting food source. Pine squirrels (*Tamiasciurus* spp.) also compete for seeds with nutcrackers and cache whitebark cones in middens. There is little pine regeneration from these middens, however. (Figure 1.6). Black bears and grizzly bears raid middens, and black bears also climb trees to harvest cones. Granivorous rodents, such as chipmunks, and mice, also consume seed and pilfer seed caches (Hutchins and Lanner 1982; McCaughey and Weaver 1990; Tomback and Kendall 2001; Lorenz, Aubry, and Shoal 2008).

The relationship between whitebark pine and Clark's nutcracker is mutualistic, with positive benefits to both

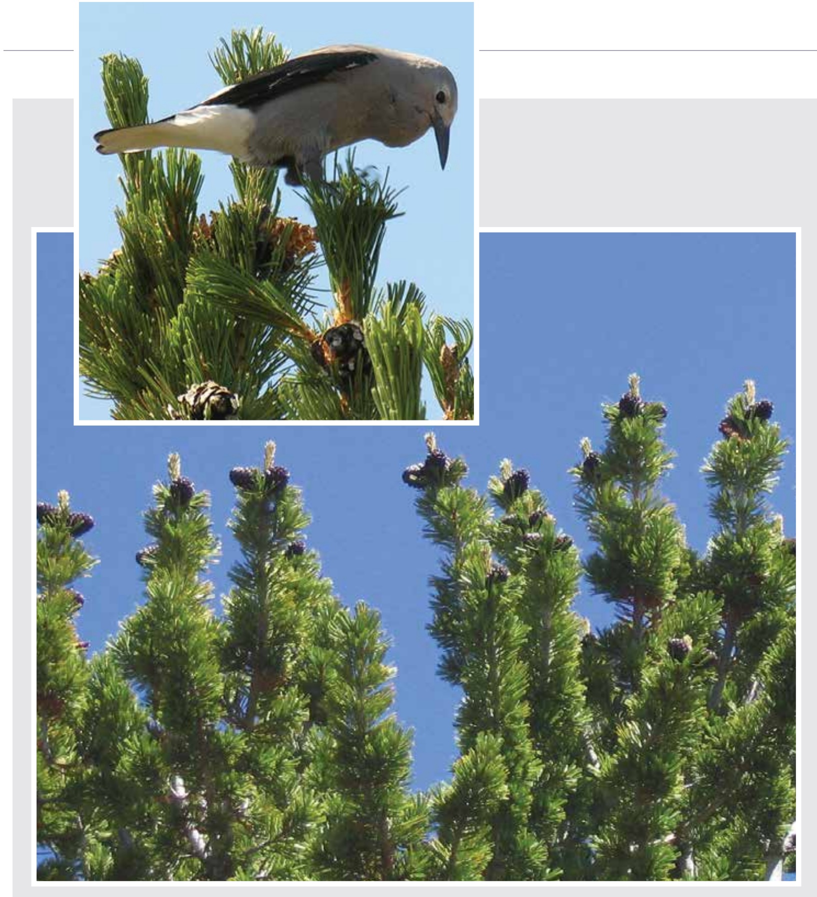


Figure 1.7 Whitebark pine cones are displayed in the top of the tree, an adaptation for bird-dispersed pines. The distended throat of the Clark's nutcracker is full of seed that the bird slips into a pouch under its tongue for transport, caching, or eating.

pine and bird (Tomback 1982; Tomback and Linhart 1990, Tomback 2001). Nutcrackers disperse seeds farther than wind disperses other conifer seeds (Tomback, Hoffman, and Sund 1990). Morphological characteristics that are adapted for the mutualistic interaction with the Clark's nutcracker (Lanner 1982, 1996; Tomback 1982; Tomback and Linhart 1990) include an upswept rounded crown where cones are displayed on vertically oriented branches to birds, and a closed, or indehiscent, cone that ensures availability of seed (Lanner 1982; Tomback 1978) (Figure 1.7).

Community Characteristics

The widespread distribution across soil types and varied disturbance histories of whitebark pine forests have led to diverse understory plant communities. In the northern Rocky Mountains and interior Pacific Northwest, common plant species on BLM land include grouse whortleberry (*Vaccinium scoparium*), gooseberry (*Ribes* spp.), thinleaf huckleberry (*V. membranaceum*), menziesia (*Menziesia ferruginea*), smooth woodrush (*Luzula glabrata*), and common beargrass (*Xerophyllum tenax*). Other species include sedges (*Carex* spp., mostly Ross' sedge, *C. rossii*) and Geyer's sedge (*C. geyeri*), pink mountainheath (*Phyllodoce empetriformis*), and broadleaf arnica (*Arnica latifolia*), depending on geographical area, aspect, and elevation (Arno and Weaver 1990; Campbell 1998; Keane and Parsons 2010b; Pfister et al.1977). Some whitebark pine forests have few to none of these understory species. In semi-arid whitebark pine community types, understory species that may occur include Idaho fescue (*Festuca idahoensis*), Parry's rush (*Juncus parryi*), silvery lupine (*Lupinus argenteus*), silky lupine *(L. sericeus*), singlehead goldenbush (*Ericameria suffruticosa, syn.* shrubby goldenweed, *Haplopappus suffruticosus*), and Wheeler's bluegrass (*Poa wheeleri*) (Arno and Weaver 1990; Aubry et al. 2008; Mancuso 2013) (Figure 1.8). While seral communities

Figure 1.8 Understory plant community on a xeric site includes: shrubby goldenweed (*Ericameria suffruticosa*), Idaho fescue (*Festuca idahoensis*), Wheeler's bluegrass (*Poa wheeleri*), prickly sandwort (*Arenaria aculeata*), and Indian paintbrush (*Castilleja* spp.).

Ectomycorrhizal fungi, Siberian slippery jack (*Suillus sibiricus*) on whitebark pine seedling roots.

Figure 1.9 Whitebark pine, like other pines, requires ectomycorrhizal fungi (white nodules – right) for survival in nature. Beneficial fungi such as Siberian slippery jack on the whitebark pine seedling (left) form a symbiotic relationship with the roots of trees and aid in nutrient and water transport. Rust-resistant seedlings must be inoculated with this beneficial ectomycorrhizae before out-planting.

generally have a lower diversity of vascular plants (Forcella 1978), high-elevation climax stands of whitebark pine may include many unique alpine, subalpine, and montane assemblages of understory species, some of which are found only in association with whitebark pine (Forcella 1978; Tomback and Kendall 2001). Forcella and Weaver (1977) found that whitebark pine forests had unexpectedly high biomass, but low productivity.

Below the ground surface, whitebark pine, like other forest trees, requires ectomycorrhizal (ECM) fungi, which improve survival on poor sites (Read 1998; Mohatt, Cripps, and Lavin 2008). ECM fungi are beneficial, forming a symbiotic relationship with the roots of trees. Siberian slippery jack (*Suillus sibiricus*) is one fungus that associates only with five-needle pines (Figure 1.9). Others include *S. tomentosus* var. *discolor, S. subalpinus,* and *Rhizopogon evadens,* although they do not grow as well in the greenhouse (C.L. Cripps, pers. comm.). Whitebark pine seedlings inoculated with ECM in Waterton Lakes National Park, Alberta, Canada, showed a 10%–15% higher survival rate over those that were not inoculated (Lonergan, Cripps, and Smith 2014). Commercial inocula should be avoided because they contain fungi that are not specific for five-needle pines, and many will not form mycorrhizae with whitebark pine. More information on the benefits of ECM fungi, inoculation in nurseries, and threats to ECM fungi can be found in the Range-Wide Strategy.

Range Margin Populations

Many whitebark pines on BLM lands occur in small, isolated disjunct stands on the range margin of the species. These populations differ from the more continuous populations that occur on USFS and NPS lands, hereafter called the "core" range. Differences include small population size, isolated stands, generally semi-arid sites, different plant community associates, and genetic differences (Anderson et al. 2009; Mahalovich and Hipkins 2011; Vergeer and Kunin 2012). Depending on aerial distance from other whitebark pine populations in relation to Clark's nutcracker seed dispersal flight distances, these isolated disjunct stands may be at an elevated risk for local extinction after a severe disturbance event, because of the possible scarcity of replacement seed from offsite sources. Nutcracker seed dispersal flight distances average 7.5 mi (12 km) (Tomback 1978; Lorenz and Sullivan 2009).

Fire

Fire is a natural component of many whitebark pine ecosystems, creating favorable conditions for establishing and maintaining whitebark pine dominance, but also causing tree mortality. Severe stand-replacing, low-severity, and mixed-severity fires all occur in whitebark pine stands, depending on drought cycles, fuel conditions, landscape burn history, associated vegetation, and high-wind events (Arno 1980; Morgan et al. 1994; Campbell et al. 2011). Reported mean fire return intervals range from 13 years to more than 400 years (Campbell et al. 2011).

Large, stand-replacing fires are often colonized by whitebark pine because of long-distance seed dispersal by Clark's nutcracker (Tomback, Hoffman, and Sund 1990; Tomback, Sund, and Hoffman 1993). When fires are severe and thus stand-replacing, whitebark pine may become dominant if regeneration is initiated by Clark's nutcrackers within a few years after the burn (Tomback, Hoffman, and Sund 1990; Tomback, Sund, and Hoffman 1993). Low- and moderate-intensity fires can reduce

Figure 1.10 A low-intensity, nonlethal surface fire burning in a whitebark pine forest. The species is able to survive some of these fires because of high crowns and deep roots. The thin bark makes it susceptible to mortality, however, when intensities are higher.

competition from conifers, shrubs, and dense grasses, thus maintaining whitebark pine (Figure 1.10). In some instances, whitebark pine crown architecture probably contributes to survival because its upswept limbs and high surface-to-crown height present fewer ladder fuels to transfer heat from passing surface fires to the crown (Larson and Kipfmueller 2010). On the highest rocky sites, where whitebark pines are widely spaced, fire frequency is low, and fire extent is small, often burning less than an acre or only an individual tree (Tomback 1986).

Although fire was historically beneficial for whitebark pine, it can also be detrimental. Climate change is believed to be driving the current trend toward longer and more intense fire seasons in the western United States (Westerling et al. 2006; Littell et al. 2010). Whitebark pine may now be at a point of lowered fire tolerance. Large high-severity fires can severely reduce or even eliminate cone-bearing whitebark pines across extensive landscapes. With additional losses from blister rust and mountain pine beetle, the loss of any whitebark pine trees may result in local stand extirpation. Subalpine fir and Engelmann spruce, co-dominants with whitebark in seral stands and where succession is advanced, are highly flammable, and a fire that moves into the crowns of these species may be "stand-replacing." If the fire becomes intense and widespread, killing most or all cone-bearing whitebark pines within the fire perimeter, seeds from unburned stands within nutcracker caching range may be available to regenerate whitebark pine. If there are no such seed sources, however, natural regeneration of whitebark pine will be extremely slow, or the species may fail to become reestablished (Keane and Parsons 2010b). This is especially critical in the isolated disjunct stands on BLM lands.

Genetics

A key component of the BLM's whitebark pine conservation and management program is the planting of rust-resistant seeds and seedlings for reforestation (Keane and Parsons 2010b; Mahalovich and Dickerson 2004; Mahalovich, Burr, and Foushee 2006). Understanding the genetics of whitebark pine is essential for developing the seed transfer guidelines to accomplish this. An individual's genetic makeup, the environment, and the interaction of an individual's genetic makeup with the environment determine an individual's phenotype (outward appearance). Phenotypic variation among individuals contributes to variation in measurable characteristics (quantitative traits) such as growth, survival, and resistance to disease and insects. Genetic variation is important because it provides the raw material for adaptation to new environments. The amount and structure of genetic variation within a population are influenced by many factors, including gene flow, mutation, genetic drift, and selection (Frankham, Ballou, and Briscoe 2002). Knowledge of a species' genetic structure is essential to ensure that management activities do not adversely affect the amount and patterns of genetic diversity.

Studies on the genetic structure of whitebark pine, blister rust resistance, drought tolerance, cold resistance, and other traits are being conducted primarily by Canadian and USFS geneticists, researchers, and academics. Whitebark pine has not been found to have a major gene resistance to blister rust, as have sugar pine (*Pinus lambertiana*) and limber pine (Schoettle et al. 2014); instead, its resistance is polygenic (that is, several genes are responsible for resistance). More information about these studies can be found in the Range-Wide Strategy, GYA Strategy, and PNW Strategy and peer-reviewed literature.

The isolated individuals and small populations on BLM-administered lands may represent the best-adapted trees for survival in the BLM's unique, characteristically dry and lower-elevation habitats. These trees are important genetic resources for future changing climates and landscapes.

Section 2: Disturbances and Threats

Overview

The decline of whitebark pine across most of its range in North America is the result of multiple, recent human-caused and natural events (Arno 1986; Kendall 1995; Kendall and Keane 2001; Tomback, Arno, and Keane 2001a; for more recent reviews, see Tomback and Achuff 2010 and Tomback et al. 2011). The major threats identified by the USFWS in its 12-month finding include white pine blister rust, mountain pine beetle, changing fire regimes, and changing climate (Federal Register 2011). At the stand level, the scale at which the BLM populations usually occur, extirpation from these threats has not yet been observed.

The most serious event was the introduction of the exotic fungal pathogen *Cronartium ribicola* to the western United States and Canada in the early 1900s. This pathogen causes the disease white pine blister rust (Geils, Hummer, and Hunt 2010; McDonald and Hoff 2001). The disease has been found in all five-needle pine species except Great Basin bristlecone pine. The pathogen enters host pines as basidiospores through the stomates in the needles. Then the spores germinate, and the mycelia grow down into the branches and eventually into the stem. Several years after infection, sporulating cankers will form, ultimately killing the branch's or tree's biomass above the canker. The individual may die if it does not possess one of several resistance mechanisms (i.e., no needle spots, needle shed, short shoot, bark reaction [Hoff 1986; Mahalovich and Hipkins 2011]) or if it does not exhibit canker tolerance.

Mountain pine beetle outbreaks are historically a natural, intermittent disturbance event in whitebark pine communities (Ciesla and Furniss 1975; Furniss and Carolin 1977; Arno and Hoff 1989). Several major, natural mountain pine beetle outbreaks during the last 90 years have killed many mature, cone-bearing whitebark pine trees across the range (Arno 1986; Perkins and Swetnam 1996; Baker, Amman, and Trostle 1971; Waring and Six 2005). The most recent mountain pine beetle outbreak, which began in the late 1990s to early 2000s, depending on location, has achieved widespread geographic extent and high levels of mortality. Mountain pine beetles create breeding chambers in the sap wood, and introduce blue stain fungi, a larval food, which spreads throughout the wood. Together these two processes interrupt water transport and girdle the tree, causing tree death (Solheim and Krokene 1998).

Changes in wildfire frequency and severity caused by changing climate and by ongoing fire exclusion practices have affected whitebark pine in several ways (Keane et al. 2012). Warmer and drier conditions have resulted in severe, stand-replacing fires that can destroy both seral and climax whitebark pine stands. In the past, during wetter and cooler climates, fires were less frequent and resulted in a patchwork mosaic of successional stages. Suppression of wildland fire has led to advancing succession, resulting in reduced whitebark pine basal area as shade-tolerant conifer species increase in size and density (Keane, Morgan, and Menakis 1994). Fires are more likely to spread and intensify in whitebark pine communities during the first few years after mountain pine beetle outbreaks, when red needles and fine twigs and branches are still on trees or have recently fallen to the ground. Seral whitebark pine stands composed of mixed conifer species may have the high densities and ladder fuels sufficient for intense crown fires.

Climate change has the potential to affect physiology and biochemical pathways (Wikelski and Cooke 2006) and phenology (i.e., the timing of recurring life history events) (Ovaskainen et al. 2013) and could change the frequency, duration, and intensity of disturbance regimes that affect whitebark pine and other forest ecosystems (Dale et al. 2001; Dale et al. 2010). In addition, warming trends will result in earlier snowmelt and changing local hydrology, which can lead to drought stress and mortality (van Mantgem et al. 2009). Further, changes in hydrology have led to more severe and longer fire seasons (Westerling et al. 2006). Inherent in climate change effects is uncertainty, with both beneficial and harmful effects forecast (Keane et al. 2012).

The cumulative effects and interactions of these four change agents—blister rust, mountain pine beetles, climate change, and fire—have resulted in a decrease in mature whitebark pine, particularly in the more mesic parts of its range (Campbell and Antos 2000; Elderd, Dushoff, and Dwyer 2008; Keane and Arno 1993; Six and Adams 2007).

In the more xeric regions, such as the Great Basin ranges of California and Nevada and some parts of central Idaho, interactions of the four change agents are less pronounced because blister rust is currently not present, or present only at low levels, and mountain pine beetle outbreaks have not been extensive (Gibson et al. 2008; C.I. Millar, pers. comm.). In central Idaho and some other areas of the northern Rocky Mountains, mountain pine beetle outbreaks have declined (Perkins, Jorgensen, and Rinella 2015). In the following sections, the current threats to whitebark pine and the extent of decline across the species' range are described in more detail.

White Pine Blister Rust

White pine blister rust is an exotic fungal disease of five-needle pines (Burns et al. 2007). It was introduced to western North America in several occurrences before and during 1910 on infected eastern white pine nursery stock grown in France and shipped to Vancouver, British Columbia (Geils, Hummer, and Hunt 2010). Since then it has spread throughout most of the range of all five-needle pines in the United States and Canada without, however, affecting Great Basin bristlecone pine.

The blister rust fungus *Cronartium ribicola* has a complex life cycle involving five different spore types on the host pine and the alternate hosts (Figure 2.1). Blister rust cankers on the five-needle white pine hosts produce aeciospores, which transmit the disease to the alternate hosts. These hosts are most commonly shrubs of the genus *Ribes,* but also may include forbs of the genera *Pedicularis* and *Castilleja* (McDonald et al. 2006; Geils, Hummer, and Hunt 2010). Basidiospores produced by the alternate hosts are fragile, short-lived spores that infect pines by entering the needle stomata. This stage of the life cycle is the most climatically limited, requiring moderate temperatures and high humidity for spore production and transmission to pines (McDonald and Hoff 2001).

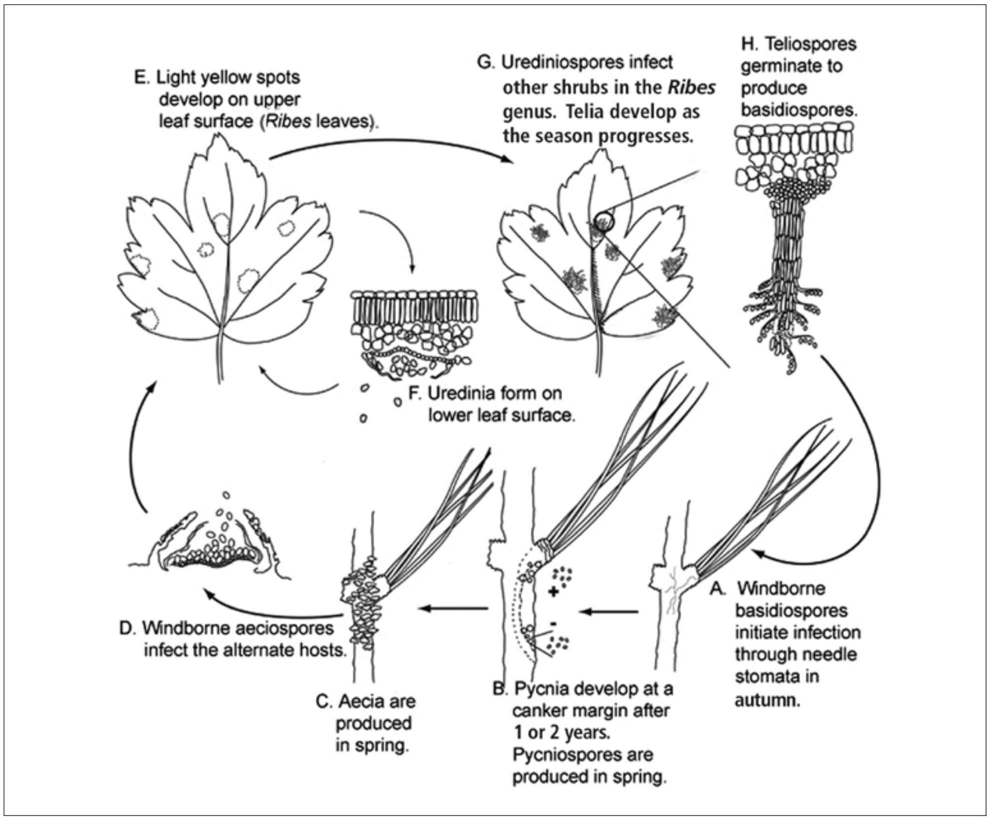


Figure 2.1 Life cycle of white pine blister rust. Initial infection site on pine host occurs through stomates in the needle (A). The complete cycle proceeds counterclockwise (B–D) to an alternate shrub host (e.g., *Ribes* spp.) (E– H). (Drawing by Vickie Brewster.)

Figure 2.2 Symptoms of white pine blister rust caused by *Cronartium ribicola*: Orange needles, called flagging, the initial site of infection through stomates in needles (upper left); aeciospores on twig (lower left); canker on bole, also with aeciospores (right).

Blister rust outbreaks in North America have often been characterized by "wave years," i.e., years when climate is especially favorable for new infections, resulting in significant intensification and spread (Mielke 1943). For successful germination and infection to occur, there must be 48 hours of 98% relative humidity and temperatures not less than 50 °F (10 °C) or more than 68 °F (20 °C) (McDonald and Hoff 2001).

Basidiospores typically travel a short distance by wind—most often a few hundred feet—but have been known to spread as far as 5 mi (8 km). Spores that germinate within the needle tissue produce hyphae, which then grow into the vascular system and into the pine stem (McDonald and Hoff 2001; Geils, Hummer, and Hunt 2010; and references therein). Between 12 and 18 months later, a slightly swollen cankered area first becomes visible.

The following information is from McDonald and Hoff (2001) and Geils, Hummer, and Hunt (2010) and references therein: Between 2 and 3 years after initial infection, the canker produces pycnia and pycniospores. The pycniospores produce gametes for fertilizing other infections and lead to development of the aeciospores (Figure 2.2). Aecia form in the same location on the canker as the pycnia in spring after an additional

12–14 months. The relatively tough aeciospores are wind-disseminated over distances as great as 310 mi (500 km) and infect leaves of alternate hosts. Infection of the alternate host also occurs under humid conditions. Within weeks of infection, uredinia are produced on the leaves of alternate hosts. Urediniospores released by the uredinia continue to infect alternate hosts throughout the summer, increasing the numbers of infected alternate hosts. In late summer to early autumn, hairlike telial columns emerge from the old uredinial pustules. Teliospores germinate in place on these columns and produce basidiospores, starting the process over again. The entire life cycle requires 3–6 years for completion, depending on climate (Boyce 1961).

There have been many failed attempts to control blister rust. Projects attempting to eradicate *Ribes* spp. from 1940 to 1960 were largely unsuccessful because the shrub can regenerate vegetatively from rhizomes, and its seeds reside in a soil seed bank and germinate after fire and other disturbances. Aerial applications of antibiotic solutions in diesel oil sprayed on whitebark pine to combat blister rust were mostly ineffective and costly, and potentially destructive to other species (Brown 1969; Maloy 1997). Management actions such as pruning infected branches and thinning infected western white pine may forestall tree mortality from blister rust, but prolong the seed production of nonresistant genotypes (Fins et al. 2001).

White pine blister rust damages and kills whitebark pine trees by girdling branches and trunks (Hoff 1992), thereby reducing seed cone production on individual trees and across forest stands. For example, in the Bitterroot Mountains of western Montana and eastern Idaho, whitebark pine cone production was significantly lower in stands with higher rust damage (canopy kill and tree mortality) compared with stands having lower rust damage that were otherwise similar in forest structure, composition, slope, and elevation (McKinney and Tomback 2007). Thus, blister rust directly constrains the ability of individual trees and forest stands to contribute propagules, and hence genetic material, to subsequent generations. Furthermore, Clark's nutcrackers are less likely to visit stands with lower cone production, thus reducing regeneration potential (McKinney, Fiedler, and Tomback 2009; Barringer et al. 2012).

Whitebark pine blister rust resistance trials initiated at U.S. Department of Agriculture, Forest Service (USDA/USFS) forest genetics centers (Rocky Mountain Research Station in Fort Collins, Colorado; Coeur d'Alene Nursery in Coeur d'Alene, Idaho; Dorena Genetic Resource Center in Cottage Grove, Oregon; Forest Service National Forest Genetics Laboratory, Pacific Southwest Research Station in Placerville, California) have found low to moderate levels of natural resistance in some populations, as evidenced by the ability of seedlings to survive multiple spore inoculations (Bingham, Hoff, and McDonald 1972; Mahalovich, Burr, and Foushee 2006; Vogler, Delfino-Mix, and Schoettle 2006; Sniezko 2006; Sniezko et al. 2011). In high rust mortality areas, resistance ranges from 33% in a small sample (n=3) (Hoff, Bingham, and McDonald 1980) to 47.4% (n=108) (Mahalovich, Burr, and Foushee 2006; M.F. Mahalovich, unpublished data) in the Inland Northwest, and 26.3% (n=43) on the Pacific Coast (Sniezko et al. 2007). The results are preliminary and may not be comparable between testing centers with different field seed sampling and resistance assessment methodologies.

Generally, seedlings grown from seed collected from healthy trees in stands that are heavily infected and damaged by blister rust have the highest probability of resistance (McDonald and Hoff 2001). This is because these stands have been exposed to the rust for longer periods of time, and the surviving trees have a higher frequency of rust resistance than the original stand. Rust-resistant seedlings (those grown from seeds from screened parent trees) have the best chance for survival when used in restoration plantings and breeding programs in the seed zone from which they were collected.

Mountain Pine Beetle

Mountain pine beetle, a native cambial-feeding bark beetle, has been considered the most damaging insect to whitebark and all other pines in western North America (Furniss and Carolin 1977). It typically attacks mature, reproductive-aged trees, generally greater than 8 in. (20 cm) diameter at breast height (dbh) (Perkins and Roberts 2003), although pole-size trees with dbh as small as 4 in., or 10 cm, may be attacked in outbreak conditions (Cole and Amman 1980). Recent outbreaks have occurred from northern British Columbia to southern Colorado and resulted in the deaths of millions of lodgepole, ponderosa, limber, and whitebark pines (Gibson et al. 2008). Trees defend themselves from bark beetles primarily through resin exudation (Raffa et al. 2005; Faccoli and Schlyter 2007; Ferrenberg, Kane, and Mitton 2014). However, when the beetles reach high densities, they can overwhelm this defense with a mass attack strategy (Logan and Powell 2001).

Typically, outbreaks last 8–12 years in individual stands before most suitable hosts are depleted and mountain pine beetle populations decline (Roe and Amman 1970; Cole and Amman 1980; Perkins and Swetnam 1996). Cold weather events and natural enemies sometimes curtail outbreaks before host populations are depleted (Safranyik and Carroll 2006; Bentz et al. 2010). The cool, high-elevation environments of whitebark pine have historically led to slow, asynchronous mountain pine beetle development and adult emergence from trees, thereby moderating outbreaks in these systems (Bentz, Logan, and Amman 1991; Logan and Bentz 1999; Bentz et al. 2014). Although mountain pine beetle epidemics have been documented in whitebark pine in the past (Ciesla and Furniss 1975; Perkins and Swetnam 1996; Perkins and Roberts 2003), tree mortality during the current epidemic that began in the early 2000s exceeds that of any previously recorded epidemic (Gibson et al. 2008). Warmer temperatures, especially warmer minimum temperatures—a consequence of climate change—are producing conditions that are conducive to more severe mountain pine beetle epidemics.

Mountain pine beetles spend most of their life cycle under the tree's bark, where the insect disrupts the connectivity of the water transport system of the tree, damaging the tree by mechanically girdling the stem with adult and larvae galleries (feeding and breeding activity) in the phloem, and introducing a blue stain fungus that inhibits water transport and ultimately kills the tree.

Signs of a mountain pine beetle attack are pitch tubes, which occur when beetles bore into the bole of the tree. On successfully attacked trees, pitch tubes are abundant on the surface of the bole and may extend more than 5 m up the stem (Figure 2.3). Pitch tubes are cream to dark-red masses of resin mixed with phloem boring dust (frass), and are approximately 1 cm long. Unsuccessful beetle attacks are called "pitch outs," because the tree's resin response is to "pitch out" the beetles as they attempt to bore into the inner bark. Whitebark pine, like other pines, may sustain "strip attacks," where a vertical portion of inner bark is killed while the rest of the stem is unaffected and continues to transport water and nutrients. Foliage of successfully attacked trees generally fades uniformly through the crown from yellowish green to shades of orange, rust, and red. Whitebark pine crowns generally fade to a rust color the year after attack, but this may take 2–3 years in some individuals. Size, stress, and health of the tree affect the foliage fade rate.

Adult mountain pine beetles begin attacking trees in the early summer in pheromone-mediated mass attacks that overcome most of a tree's

Figure 2.3 A successful mountain pine beetle mass attack characterized by pitch tubes and frass (boring dust from beetle activity). Mass attacks are lethal to host pines.

chemical defenses (Progar et al. 2014). Beetles develop through four stages: egg, larva, pupa, and adult (Figure 2.4). Adults mate and then lay eggs that hatch into larvae, which develop in the phloem of the tree, completing the life cycle. Larval growth is aided by the symbiotic fungi *Grosmannia clavigera* and *Ophiostoma montium* (Six and Adams 2007; Six 2003; Six and Paine 1998). Adult beetles deposit the fungi in the tree as they excavate galleries where the females lay eggs. The fungi colonize the phloem and sapwood of the infected tree, and the fungal hyphae are the primary food source for beetle larvae (Six 2003). Adult beetles also feed on fungal spores in the pupal chambers before emergence and dispersal from the host tree. One to several months after the tree is infested, the sapwood discolors to a bluish tint caused by the fungus. Adult mountain pine beetle galleries found under the bark are J-shaped and vertically aligned with the stem; larvae galleries run perpendicular to the adult galleries and terminate in pupal chambers (Figure 2.4). Adult galleries range in length from 2 to 3 in. (5–7 cm) to more than 24 in. (60 cm) and are diagnostic of mountain pine beetle attack.

Mountain pine beetle life cycles span 1–2 years, and many empirical, laboratory, and modeling research studies have sought to understand the cause of this life cycle variability (Bentz, Logan, and Amman 1991; Logan and Powell 2001; Powell, Logan, and Bentz 1996). Over most of its range, the beetle has one generation per year, but at cooler, high-elevation areas, including whitebark pine forest, each generation typically takes 2 years (Logan and Powell 2001). Previously, these forests were generally associated with lower beetle-caused mortality because the cold environment creates unfavorable heat balance for beetle development (Amman 1973; Logan and Bentz 1999). Cool temperatures retard development, resulting in longer life cycles and/or a disruption of the critical timing of summer emergence necessary for a coordinated and successful mass attack. Although mountain pine beetles have mechanisms to survive in subzero temperatures, sustained subfreezing temperatures may result in mortality in all life stages (Amman and Cole 1983; Bentz et al. 2010).

Mountain pine beetle outbreaks and resulting tree mortality have been an intermittent and natural disturbance factor in western forests (Amman 1973; Perkins and Swetnam 1996). These outbreaks influence canopy closure, stand structure, species composition, forage production, wildlife habitat, fuel loading, water yields, and aesthetics. Following the death of the host overstory in outbreak conditions, advanced regeneration of both whitebark pine and its competitors (e.g., lodgepole pine, subalpine fir) is expected to release. Species composition plays a critical role at this time; if the stand is composed of shade-tolerant species, these competitors would be expected to remain dominant. If the stand is a climax whitebark pine community, the expectation is for whitebark pine persistence.

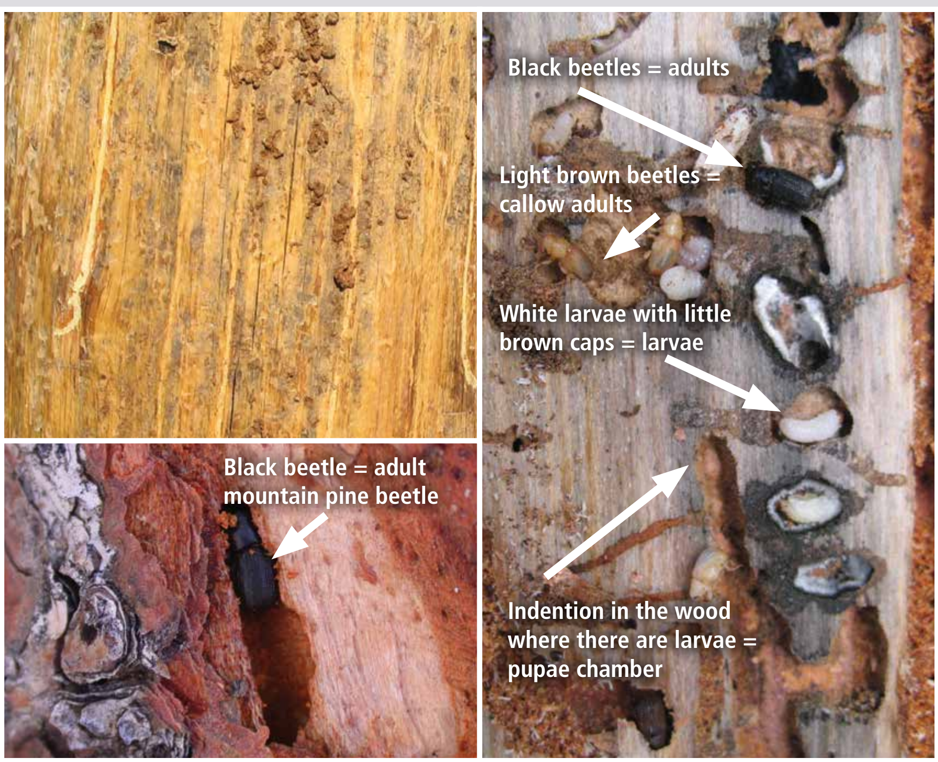


Figure 2.4 J-shaped mountain pine galleries made by adult mountain pine beetles (upper left); an adult mountain pine beetle (lower left). Multiple life stages of mountain pine beetle (right), including an adult, callow adults (light brown bodies), and larvae stages.

Climate Change

The response of whitebark pine to climate change is uncertain. Changing temperature and precipitation patterns and timing will affect the phenology and synecology of whitebark pine and Clark's nutcracker, as well as the frequency, duration, and intensity of disturbances, but outcomes are largely unknown.

A new USFS Rocky Mountain Research Station technical report by Robert Keane and others, "Restoring Whitebark Pine (*Pinus albicaulis*) Ecosystems in the Face of Climate Change" (in press), covers climate change as it relates to whitebark pine restoration. This report should be used alongside the Range-Wide Strategy. Tomback and Achuff (2010) and references within also summarize different climate change scenarios for whitebark and other white pine species.

Some of the greatest effects of climate change will be:

- Increases in temperature and more frequent drought
- Increased wildfires
- Changes in insect and disease outbreaks
- Altered distribution, synecology, and phenology of whitebark pine and other conifers
- Changes in distribution and abundance of plant and animal species
- Changes in soil water availability

The 2014 National Climate Assessment (NCA) forecasts that the climate in areas currently occupied by whitebark pine will change significantly by 2040–2060 (Melillo, Richmond, and Yohee 2014). In Idaho, Montana, and Wyoming, the NCA forecasts temperature increases of 4.5 °F – 5 °F. Forecasts from climate models from the Middle Rockies Rapid Ecoregional Assessment (REA) (BLM 2012) and chapter 7 of the Wyoming Basin Rapid Ecoregional Assessment (Ray, Liebmann, and Allured 2015) forecast temperature changes within the same range. Global circulation models of temperature are in general agreement, showing increasing temperature trends over several decades, depending on the CO_2 emission scenario. Slightly wetter conditions (2%–9%) within the Idaho, Montana, and Wyoming portions of whitebark pine's range are projected by the third NCA (chap. 19, Ojima et al. 2014), a National Oceanic and Atmospheric Administration assessment (Kunkel et al. 2013), the Middle Rockies REA (BLM 2012), and the Wyoming Basin REA (Ray, Liebmann, and Allured 2015). Models indicate that precipitation will increase in the winter and decrease in the summer across most of the core range of whitebark pine in this three-state region. Reductions in rainfall during dry seasons for the next thousand years, however, are forecast for some regions, even if carbon emissions were to cease completely (Solomon et al. 2009).

Many climate change studies consistently project drier conditions across the range of whitebark pine. This could result in large increases in the annual number, size, and intensity of wildfires and the area burned (Westerling et al. 2006; Flannigan et al. 2008; Krawchuk et al. 2009; Marlon et al. 2009). Modeling by Littell (2011) and Means and Littell (2014) forecasts that by 2040, wildland fire acreages may increase by 500%–600% within the core BLM whitebark pine areas in Idaho, Montana, and Wyoming.

Other disturbance agents, such as insect and disease outbreaks, will also be affected by climate change. The current large-scale mountain pine beetle outbreaks are likely a result of warmer winter temperatures, which facilitate beetle expansion and population establishment in the higher-elevation whitebark pine zones (Bentz et al. 2010; Logan and Powell 2001). The response of white pine blister rust to warmer temperatures is considerably more complicated, because the pathogen is also affected by humidity and response of the host species to climate change (Keane et al. 2015).

Bioclimatic envelope modeling has been used to project changes in whitebark pine distributions under different climate scenarios (Tomback and Achuff 2010). These models use climate data as independent predictor variables and biological data as dependent variables to predict species range; they have no inputs for seed dispersal, disturbance regime, topography, seedling survival, or soils and thus serve only as coarse scale assessments. Hamann and Wang (2006) predicted a 73% loss in habitat in whitebark pine habitat by 2085, but with an offset gain in habitat amounting to 76% of the original area. McKenney et al. (2007) projected a 42% decrease in whitebark pine's range. These models are generally in agreement with other bioclimatic models (including Warwell, Rehfeldt, and Crookston 2007; and Schrag, Bunn, and Graumlich 2008) that show a decrease in whitebark pine distribution.

Keane et al. (2015) discuss the uncertainty of climate change models and species' responses. As an example of uncertain responses, there could be higher frost mortality of whitebark cone crops due to earlier onset of the growing season coupled with high daily temperature variability. Or, cone crops could be reduced in the future because of the high tree stress from drought. Or, because whitebark pine is both drought tolerant and cold tolerant, changes in climate variability and timing could have minimal impact on species reproduction.

Climate change will also affect the distribution of many species across the landscape. Subalpine fir, alpine larch (*Larix lyallii* Parl.), and spruce are moving into subalpine meadows as a result of recent sequential warm years, which have led to increased high-elevation regeneration (Keane et al. 2015). Recent work by Daly, Conklin, and Unsworth (2009) suggests that cold air drainages within the current range of whitebark pine may become refugia in times of changing climatic conditions. ("Refugia" is used here to mean areas where environmental conditions may favor or enable a species or community of species to survive where it might otherwise perish.) Many of the BLM's whitebark pine stands are on the range margins, and there is anecdotal evidence of whitebark pine establishing in downslope drainages—in effect, refugia—on BLM lands (W.C. Hensley, pers. comm.; R.E. Means, pers. comm.).

Paleoecological data spanning the last 15,000 years from the Greater Yellowstone Area describe the response of vegetation to past climate variability. They suggest that five-needle pines have been surprisingly resilient to high summer temperature and fire activity in the past, but that these pines may be more vulnerable to projected warmer and drier winters (Iglesias, Krause, and Whitlock 2015). Keane et al. (2015) also report evidence of warmer climates in paleoecological records, which indicate that whitebark pine was maintained and even increased in some parts of its range (Tausch et al. 1993; Whitlock and Bartlein 1993). Whitebark pine can grow within a broad upper elevation zone in western North America and grows best at high elevations, where there is little competition from other species (Arno and Hoff 1989). In fact, Arno, Reinhardt, and Scott (1993) found that before the modern fire suppression era, whitebark pine's elevation range extended more than 500 ft below the current lower-elevation limits in the Bitterroot Mountains of Montana. In addition, whitebark pine occupies the largest range of any five-needle white pine in the western United States and Canada, including about 18 degrees of latitude and 21 degrees of longitude, indicating tolerance to different climates (Tomback and Achuff 2010).

Other modeling efforts have shown that whitebark pine might be maintained on the landscape if the predicted increase in large, stand-replacement fires creates large, competition-free burned areas (Loehman, Corrow, and Keane 2011; Keane et al. 2015). Moreover, whitebark pine may be resilient to changing climates in the northern Rocky Mountains because of high levels of genetic diversity (e.g., Bruederle et al. 2001; Mahalovich and Hipkins 2011), moderate to high heritabilities in key adaptive traits (M.F. Mahalovich, in press), demonstrated blister rust resistance (Hoff, Bingham, and McDonald 1980; Mahalovich, Burr, and Foushee 2006; Sniezko et al. 2007), minimal inbreeding (Bower and Aitken 2008; Mahalovich and Hipkins 2011), and generalist adaptive strategies (M.F. Mahalovich, in press).

In summary, although the effects from global climate change on whitebark pine are complex and difficult to predict, this is no reason not to implement restoration projects (Hobbs and Cramer 2008). Keane et al. (2015) state that, because of human-caused factors leading to whitebark's decline as well as the uncertain effects of climate change, "Active restoration is the only course of action for conserving whitebark pine ecosystems." Climate change scenarios can be incorporated into adaptive management and used to guide the design, approach, and types of conservation activities across the range of whitebark pine. The future will develop most likely as combinations of scenarios, some of which will be novel and unexpected (Millar, Stephenson, and Stephens 2007).

Extent of Decline

Many upper subalpine ecosystems in the western United States and Canada are losing whitebark pine. A number of assessments, peer-reviewed papers, and technical reports have documented this decline (see the Range-Wide Strategy, Table 1.1, p. 31). "The USFS 2013–2027 National Insect and Disease Forest Risk Assessment" (Krist et al. 2014) forecasts that the basal area losses for whitebark pine will approach 60% during the next 15 years, primarily as a result of mountain pine beetle and white pine blister rust.

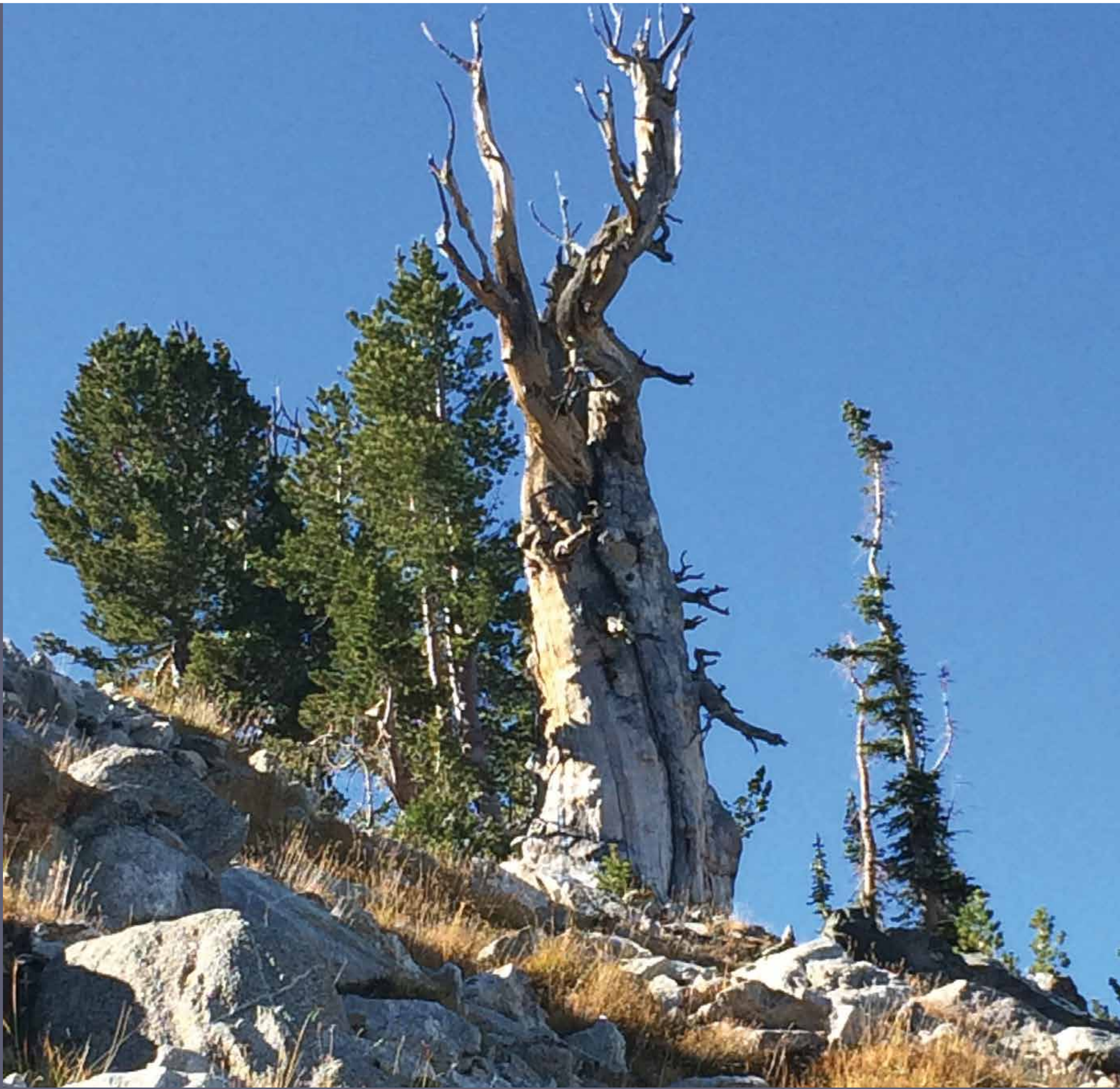
In northern Idaho on USFS-administered lands, repeated monitoring of natural regeneration in 1995–2012 revealed a 4.3% annual increase of white pine blister rust; average mortality in 1995 was 12% and increased to 59% in 2012. After 17 years, only 2.4% of whitebark pine greater than 5 in. dbh were not infected by white pine blister rust, and only 15% of the trees less than 1 in. dbh were not infected. These results indicate that whitebark pine in northern Idaho stands is in serious decline, and survival of natural regeneration is in jeopardy due to blister rust (Schwandt et al. 2013).

The Greater Yellowstone Whitebark Pine Monitoring Working Group repeated measurements of permanent belt transects from two time steps, or periods: 2004–2007 and 2008–2011. This work showed a 20% loss of whitebark pine from all causes (mountain pine beetle, white pine blister rust, fire, and other). Blister rust infection transition from canopy to bole occurred in 30% of the revisited trees, while overall infection rates remained nearly constant at 0.22 for the first time period and 0.23 for the latter time period (Greater Yellowstone Whitebark Pine Monitoring Working Group 2013).

Forest inventories using standard stand exam and FORVIS (Forest Vegetation Information System, National Science and Technology Center, Denver, Colorado) methods were conducted on 1,800 ac of whitebark pine, mixed whitebark and limber pine, and limber pine stands inventoried on BLM lands in 2011–2014. Mortality ranged from 15% to 52% from the recent (ca. 2000s) mountain pine beetle epidemic, and blister rust levels ranged from 0% to 43% for stand-level averages.

The Whitebark and Limber Pine Information System (WLIS) database is a compilation of all plot data documenting the condition and decline in whitebark and limber pine in the Pacific Northwest and Rocky Mountains, and has recently been improved and updated. WLIS may be queried to document stand-level declines and conditions. (See link below.)

http://www.fs.usda.gov/wps/portal/fsinternet/!ut/p/c4/04_SB8K8xLLM9MSSzPy8xBz9CP0os3gDfxMDT8MwRydLA1cj72DTUE8TAwjQL8h2VAQAMtzFUw!!/?ss=1101&navtype=BROWSEBYSUBJECT&cid=stelprdb5157913&navid=140000000000000&pnavid=null&position=Not



Section 3: Conservation Actions

This section provides direction on how to manage whitebark pine on BLM-administered lands. Our goal is to conserve and maintain whitebark pine forests and potential habitats experiencing white pine blister rust, mountain pine beetle, wildland fire, and a changing climate (Figure 3.1).

The direction provided is consistent with the BLM's "Assessment, Inventory, and Monitoring Strategy: For Integrated Renewable Resources Management" (Toevs et al. 2011) and "Adaptive Management: The U.S. Department of the Interior Technical Guide" (Williams et al. 2009). The components and actions outlined in the following sections adhere to assessment, inventory, and monitoring (AIM) elements: 1) standard set of

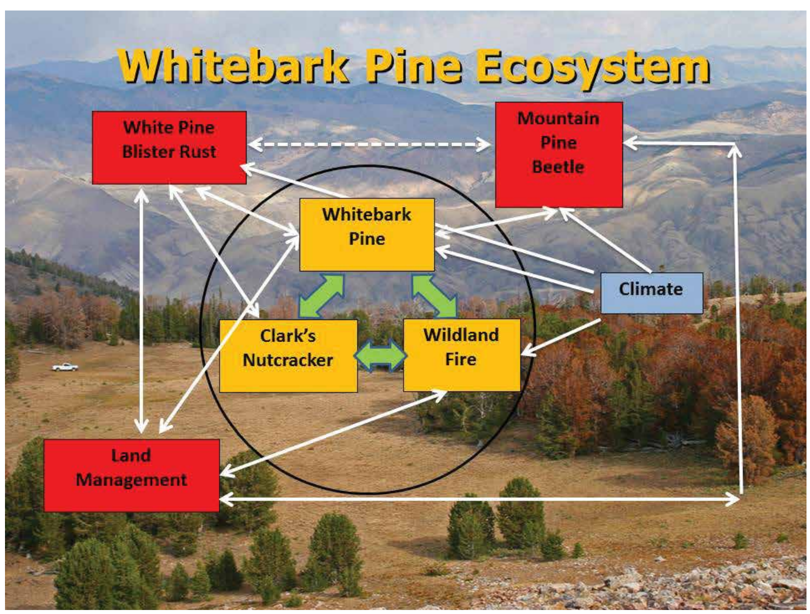


Figure 3.1 Feedback diagram from "Restoring Whitebark Pine (*Pinus albicaulis*) Ecosystems in the Face of Climate Change" (Keane et al., in press), which shows the key components of whitebark pine ecosystem dynamics. The background shows whitebark pine mortality caused by a mountain pine beetle outbreak in 2007 on BLM-managed lands. BLM-Idaho, Challis Field Office.

core quantitative indicators and methods, 2) statistically valid sampling design, 3) integration with remote sensing, 4) electronic data capture and management, and 5) implementation process. The decision to implement activities in the face of uncertainty can be adjusted as management and research outcomes become understood (Williams et al. 2009). This is a working document and is intended to be updated as needed. It also follows the principles of the Range-Wide, GYA, and PNW strategies, including the associated actions to guide the design, planning, and implementation of conservation activities and to protect existing habitats.

The BLM's conservation objectives for whitebark pine are:

1) Protect and maintain the genetic diversity of whitebark pine
2) Increase white pine blister rust resistance in future whitebark pine populations
3) Document conditions of current and potential whitebark pine habitats
4) Protect known or potential rust-resistant seed sources
5) Use silvicultural practices, including prescribed fire, to restore and maintain populations

Treatments based on current scientific information will have the greatest success and will be the most efficient. Two annotated bibliographies address whitebark pine ecology, research, and management. The following source was published in 2008 and is updated annually: *http://www.fedgycc.org/wp-content/uploads/2015/06/whitebarkbibilio_dec162008_nb.pdf*

Another source of current research is the Whitebark Pine Ecosystem Foundation website (*www.whitebarkfound.org*) and references within. We recommend that the BLM designate a whitebark pine contact person to coordinate activities among states, provide technical expertise, and act as the liaison with the other agencies and nongovernment organizations that are involved in whitebark pine management and conservation.

The actions supporting the above-described objectives are:

1) Mapping
2) Inventory
3) Monitoring
4) Gene conservation
5) Cone (seed) collection for rust-resistance screening
6) Protection of seed sources and rust-resistant stock
7) Silvicultural practices
    a) Cone collection
    b) Seed transfer
    c) Planting
    d) Density management
    e) Prescribed fire

Mapping

Initial efforts to map whitebark pine population on BLM lands have been conducted in Idaho, Montana, and Wyoming, and have focused on areas bordering USFS areas where the species is most likely to occur. As previously mentioned, BLM acreage estimates have been based on USFS-FIA data and bioclimatic models (Warwell, Rehfeldt, and Crookston 2007), and vary from approximately 47,000 ac (USFS-FIA data) to greater than 145,000 ac (Warwell, Rehfeldt, and Crookston 2007; D.L. Perkins and B. Weihausen, unpublished data; Table 1).

The area occupied by whitebark pine on BLM-administered lands was calculated by Perkins and DeArmond (2009) using the 80% probability of occurrence threshold from the Warwell, Rehfeldt, and Crookston (2007) bioclimatic model and the *Atlas of United States Trees* (Little 1971). However, results underestimated the actual area occupied. For example, estimates from this map for Wyoming were approximately 300 ac, as compared with 10,000 ac from aerial mapping (Means, pers. comm.) and 11,700 ac from FIA analysis. As a new starting point for distribution mapping, a 60% probability of occurrence has been found to be the most accurate predictor of whitebark pine habitats on BLM-managed lands. The new map has been evaluated by foresters in Idaho, Montana, and Wyoming, and presence data have been confirmed (E. Guiberson, W. Hensley, R. Means, pers. comm.) (Figures 3.2–3.4). We recommend that BLM resource managers use these maps to confirm presence and/or to look for new populations of whitebark pine.

We estimate that the BLM manages an estimated 1%–2% of whitebark pine stands throughout the species' entire range. This is a small but important portion, because the BLM's whitebark pine populations often border core areas of the range, and also exist on the range margins, in isolated stands, and at lower elevations. These areas are largely unmapped.

Approximately 84% of whitebark pine occurs on federal land, and 48% occurs in designated and recommended Wilderness (Keane 2000). On BLM-administered lands, 76% of potential and actual whitebark pine habitat is in designated Wilderness or Wilderness Study Areas. Other areas that may have whitebark pine include BLM Areas of Critical Environmental Concern (ACECs) and Research Natural Areas (RNAs). These designations pose challenges, both legal and philosophical, for whitebark pine conservation and management efforts. From a practical standpoint, management activities are logistically challenging in areas that have no roads and where motorized equipment and mechanical transport is prohibited.

BLM field offices are currently inventorying and mapping areas accessible by roads in Idaho, western Montana, and western Wyoming. This location and accessibility information can be used to prioritize conservation and

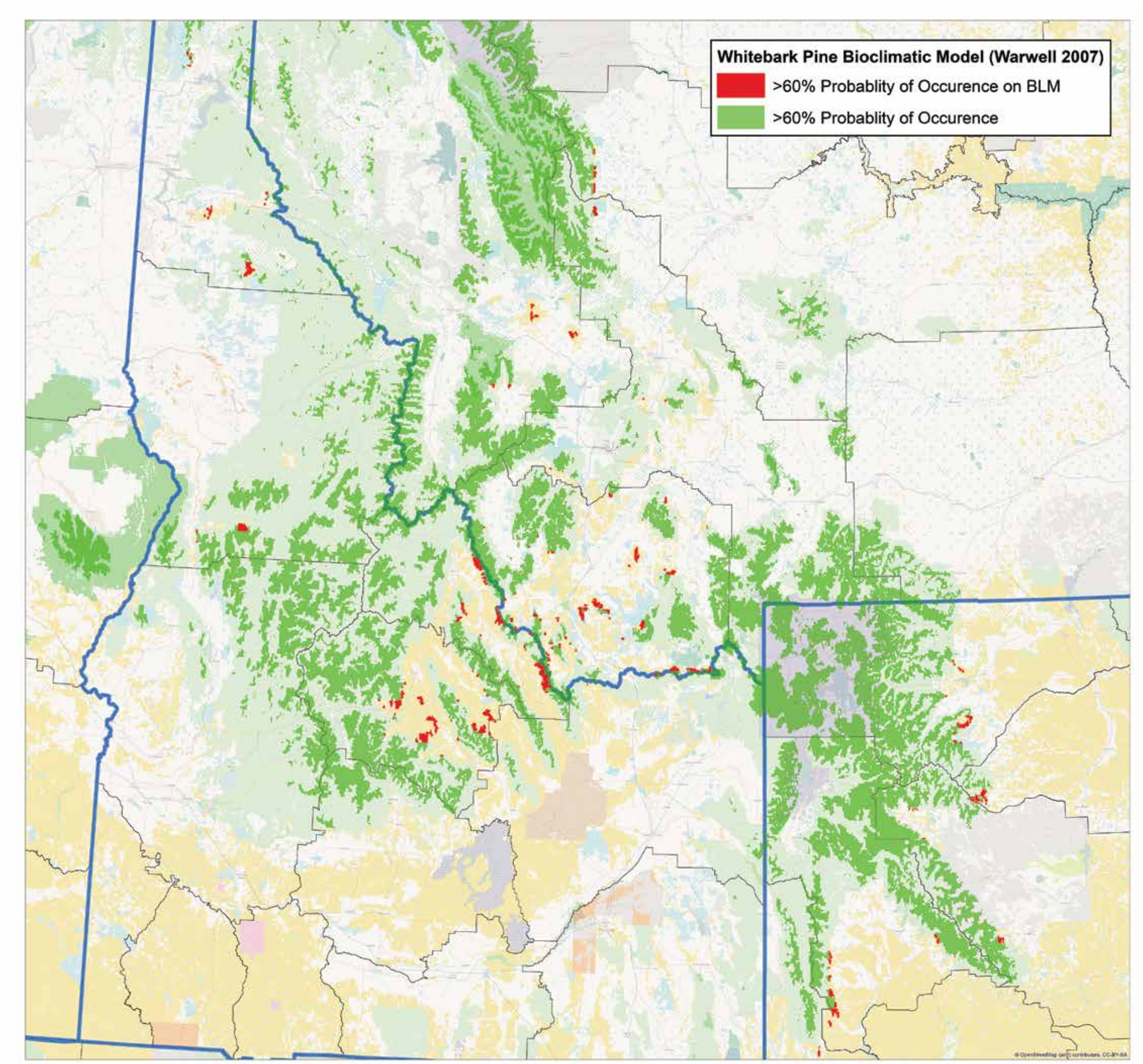


Figure 3.2 Whitebark pine distribution mapped using a 60% probability of occurrence from a bioclimatic model. Red polygons depict areas on BLM-administered lands where whitebark pine occurs or is likely to occur (Warwell, Rehfeldt, and Crookston 2007).

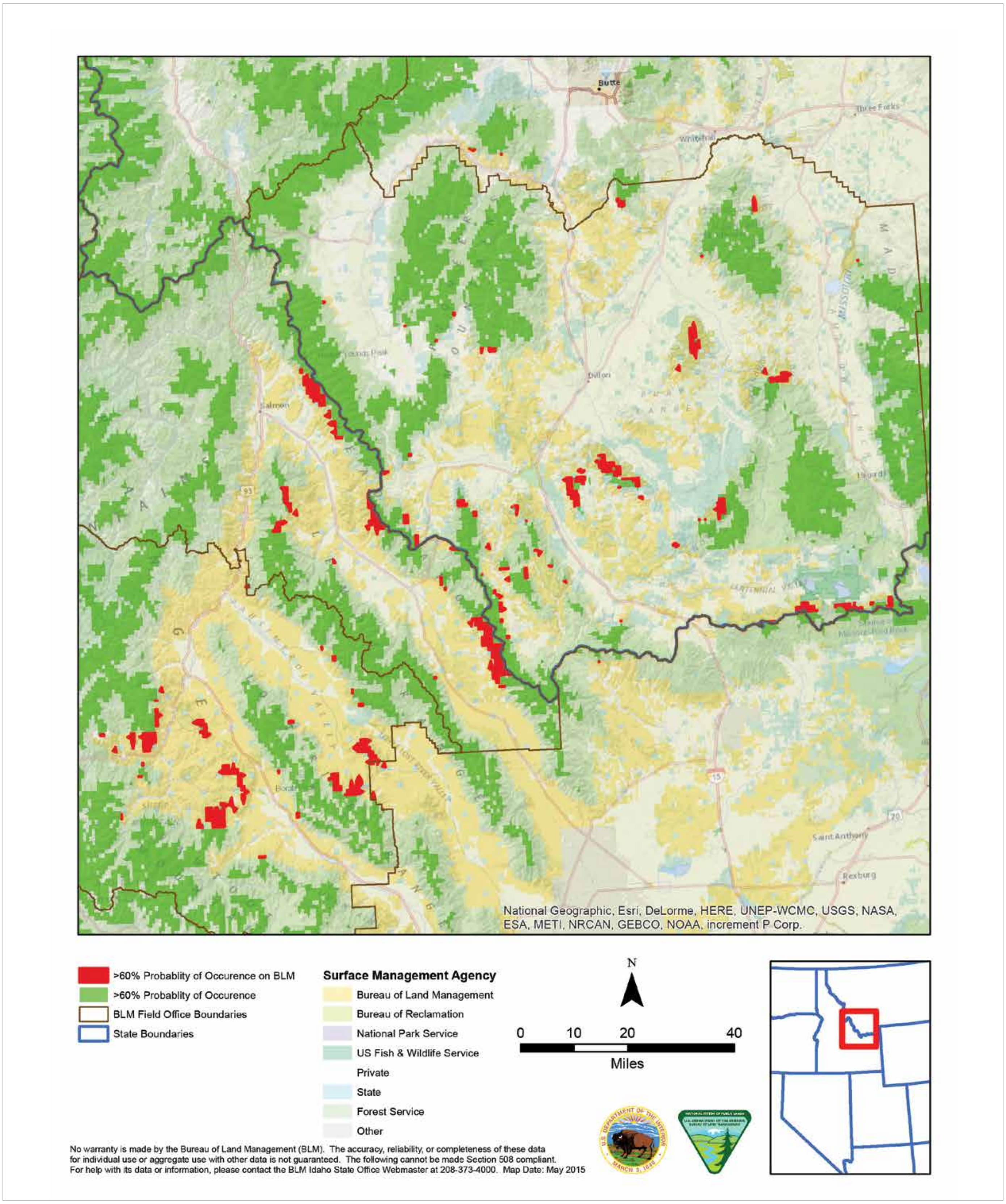


Figure 3.3 BLM-Idaho and BLM-Montana whitebark pine occurrence map (red polygons) based on a 60% probability threshold from a bioclimatic model. Green polygons represent all lands where whitebark pine occurs at a probability of 60% (Warwell, Rehfeldt, and Crookston 2007).

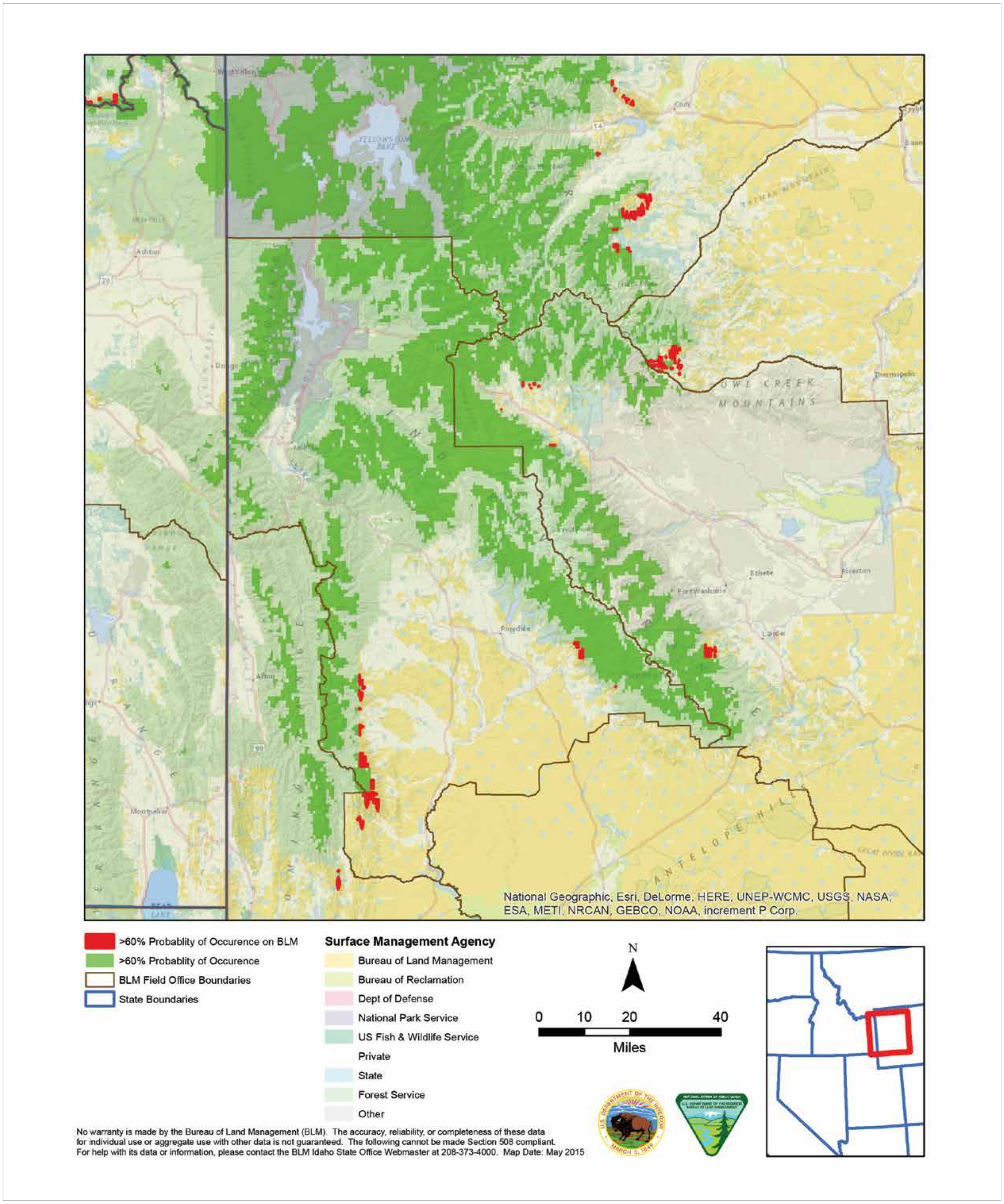


Figure 3.4 BLM-Wyoming whitebark pine occurrence map (red polygons) based on a 60% probability threshold from a bioclimatic model. Whitebark pine distribution in the Greater Yellowstone Area, calculated from the same model, is shown in green (Warwell, Rehfeldt, and Crookston 2007).

management actions in these states. Less reconnaissance work has been done in California, Nevada, Oregon, and Washington; whitebark pine occurs on several isolated ranges on BLM lands in Nevada (Charlet 1996) and eastern California but has not been fully mapped or inventoried. (See Appendix 1.)

Screening tools that can be used to identify potential whitebark pine populations include:

1) Local knowledge and Resource Management Plan vegetation maps
2) *Atlas of United States Trees* (Little 1971), *http://www.fs.fed.us/nrs/atlas/littlefia/*
3) Forest Inventory and Analysis National Program, *http://www.fia.fs.fed.us/*
4) LANDFIRE and vegetation mapping product links, *http://www.landfire.gov/vegetation.php*
5) National Gap Analysis Program (GAP)/Land Cover Data Portal, *http://gapanalysis.usgs.gov/gaplandcover/viewer/*
6) *The Atlas of Nevada Conifers* (Charlet 1996)
7) Research on Forest Climate Change: Potential Effects of Global Warming on Forests and Plant Climate Relationships in Western North America and Mexico, *http://forest.moscowfsl.wsu.edu/climate/* (includes current and projected whitebark pine distribution maps)
8) United States National Vegetation Classification Standard, *http://usnvc.org/overview/*
9) Individual states' natural heritage programs may have additional locations and information on whitebark pine stands and communities

This suite of existing resources (i.e., remote sensing imagery, vegetation and bioclimatic models) may be used with aerial surveys and ground confirmation to map extent. Spatial data must be stored in a Geographic Information System (GIS) database at the state level for transmission to the National Operations Center in Denver and to the BLM's Washington Office forestry lead.

Inventory

After and/or concurrent with mapping, forest inventories should be initiated to document the status and trend of whitebark pine communities. Forest inventory is based on a set of objective sampling methods designed to quantify stand structure, spatial distribution, species composition, and other forest attributes (e.g., growth, pathogen or insect presence, fuels, vascular plant understory) within specified levels of precision (Society of American Foresters 1998). If inventories are repeated, they can be used to calculate rates of change.

The primary objectives of inventory and monitoring are to document:

- Levels of white pine blister rust infection
- Overstory and understory species composition
- Age and stand structure
- Natural and planted seedling survival
- Level of mountain pine beetle infestation (none, endemic, epidemic)
- Fuel loads

Forest inventories, commonly known as "stand exams," should be compatible with current BLM databases, such as FORVIS, and with future potential databases, such as EcoSurvey and MicroStorms. Walk-through assessments are also acceptable provided they meet specific objectives. Training field personnel to identify white pine blister rust symptoms and mountain pine beetle activity is imperative for successful inventory and monitoring efforts. USFS Forest Health Protection pathologists and entomologists are the best choices for instructors. They have systematic protocols for identifying severity of blister rust and attack status of mountain pine beetles. An example of blister rust severity ranking and mountain pine beetle activity rating is provided in Appendix 2.

Once information is in FORVIS, it can be exported to the USFS Forest Vegetation Simulator (FVS) and used for answering questions about natural succession, disturbances, and management actions (*http://www.fs.fed.us/fmsc/fvs/)*. FVS is a suite of growth simulation models developed over decades and based on scientific knowledge and natural resources research and experience. Different geographic areas of the country are represented as "variants," and numerous supplementary extensions to the base models can be used to analyze the effects of disease, insects, and fire.

In 2010–2014 approximately 1,300 ac of whitebark pine habitat were inventoried with stand exam methods on

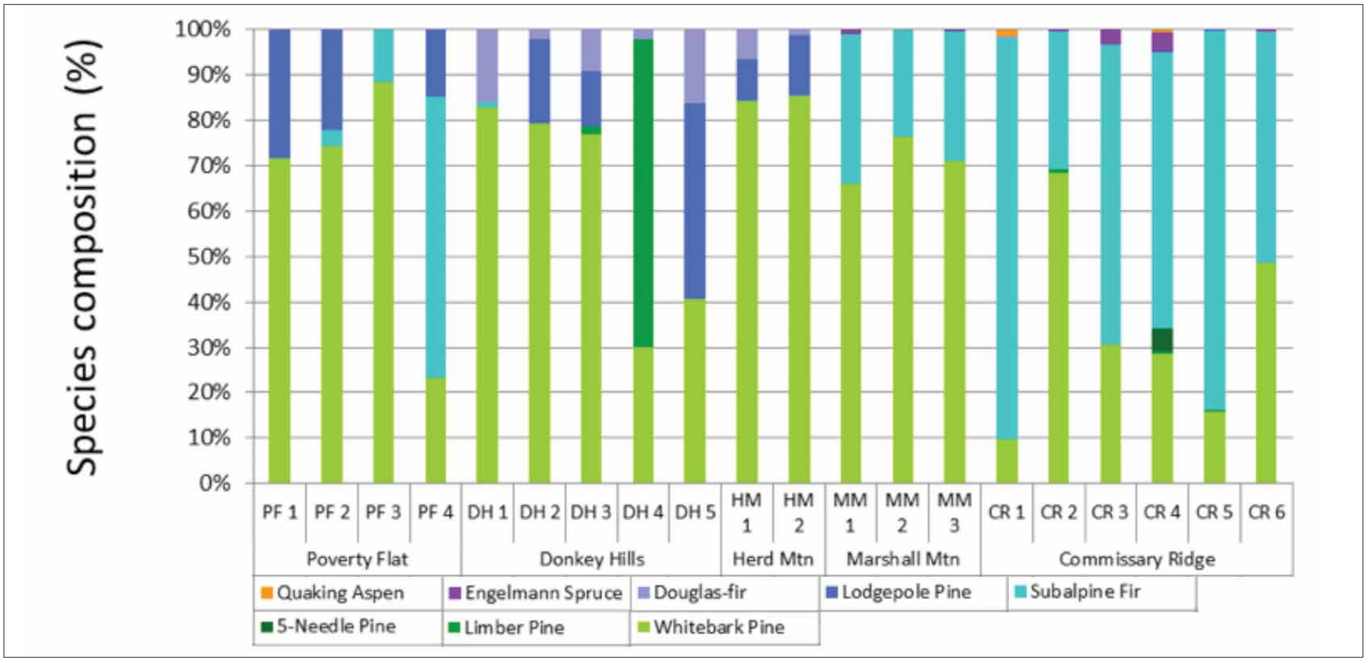


Figure 3.5 Species composition from 14 stands in central Idaho and 6 stands in Wyoming. Light green represents whitebark pine; aqua, subalpine fir. This is an example of information summarized from forest inventory (BLM FORVIS–fixed plot stand exams completed during 2011–2014 in Idaho, Montana, and Wyoming).

BLM lands in Idaho (624 ac), Montana (445 ac), and Wyoming (218 ac). Fixed-area plots (1/10-ac plots for trees greater than 5 in. dbh), and nested plots (1/100-ac plots for trees less than 5 in. dbh) were used to record tree size, age, and disease and insect conditions (primarily blister rust and pine beetle), habitat type, and other tree-level and stand-level metrics. Species compositions for 20 whitebark pine–dominated stands in Idaho and Wyoming are shown in Figure 3.5.

Currently, a stand-alone FORVIS database and a master Microsoft Excel file houses all BLM whitebark pine and limber pine information at BLM state offices. The Excel files include scores of graphs and pivot tables displaying common stand exam metrics. These are housed at BLM state offices and are also available on the BLM's internal website (*https://blmspace.blm.doi.net/oc/sites/forestry/Shared%20Documents/Forms/AllItems*).

Monitoring

Monitoring is the collection of information over time, generally on a sample basis, by measuring change in an indicator or variable (Society of American Foresters 1998). In addition to inventories, the installation of fixed-area belt transects, primarily for monitoring of white pine blister rust infection levels, are widely used in the western United States and Canada. There are several commonly accepted transect methods:

1) The Greater Yellowstone Whitebark Pine Monitoring Working Group housed under the Greater Yellowstone Network (GRYN), *http://science.nature.nps.gov/im/units/gryn/monitor/whitebark_pine.cfm; http://whitebarkfound.org/wp-content/uploads/2013/10/GYE_Whitebark_Monitoring_Protocol_June_2011_Version1_1.pdf*
2) Whitebark Pine Ecosystem Foundation (WBPEF) protocol, *http://whitebarkfound.org/wp-content/uploads/2013/07/Methods-for-Surveying-and-Monitoring-Whitebark-Pine-for-Blister-Rust.pdf*
3) The Forest Insect and Disease Tally program (FINDIT) (Bentz 2000) is another method for monitoring conditions, particularly mountain pine beetle infestations; Forest Health Protection, USFS Region 1, Missoula, Montana, is coordinating efforts to update and maintain the FINDIT program

We recommend following the GRYN protocol for a 10-year re-measurement schedule, to track the emergence and level of the primary risk factors and to quantify them spatially and temporally. A new "rapid assessment" method has been developed by the GRYN team and is being tested on BLM lands in Wyoming, within the Greater Yellowstone Ecosystem (see Appendix 3 for results).

Measurements from inventory and monitoring can be used to determine:

- Susceptibility and risk of mountain pine beetle infestation
- Clark's nutcracker presence
- Targets for thinning other conifers
- Site potential for planting rust-resistant seeds or seedlings based on vascular plant cover
- Wildfire risk
- Targets for prescribed burning

Stand-level metrics have been used in a few studies to quantify whitebark pine stand susceptibility to mountain pine beetles and to predict Clark's nutcracker occurrence. Mountain pine beetle outbreaks in host pines, including whitebark pine, have been positively correlated with large-diameter pines and stand density (Perkins and Roberts 2003). Probability of a stand being attacked by mountain pine beetles in the widespread epidemic of the 1930s was 100% for climax whitebark pine stands that exceeded a basal area of 45 ft^2/ac or a Stand Density Index (SDI) of 80 (Perkins and Roberts 2003).

For nutcracker occurrence, McKinney, Fiedler, and Tomback (2009) equated cone density (~400 cones/ac [1,000 cones/ha] to a minimum basal area of 22 ft^2/ac [5.0 m^2/ha]), with a preferred basal area of 65 ft^2/ac [15 m^2/ha] of whitebark pines for the likelihood of seed dispersal by Clark's nutcracker. Barringer et al. (2012) found a lower minimum basal area of greater than 9 ft^2/ac (2.0 m^2/ha) needed for cone production to support Clark's nutcracker visitation reliably. The results from these studies may serve as guidelines for thinning to reduce risk of mountain pine beetle and for retaining sufficient mature, cone-bearing trees to attract Clark's nutcrackers (see Section 3, Conservation Actions, "Silvicultural Practices").

Gene Conservation

The full genetic diversity across the range of whitebark pine should be preserved for the future by collecting and archiving seeds and growing and planting genetically diverse seedlings that also have resistance to blister rust. Trees that are putatively resistant to blister rust are called plus-trees. Superior (or elite) trees are individuals with proven rust resistance documented in screening trials or with genetic methods. Plus-tree collections, as well as bulk collections, should be archived for gene conservation at the USDA, Agricultural Research Service (ARS), National Center for Genetic Resources Preservation and should be coordinated with BLM's Seeds of Success (SOS) program, consistent with the "National Native Seed Strategy for Rehabilitation and Restoration, 2015–2020" (BLM 2015). As previously mentioned, seeds should be stored for blister rust screening trials and for growing seedlings for operational plantings. Seed inventories should be periodically assessed for viability and to ensure that effective population sizes are being maintained. With adequate seed supplies, the BLM and cooperators can provide diverse genetic resources that would enable the species to adapt to a changing climate or other stressors.

Tree seed collections from the BLM have historically been processed in the BLM's forest nurseries or with cooperators in USFS nurseries and regional cooperatives (e.g., Inland Empire Tree Improvement). Additional opportunities for long-term storage of whitebark and other five-needle pine genetic resources are available through the BLM's SOS program (*http://www.blm.gov/mt/st/en/prog/botany/sos.html*). As part of the federal interagency Native Plant Materials Development Program, SOS supports and coordinates seed collection of native plant populations in the United States. The goal is to partner with the seed-producing industry to increase the number of species and the amount of native seed available for stabilizing, rehabilitating, and restoring lands in the United States. A whitebark pine preservation orchard has been established at the BLM's Tyrrell Seed Orchard in Eugene, Oregon (contact the BLM-Oregon forestry lead). Agency cooperators are listed in Table 2.

The BLM, in addition to collecting, testing, and storing seed, also needs scion and pollen for seed orchard root stock and for clone banks. See Appendix 4 for instructions on collecting scion and pollen. Parent tree selections possessing desirable characteristics of blister rust resistance, cold hardiness, and mountain pine beetle tolerance are traits currently being evaluated at USFS nurseries, universities, and USFS and ARS forest genetic facilities (Table 2). Scion and pollen collection target trees are selected by USFS geneticists and tree improvement specialists.

Table 2. Facilities that extract seed, store seed, sow and grow seedlings, conduct white pine blister rust research, and/or develop seed orchards in the Northwest and intermountain regions.

Cooperators	Agency – location	Services
Tyrrell Seed Orchard	BLM - Eugene, OR	Growing, orchards, BLM's Whitebark Pine Preservation Orchard
Horning Seed Orchard	BLM - Colton, OR	Growing, orchard
Bend Seed Extractory	USFS - Bend, OR	Seed extraction
Dorena Genetic Resource Center	USFS - Cottage Grove, OR	Genetics, rust screening, growing
Coeur d'Alene Nursery	USFS - Coeur d'Alene, ID	Rust screening, growing
Forest Service National Forest Genetics Laboratory	USFS - Placerville, CA	Genetics, rust screening, growing
National Center for Genetic Resources Preservation	USDA, ARS - Ft. Collins, CO	Molecular testing, genetics, long-term storage

Cone Collection for Rust Resistance – Plus-Tree Selection

The most important action in restoring whitebark pine is to ensure that future populations of the species are resilient to white pine blister rust, by increasing the frequency of trees with genetic resistance to the blister rust pathogen. All conservation plans and activities must first address how natural or planted whitebark pine regeneration will survive with blister rust. The BLM should 1) support selective breeding programs to develop and plant blister rust-resistant whitebark pine, and 2) facilitate and accelerate natural selection for blister rust-resistant genotypes in stands using proactive restoration strategies (Schoettle and Sniezko 2007; Keane et al. 2012).

The first step is to identify the plus-trees as permanently designated leave trees that are phenotypically resistant to blister rust. These plus-trees are easiest to identify in stands where blister rust incidence is high, because they have been exposed to the rust for longer periods of time and therefore have demonstrated a higher frequency of resistance to rust (i.e., no, to low levels of, symptoms) than uninfected stands or recently infected stands. In uninfected or recently infected stands it is difficult, if not impossible, to identify trees that are phenotypically resistant to rust (all trees look healthy). Only during multiyear experimental testing, when seedlings are exposed to blister rust spores, will individuals prove their level of resistance. When selecting plus-trees, look for trees that:

- Have no, to low levels of, blister rust
- Are dominant or co-dominant trees
- Have potential to bear cones
- Are free of insects and disease
- Have a single stem where possible
- Are within 400 ft of trail or road
- Are at least 300 ft apart, to avoid relatedness
- Are safe to climb to collect seed

Complete procedures and details can be found in Mahalovich and Dickerson (2004) (*http://www.fs.fed.us/rm/pubs/rmrs_p032/rmrs_p032_181_187.pdf*). In the northern Rocky Mountain region, synchronous abundant cone crops (masting years) occur every 2–4 years, with an average of 3.2 years (M.F. Mahalovich, pers. comm.). The most efficient and economical collections are usually made when most trees are producing cones. To date, the BLM has identified 51 whitebark pine plus-tree candidates in Idaho, Montana, Oregon, and Wyoming (Appendix 5).

Protection of Seed Sources

High-value individuals (e.g., plus-trees and old growth trees) and a diverse suite of age classes need protection from mountain pine beetle, unwanted wildfire, and timber cutting, so that the seed can be harvested into the future, and ecosystem structure is preserved. Old growth whitebark pines on BLM lands should be protected from fire and other disturbances to the extent possible, and mapped in a geographical information system (GIS).

Protection from mountain pine beetle may include either insecticide application or anti-aggregating pheromones to protect individual high-value trees, small groups of trees, or larger areas. The insecticide Carbaryl provides nearly 100% protection from pine beetle infestations when applied according to manufacturer specifications, and is useful where seed tree locations are accessible by vehicles. Even where access is limited, a pack animal sprayer, like the one developed in USFS Region 1, may be used to spray Carbaryl. An alternative, especially useful in remote locations, is the anti-aggregating pheromone Verbenone, or Verbenone with additives (Progar et al. 2014; Perkins, Jorgensen, and Rinella 2015; Kegley et al. 2003; Kegley and Gibson 2004; Kegley and Gibson 2009; Fettig et al. 2012), which may be delivered several ways for stand- or tree-level protection (Bentz et al. 2005; Progar et al. 2014). An annual application of 15 g (two 7.5-g pouches) of synthetically produced Verbenone doubled survivorship throughout a 7-year mountain pine beetle outbreak (Perkins, Jorgensen, and Rinella 2015) (Figure 3.6). Other delivery systems include aerial application of Verbenone in small flakes (Gillette et al. 2012) and Verbenone with additives such as SPLAT (Progar et al. 2014). We suggest that the BLM consult with USFS Forest Health Protection entomologists and pathologists for expertise and updates on tree protection methods.

Figure 3.6 Verbenone, an anti-aggregating pheromone used to deter mountain pine beetles from attacking whitebark pines, is stapled to the northwest and northeast sides of a mature tree.

To protect high-value trees from wildfire, we recommend removing live and dead fuels within one to several tree height distances from the target high-value tree. Fuel specialists *must* be consulted to determine clearing distances. Plus-trees, old growth, and other high-value tree geolocations should be given to fire management personnel in GIS formats, stored at BLM state, district, and field office levels, and made part of the Fire Resource Advisor package that the field office usually provides to fire incident personnel.

Timber harvest plans should specify no cutting of whitebark pine. Where whitebark pine exists within a timber sale's boundaries, Section 42, Special Provisions, of the contract should state that no cutting or other disturbance of whitebark pine is permitted.

Silvicultural Practices

Silviculture is the art and science of controlling the establishment, growth, composition, and quality of forest vegetation for the full range of forest resource objectives (Society of American Foresters 1998). As an important component of its management and conservation efforts, the BLM should consider for silvicultural treatment those whitebark pine forests that are declining from the impacts of disease, insects, or advanced succession.

The natural disturbances that shape whitebark pine landscapes, as discussed in Section 2, Disturbances and Threats, can be simulated at different scales to restore and conserve the species. Both prescribed fire and silvicultural thinning treatments can be used to simulate natural site preparation where natural seed sources are distant, and nutcracker visits are unlikely or uncertain, or where whitebark pine cone production is declining. Planting rust-resistant seedlings will augment natural regeneration where it might not otherwise occur.

Figure 3.7 Hardware cloth cages were installed to protect the cones of this whitebark pine from predation by Clark's nutcrackers and squirrels. Cages were removed in early September, when cones were harvested. Seed was sent to USFS nurseries for growing seedlings to be used in screening trials for white pine blister rust resistance. This tree exhibited no symptoms of blister rust infection and has been identified as phenotypically rust-resistant (i.e., a plus-tree) until screening trials can confirm that it is resistant (i.e., an elite tree) or discount this. BLM-Idaho, Cottonwood Field Office.

Silvicultural treatments emphasized in this section are:

- Collecting cones (seed)
- Planting rust-resistant seedlings to accelerate the effects of selection
- Thinning to reduce competing conifer vegetation to increase the vigor (growth) of whitebark pine
- Use of prescribed fire and wildfire

Cone Collection

Cone collections from plus-trees for operational collections are described in the Whitebark Pine Cone Collection Manual (Ward, Shoal, and Aubry 2006a) (*http://ecoshare.info/uploads/whitebarkpine/Cone_Collection_Manual.pdf*). BLM tree climbers are certified through the USFS National Tree Climbing Program, described at *http://www.fs.fed.us/treeclimbing/intro/2/*. Individuals work in pairs to climb trees without damaging the tree (i.e., no spurs and with light shoes), using orchard ladders and custom-made tree-tongs (Davies and Murray 2006).

After trees are identified for collection, hardware cloth cages must be used to protect the cones from seed predation by Clark's nutcracker, squirrels, and other animals. Instructions for constructing hardware cages are given in the Ward, Shoal, and Aubry (2006a) cone manual. Cages should be placed over immature cones in early summer, generally mid to late June (Figure 3.7). Cones mature/ripen in late summer. The method to determine seed ripeness is to cut seeds longitudinally and confirm that the embryo fills 90% or more of the embryo cavity (Burr, Eramian, and Eggleson 2001); however, a cavity that is filled 75% or more may yield acceptable germination rates. Cutting cones in half with a cone cutter will reveal the half-section face with seven to eight seeds, and is the easiest method to inspect the embryos. Once cones are ripe, the cages are removed and cones are collected and put in burlap sacks or equivalent breathable material. Repeated visits to determine cone ripeness are time-consuming, but because cones are caged, collections can occur after seed maturation.

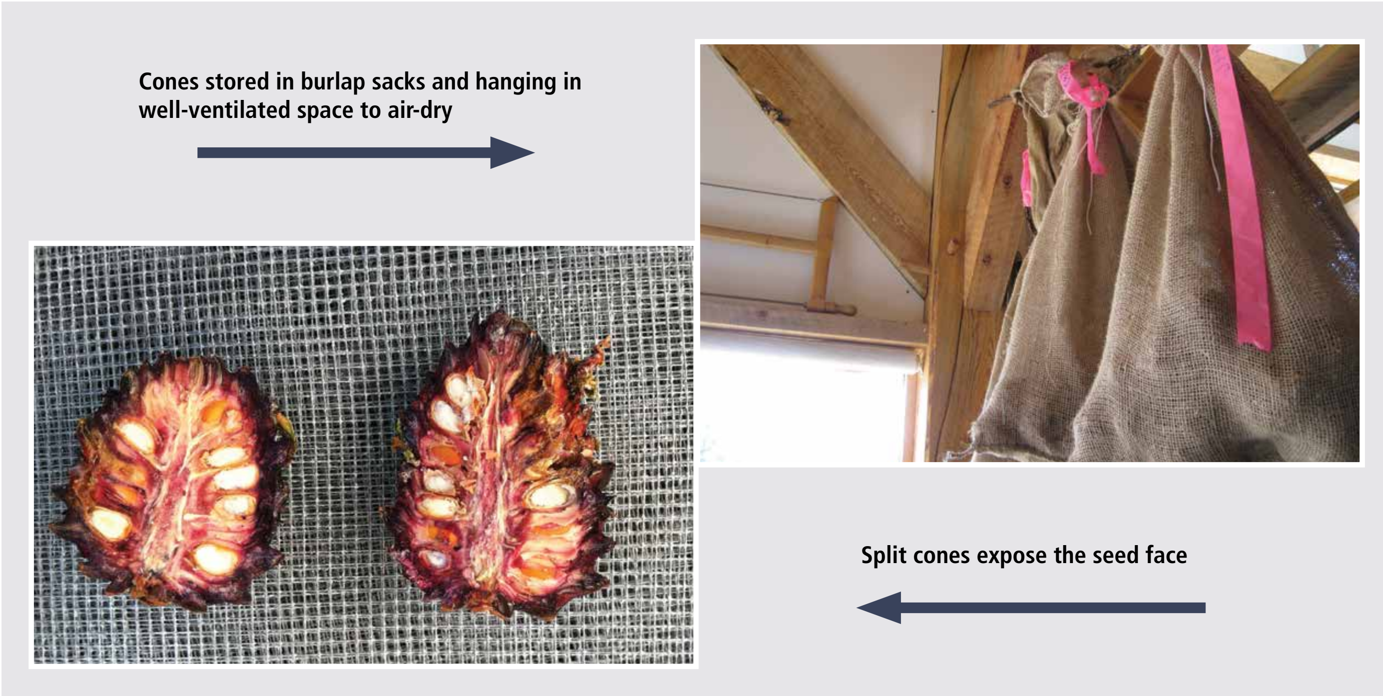


Figure 3.8 The easiest method to inspect embryos for seed maturity is to cut cones longitudinally in half with a cone cutter, revealing the half section faces of seven to eight seeds. Seeds are mature when the embryo fills 90% or more of the embryo cavity. Once ripe cones are harvested, they are put in burlap sacks or equivalent breathable material and stored in a well-ventilated space to dry.

To prevent infection from insects or pathogens, no cones should touch the ground; tarps placed beneath collecting areas are needed. For plus-tree collections, all cones from the same tree must be in their own sacks. The sacks should be underfilled, approximately 1/3–1/2 full, with the tie closure within 3 in. of the top to allow adequate ventilation. Sacks must have tree cone collection tags (identification number, locations, administrative unit, etc.) inside the bag and also tied to the outside. It is critical to store sacks of cones in a dry, well-ventilated environment until they are shipped to nurseries and the seed is extracted (Figure 3.8; Appendix 6).

Once seed is available from production seed orchards, cone collections should shift from the field to the seed orchards that have been designed for improved blister rust resistance, broad adaptability, and minimal inbreeding.

We recommend that the BLM allocate funding for:

- Long-term, rust-resistant testing of whitebark pine seed lots
- Seed orchard development and maintenance with agency partners

Seed Transfer

Seed transfer zones have been developed to minimize maladaptation risks of geographic and climatic variables to acceptable levels (Aubry et al. 2008; Bower and Aitken 2008; Mahalovich and Dickerson 2004). Plantings of seeds and seedlings from rust-resistant stock must be obtained from within the seed zone where planting will occur. Mahalovich, Burr, and Foushee (2006) have currently identified four whitebark pine seed zones that cover the Inland Northwest, where most of the BLM's whitebark pine populations occur (Figure 3.9).

1) Bitterroots - Idaho Plateau (BTIP)
2) Central Montana (CLMT)
3) Greater Yellowstone - Grand Teton (GYGT)
4) Inland Northwest (INLA)

BLM field offices should partner with national forests in their respective seed zones to develop seed orchards and secure future rust-resistant seed sources. BLM offices in Montana and Wyoming have entered into an agreement with the Greater Yellowstone Coordinating Committee for whitebark pine conservation. As part of this agreement, the Gallatin National Forest is establishing a whitebark pine orchard to produce sufficient genetic diversity of

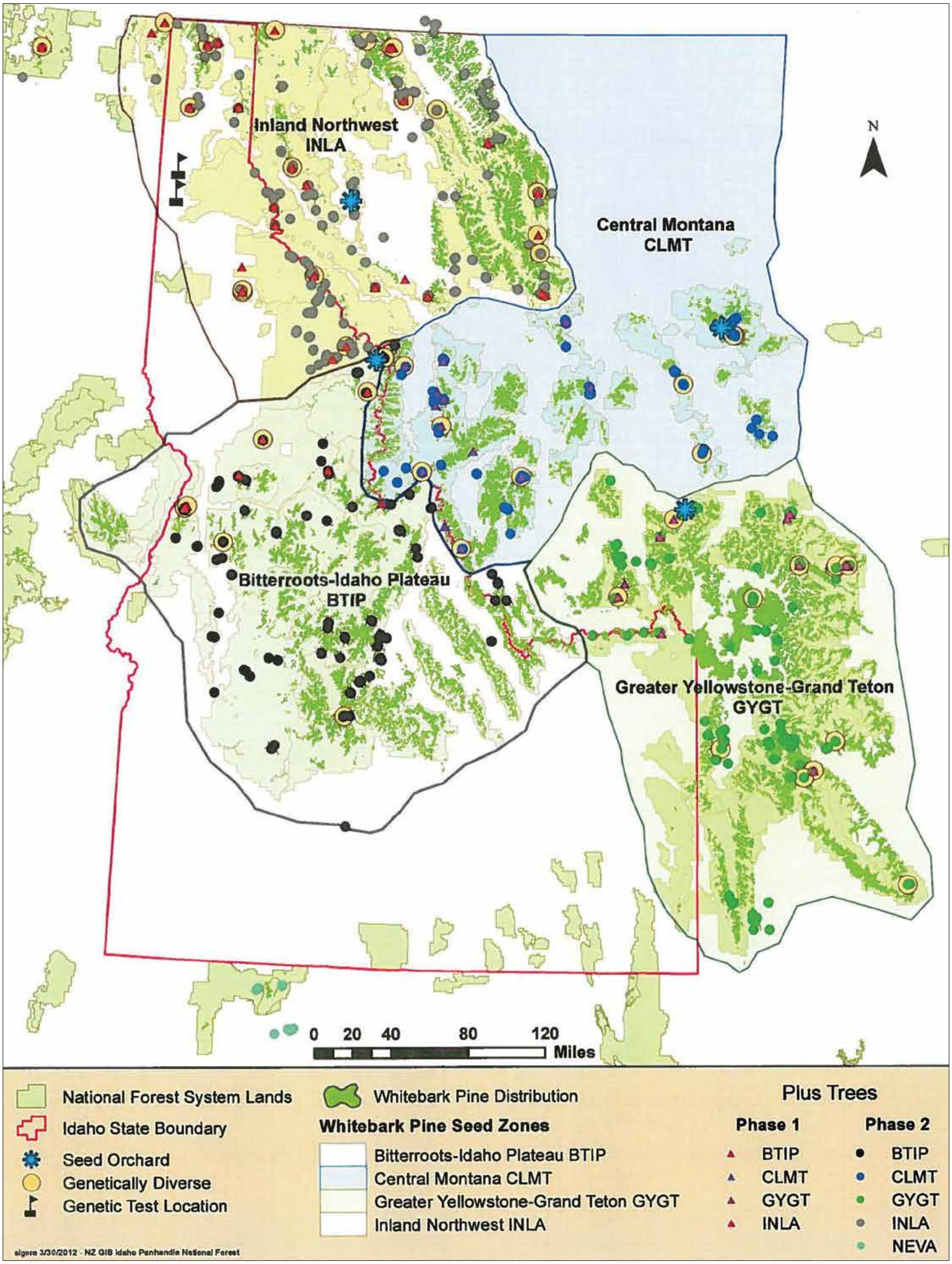


Figure 3.9 Four whitebark pine seed zones that cover most of the BLM's whitebark pine populations.

seeds from rust-resistant seed sources. Both BLM-Montana and BLM-Wyoming will have access to seeds in the GYGT zone when the orchard becomes operational.

Planting

Overview

When seeds from rust-resistant parent trees become available in the appropriate seed zones for BLM areas, we recommend growing seedlings for planting in openings created by wildland fire, prescribed fire, or mechanical treatments, and "in-plantings" after mountain pine beetle outbreaks.

Seedlings should be planted in the autumn, to avoid summer drought stress, at approximately 200–250 seedlings per acre, with the goal of having 3- to 5-year survival of 85–100 trees per acre. It is critical that initial site preparation be done to remove competing vegetation, using prescribed fire or mechanical methods such as thinning and scalping.

Planting seedlings has yielded higher long-term survival rates than direct sowing of seeds (DeMastus 2013). Where access and cost is not prohibitive, planting of seedlings is the preferred method. Otherwise, direct sowing of warm-stratified seed from rust-resistant stock is recommended. Seeding trials conducted on six sites in western Montana and northern Idaho found that seeds treated with warm stratification procedure had 51% germination and survival rates over a 2-year period, compared with a 33% for controls; 44% for warm stratification and scarification; and 18% for scarification only (Schwandt and DeMastus 2011).

Planting Guidelines

The following are planting guidelines adapted from McCaughey, Scott, and Izlar (2009):

1) Plant large, hardy seedlings with well-developed root systems. Seedling vigor is important for both survival and growth of planted seedlings.
2) Reduce overstory competition. Although there are no defined basal area or trees-per-acre guidelines for overstory removal, experience suggests removing all overstory trees within a minimum 20-ft radius around the planted seedling.
3) The planting design should be a patchy pattern with densities similar to that of nearby stands. Microsite placement is critical. The seedlings should be planted in a moist, protected microsite on the north side of a log, rock, or stump.
4) Plant in habitats that support whitebark pine. Whitebark pine is outcompeted by other species on milder mid-elevation sites, but has a slight competitive advantage on high-elevation, windswept ridge tops with shallow soils.

    a) Avoid planting in burned lodgepole pine stands. Lodgepole pine typically regenerates quickly with high seedling numbers and rapidly outcompetes whitebark pine.
    b) Do not plant in "mixed plantings" with other conifers. Whitebark pine seedlings grow slowly and may eventually be suppressed by lodgepole pine, Douglas-fir, subalpine fir, and Engelmann spruce (Izlar 2007).

5) Reduce understory vegetation to make soil moisture and nutrients available. Competing vegetation such as grasses and sedges should be removed, or scalped, in a 2-ft radius around the planted seedling. Do not plant seedlings within 2 ft of beargrass. On more mesic sites, grouse whortleberry should be retained. (Lower elevation xeric sites may not have these vegetative components.)
6) Avoid planting in swales and where soils are deep. Gophers feed on roots and bury trees, so avoid planting in areas of deep soils and swales where they burrow. Ridge tops or exposed slopes are generally more suitable planting sites (McCaughey 1993; Scott and McCaughey 2006).
7) In burned areas, remove overstory snags to prevent them from falling on seedlings.
8) Plant when there is adequate soil moisture. Autumn plantings are preferred, so that planted seedlings are not subject to summer drought stress.
9) Ideally, out-plant only seedlings that have been inoculated with mutualistic ectomycorrhizal fungi, such as Siberian slippery jack, in the greenhouse or nursery (Lonergan, Cripps, and Smith 2014) (Figure 1.9).

Seedling Survival

Whitebark pine seedling survival depends on many factors. The lack of competition, the presence of *Vaccinium* species on mesic sites, and the protected microsite conditions that nutcrackers select appear to be the most important factors leading to survival in the plant communities studied (Izlar 2007; McCaughey, Scott, and Izlar 2009; Tomback et al. 2011). At the Dillon Field Office, BLM Montana, monitoring of a 2012 burn planted with whitebark pine seedlings in 2013 and 2014 has shown 98% survivorship thus far (E. Guiberson, pers. comm.) (Figure 3.10). Follow-up monitoring of planted sites should provide estimates of survivorship, height, growth, and rust resistance.

Density Management

Metrics

Density metrics such as basal area, trees per acre (or hectare), and Stand Density Indexes should be calculated after forest inventories and monitoring efforts. These metrics can be used to quantify stand structure and to develop silvicultural prescriptions for prescribed fire and thinning. In general, thinning whitebark pines is not recommended, because of the potential loss of rust-resistant and genetically diverse individuals. However, under some circumstances, such as severe rust infections that have top-killed mature trees, removal of individuals is warranted.

Density management is a critical factor in the maintenance and restoration of whitebark pine. Stand-level objectives must be characterized in terms of stand composition and structure. The overall silvicultural objective is to protect and preserve the population (stand) for its function and structure, not the individuals within it. Silvicultural treatments and management guidelines are described for limber and whitebark pines on BLM lands in Wyoming in Instruction Memorandum WY-IM-2011-041 (shown in Appendix 7).

Recently, Stand Density Index nomograms have been developed for whitebark pine from FIA data. SDI nomograms can be used to determine the condition of the stand in terms of crown closure, site occupancy, limits of self-thinning (site occupancy), and self-pruning levels. The SDI of a stand can also be calculated by using the Forest Vegetation Simulator. The maximum SDI for whitebark pine is 675, as calculated from a sample of

Figure 3.10 Post-wildfire planting of whitebark pine seedlings in 2013 at Windy Pass. BLM-Montana, Dillon Field Office. All seedlings were planted near stumps, fallen logs, and rocks, which protect them from environmental extremes.

520 FIA plots (J. Long and J. Shaw, in press) (Figure 3.11). Prescriptions for whitebark pine should be a percentage of 675 SDI, depending on silvicultural objectives. Breakpoints are:

- 25% for crown closure/onset of competition
- 35% lower limit of full site occupancy
- 60% lower limit of self-thinning
- < 60% to maintain vigor and avoid self-thinning
- <25% to delay self-pruning
- >25% to promote self-pruning

Mechanical Treatments

Properly designed silvicultural thinning in whitebark pine stands can simulate the effect of mixed-severity and nonlethal surface fire (Keane and Arno 2001), create clearings for Clark's nutcracker seed caching and natural regeneration, and create early seral conditions to reduce competition from shade-tolerant conifers. Treatment sizes and shapes should be similar to the patterns left by past fires, but should be planned in relation to the amount of available whitebark pine seed source in surrounding stands (Keane and Parsons 2010b; Keane et al. 2012).

Thinning treatments that remove competing overstory tree species are currently recommended to maintain or increase the presence of whitebark pine on suitable sites. Thinning may increase the vigor of existing whitebark pines and provide caching sites for Clark's nutcrackers. Few studies have sufficient growth release information on whitebark pines following reduction of non–whitebark pine species; however, based on a small sample of trees (n=48), almost all trees showed an increase in radial growth following silvicultural cuttings (Keane, Gray, and Dickinson 2007). Diameter release was greatest in dense stands and in older and larger-diameter trees. Suppressed seedlings and saplings of poor vigor and less than 4 in. (10 cm) dbh may not release, but vigorous saplings are likely to release after thinning. Species most often targeted for removal include subalpine fir, Engelmann spruce, and lodgepole pine. Limber pine should not be removed, because it faces the same threats (e.g., white pine blister rust and mountain pine beetle) as whitebark pine.

Because of the potential loss of blister rust resistance in a stand, any thinning of whitebark pine should be undertaken with care and only because of demonstrated need, such as a significant pine beetle infestation within the immediate area, or environmental stress that is causing widespread mortality, and only after consultation with a silviculturist. In cases such as these, a combination of the McKinney, Fiedler, and Tomback (2009) guidelines; Barringer et al. (2012) guidelines about basal area and cone production; and the Perkins and Roberts (2003) thinning guidelines should be used, with the resultant stands having a basal area greater than 9 and less than 45 ft^2/ac (10.3 m^2/ha) (see Section 3, Conservation Actions, "Monitoring"). The preferred target trees for removal are those with blister rust cankers on the bole, on limbs within 6 in. of the bole, or with greater than 50% crown loss.

Another density management option that is more critical in the isolated disjunct BLM stands is the treatment of adjacent lower-elevation stands of mixed conifers to reduce density and fuel loadings. In the event of wildfire, thinned stands are more likely to produce a mixed-severity, patchy burn pattern throughout the stand rather than a stand-replacing crown fire. This is especially important for those stands more than 6.2 mi (10km) from another whitebark pine seed source (Keane and Arno 2001). A stand-replacing fire in more distant stands may cause local extirpation, because of the lack of visitation by Clark's nutcrackers to cache offsite seeds.

Disturbances such as mountain pine beetles outbreaks, avalanches, and wildfire can naturally thin stands. A twofold to threefold increase in the previous 3 years of meristem leader growth has been observed in whitebark and limber pine stands where pine beetles have killed as

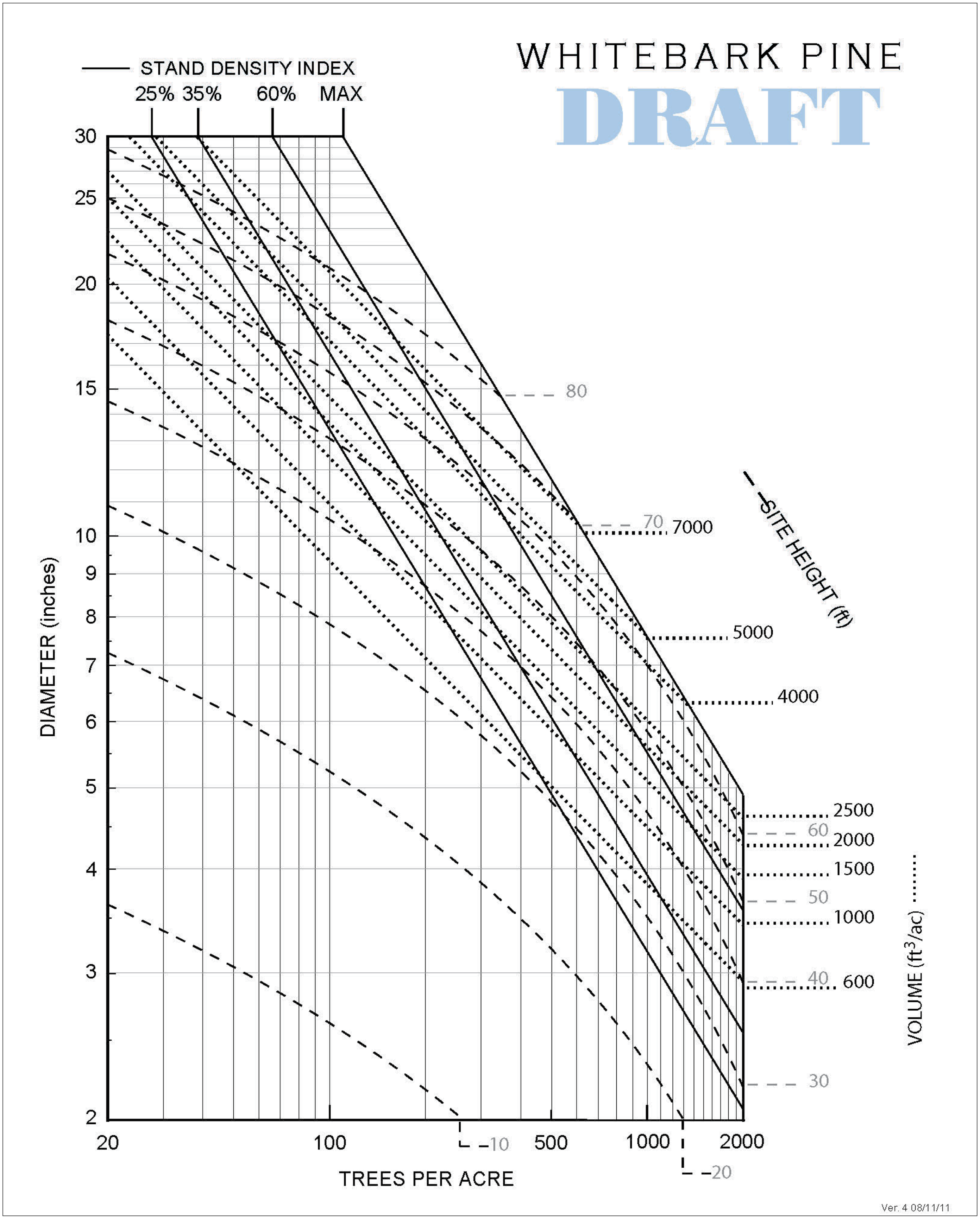


Figure 3.11 A draft Stand Density Index for whitebark pine (Long and Shaw, in press).

Figure 3.12 BLM Forester Mike DeArmond examining growth release of whitebark pine advance regeneration in 2010. Apical meristem growth increased fourfold after the 2008 decline in a mountain pine beetle outbreak that produced overstory mortality.

Figure 3.13 Whitebark pine regeneration following a stand-replacing wildfire in 1966 on the Salmon-Challis National Forest. Photo taken in 2013 at Bald Mountain near Clayton, Idaho.

much as 70% of the overstory (D.L. Perkins, pers. obs.) (Figure 3.12). With increases in wildfire frequency and mountain pine beetle outbreaks across the western United States beginning in 2000 (Gibson et al. 2008), these natural disturbances may themselves act as thinning agents in some areas.

Because whitebark pine stands are often found in Lynx Analysis Units, planning and implementation of all mechanical treatments, prescribed fires, and use of wildland fire for resource benefit (WFRB) should meet any conditions about the type and amount of disturbance allowed that emerge from USFWS-BLM consultation and Biological Opinions.

Prescribed Fire

Because wildland fire is the disturbance that shaped most whitebark pine landscapes, restoration treatments should be designed to mimic fire's historical effects on whitebark pine habitats (Keane and Arno 2001; Perera, Buse, and Weber 2004). Both severe and large area fires can eliminate other subalpine conifers and their seed, and provide ideal conditions for nutcracker caching sites and subsequent natural whitebark pine establishment. A stand-replacing wildfire in 1966 at an elevation of approximately 9,500 ft (2,800 m) has regenerated into a nearly pure stand of whitebark pine (Figure 3.13). These areas may also be excellent sites for rust-resistant whitebark pine plantings, and in situations where natural seed sources are distant, or decimated from other disturbances, this is the best option.

Prescribed fire can be used to create areas for Clark's nutcracker seed caching and natural regeneration, prepare sites for planting, and reduce competition. Prescribed fire can also be designed to mimic the three types of fire regimes common in whitebark pine forests and woodlands. The primary objectives of a low-intensity surface fire are to remove the competing conifer reproduction, to reduce dead and down fuel loading, to remove portions of the litter and duff to expose bare soil, and to recycle nutrients bound up in vegetative materials, while keeping the primary overstory components such as whitebark pine. Moderate-intensity prescribed fire can be used to mimic mixed-severity fire (where passive crown fire behavior is common as dense patches of conifer crowns are torched), opening up niches for Clark's nutcracker seed caching as well as removing the surface fuels. High-intensity prescribed crown fires are difficult to implement because of the extreme conditions required for ignition; they are very difficult to control and are not recommended.

Weather considerations, site preparation, and ignition methods for lighting prescribed fires in the subalpine zone where whitebark pine is a community component are described in the Range-Wide Strategy and also in Keane and Arno (2001) and Keane and Parsons (2010a and 2010b). Prescribed burning when soils are frozen and/or moist and when snow is still on the ground may prevent spread to nontarget vegetation. An early spring prescribed burn to eliminate subalpine fir from whitebark pine habitat is shown in Figure 3.14.

WFRB can be used effectively in whitebark pine ecosystems, particularly in those areas under wilderness management. To be most effective, the whitebark pine stands in these areas need to be evaluated and have specific fire management plans written for them with the applicable fire behavior and weather conditions for the desired outcomes. The increase in large, severe burns from warmer climates and drier

Photo by Peter Weir, USFS, Boise National Forest

Figure 3.14 Prescribed fire used to kill subalpine fir in early spring. Winter snowpack prevents fire from spreading from the target tree. Whitebark pine is visible in the upper left corner of the photo.

conditions (see Section 2, Disturbances and Threats, "Climate Change") may provide opportunities for whitebark pine establishment.

Mechanical fuel reduction treatments (thinning) in lower-elevation conifer stands that are adjacent to whitebark pine stands may be considered necessary to reduce the potential of high-severity wildfire behavior and to ensure a residual stocking level of whitebark pine. To develop a management plan with narrow fire behavior prescriptions, recommendations from McKinney, Fiedler, and Tomback (2009), Barringer et al. (2012), and Keane and Arno (2001) should be followed.

Prioritization of Stand Treatments

Different forest conditions (i.e., stand structures and ages, species composition, pathogen and insect levels) require a flexible, multipronged approach for prioritizing conservation activities. Adaptive management can be used to incorporate new information and uncertainty, such as changing climatic conditions.

The following factors must be considered for implementing conservation actions:

1) Presence of risk factors, such as white pine blister rust and mountain pine beetle
   a) The level of blister rust infection (percent stand infected, severity of infections)
   b) The level of pine beetle infestation (endemic, accelerating, epidemic, declining)
2) Successional stage of the stand
   a) Seral
   b) Climax
   c) Species and composition and structure
3) Accessibility (by vehicle, foot, pack stock)
4) Past disturbance (fire, pine beetle outbreak, landslide, mining disturbance)
5) Wilderness and other land management directives

Table 3, adapted from the GYA Strategy, provides a method for ranking sites for protection or restoration. Protection refers to monitoring efforts, plus-tree identification, seed collection, Verbenone and Carbaryl treatments to protect from mountain pine beetle, thinning of competing conifers, and pruning blister rust cankers. Restoration includes such activities as site preparation, prescribed fire, planting, and density management of all conifers.

Table 3. Stand-level priorities for determining protection or restoration actions, adapted from the GYA Strategy (2011), p. 13

BLM WHITEBARK PINE STAND-LEVEL CONDITION ASSESSMENT Scoring system to assist in determining need/priority for protection or restoration	Protect*	Restore**
Stand Damage Agents (Canopy)		
No current MPB activity, no recent canopy damage	5	0
Low endemic levels of MPB activity, low canopy damage (0%–10%)	5	0
Increasing MPB activity (transition from endemic to epidemic), low to moderate canopy (10%–50%)	5	0
High epidemic levels of MPB activity, high canopy damage (50%–100%)	0	5
Low/decreasing MPB activity, high recent canopy damage (50%–100%)	0	5
Low to no MPB activity, very high recent canopy damage (50%–100%)	0	5
WPBR nonexistent or incipient infection (0%–5%)	5	1
WPBR evident with branch cankers and occasional bole canker, moderate limb mortality in cone-bearing trees and reproduction	2	3
WPBR extensive mortality (tree or limb) in cone-bearing trees and reproduction	0	5
Root rot (any species) or twig beetles (*Pityophthorus* spp., *Pityogenes* spp., *Pityoborus secundus*) present	3	1
Stand Damage Agent Score	0–25	0–25
Current Stand Structure		
Basal Area (WBP)		
Basal Area between 22 and 45 ft^2/ac	5	0
Basal Area <22 ft^2/ac	0	5
Basal Area >45 ft^2/ac	3	3
Mixed conifer/WBP stand with mixed conifer dominant in overstory	2	2
WBP stand with recent mixed conifer expansion – reproduction/pole-sized conifers	5	0
WBP and mixed conifer open woodland structure	5	0
Recently burned WBP stands with adjacent WBP seed source	0	5
Recently burned WBP stands *without* adjacent WBP seed source	0	5
Reproduction >250 seedlings/ac	5	0
Reproduction <250 seedlings/ac	0	5
Current Stand Condition Score	0–25	0–25
Other Planning Considerations	Yes	No
Stand is within predicted future range of WBP as per SDM		
Distance from other WBP stands		
<10 km (6.2 mi)		
>10 km (6.2 mi)		
Accessible by road or trail – within 1/4 mi		
Wilderness Study Area/Wilderness/ACEC/RNA – other special designation		
Threatened & Endangered/Special Status Species		
Grizzly Bear		
Lynx		
Wolverine		
Other		
Sum of Y/N Other Planning Considerations	0–9	0–9
Total Score of Stand Damage Agents + Current Stand Structure These totals can aid in determining the type of work to be done and other planning considerations when ascertaining feasibility.	0–50	0–50

*Protect = monitoring, plus-tree identification, seed collection, Verbenone treatments, thinning of competing conifers, pruning, use of chemical repellents
**Restore = site preparation, planting, density management of all conifers
Scoring = 0 for least critical action, 5 for most critical action
MPB = mountain pine beetle, SDM = Species Distribution Model, WPBR = white pine blister rust

Three examples of conservation actions based on existing stand conditions are:

1) In the more mesic portions of the species' range, blister rust was recently reported as increasing at 4.3% per tree per year Schwandt et al. (2013). Some BLM areas have stand infection rates as high as 43%. In these areas, conserving genetic resources by protecting rust-resistant elite trees, collecting seeds for rust screening, and planting rust-resistant seedlings (or seeds) are priorities.
2) In the more xeric portions of the range, where blister rust occurs at low levels, management priorities might focus on removing other conifers to facilitate whitebark pine dominance, pruning of blister rust branch and limb cankers, planting rust-resistant stock to increase resilience, and identifying and testing sources of potential rust-resistant stock. Rust screening trials should identify resistance in these asymptomatic populations.
3) If mountain pine beetle populations are high or accelerating, then individual tree or stand protection with anti-aggregating pheromones, pheromones with additives, and/or Carbaryl should be considered to protect some seed sources (Progar et al. 2014; Perkins, Jorgensen, and Rinella 2015).

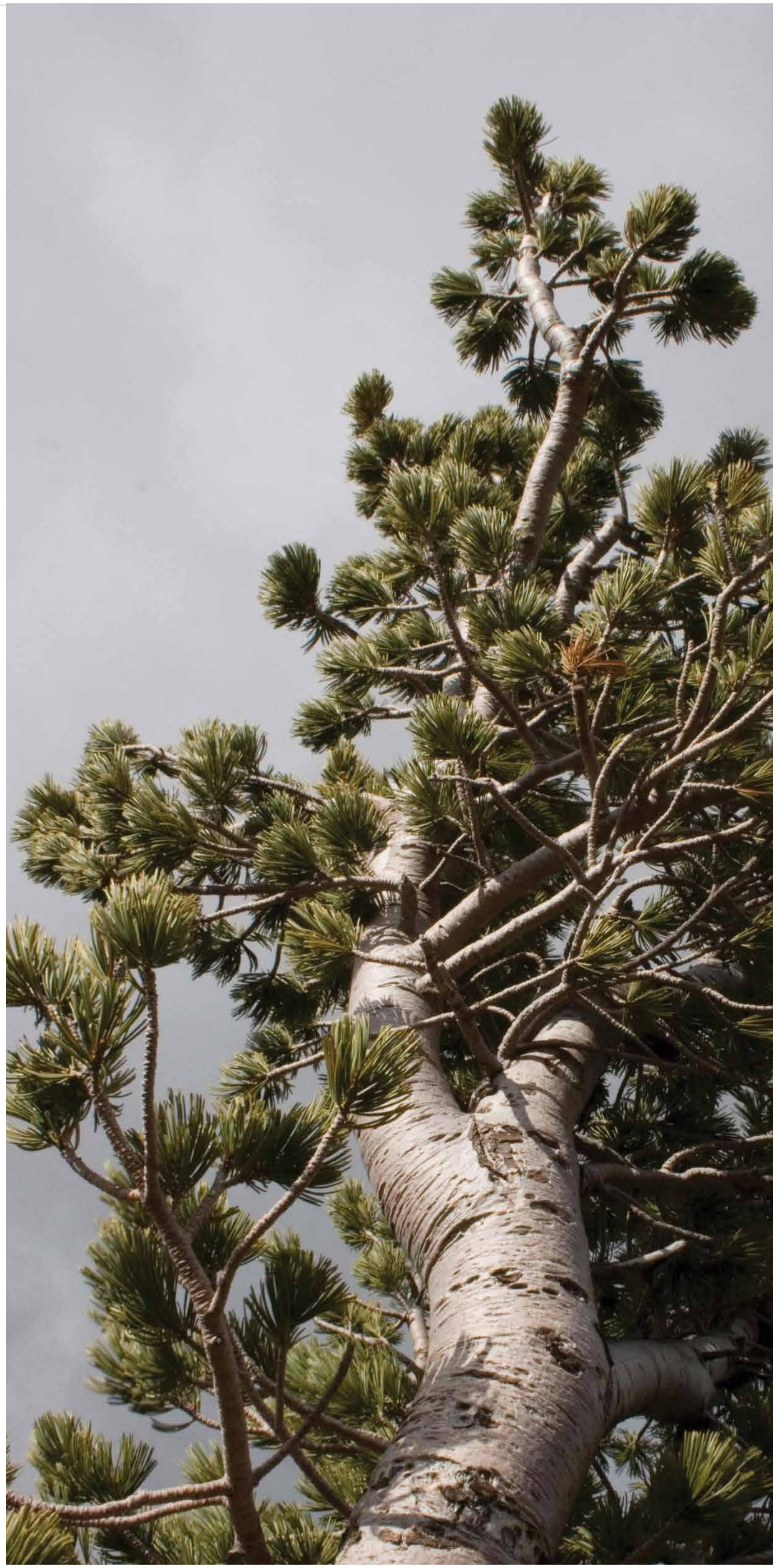


Photo by Donald Owen, California Department of Forestry and Fire Protection, Bugwood.org

Summary

The key to successful whitebark pine conservation on BLM lands in the future is the planting of rust-resistant seedlings after wildland fires, whether these fires are controlled wildfires, uncontrolled wildfires, or prescribed fires. Planting after mountain pine beetle outbreaks may also be recommended, depending on the condition of suppressed regeneration. The genetic diversity of planted seedlings should be maximized to ensure whitebark pine remains on the landscape as the climate changes. Maintaining a diversity of age classes that contain rust-resistant whitebark pine is critical to sustaining the species over long periods, because it provides both the resilience to survive unwanted wildfires and the resistance to outbreaks, disease, and climate change. While estimates of the area occupied by whitebark pine on BLM lands are low compared with areas on USFS and NPS lands, the small but important contribution of range margin habitats and isolated populations deserves conservation, particularly in the face of climate change. Where seed sources are still healthy, we recommend a proactive management approach promoting blister rust resistance and genetic diversity, coupled with silvicultural thinning to improve whitebark pine vigor and encourage natural regeneration.

Managing with uncertainty—for example, climate change—requires an adaptive approach. Using adaptive management—that is, having the flexibility to change management actions based on results and new information—fits well with the following whitebark pine conservation and management actions.

Plan activities. Design plans, including mapping, inventory, and possible treatments for restoring whitebark pine ecosystems. This includes locating, prioritizing, and scheduling areas to treat.

Implement treatments. Create conditions that encourage whitebark pine regeneration, conserve seed sources, and promote rust resistance. This includes creating nutcracker caching habitat, reducing competing vegetation, decreasing surface and canopy fuels using direct or indirect treatments, manipulating forest composition, and diversifying age class structure.

Protect seed sources. Protect valuable rust-resistant, seed-producing whitebark pine from future mortality caused by disturbance, climate, and competition.

Gather seed. Collect seed from trees that are proven rust-resistant, phenotypically rust-resistant, and in areas yet to be exposed to blister rust for archiving genetic diversity and variation, growing seedlings for operational planting, and possibly for direct sowing. Make collections throughout the range to capture the range of genetic diversity before it is reduced by various human activities. Identify putatively rust-resistant trees, and collect seed from those trees for the rust-resistance screening process needed for genetic rust-resistance breeding programs. Manage and periodically assess seed inventories to ensure that effective population sizes are being maintained in space and time. This will better position agencies to be proactive in conservation, and will provide a buffer for climate change.

Grow seedlings. Grow whitebark pine seedlings from seed of proven (genetically tested in a rust screening) rust-resistant trees; document levels of rust-resistance performance in the parent trees and their seedlings; establish seed orchards; and plant seedlings in areas that have been treated with the appropriate site prescriptions.

Plant seedlings. Plant rust-resistant seedlings and use direct sowing in treated or burned areas, especially in areas experiencing heavy whitebark pine mortality. Areas with few whitebark pine seed sources are not likely to produce enough seed to provide for nutcracker energy requirements and adequate whitebark pine regeneration.

Monitor activities. Pre- and post-activity field sampling is critical to document the success and failure of restoration treatments. Analysis of periodic data obtained from monitoring is needed to assess:

- changes in levels of blister rust
- changes in species composition
- seedling survival after planting
- changes in fuel load
- insect activity (mountain pine beetle and other bark beetles)

Research and Management Needs

Genetics

Conservation biology emphasizes the maintenance of native gene pools as an important function in maintaining ecosystem and species integrity. Jackson and Betancourt (n.d.) state: "Finally, our results underscore the growing need to focus more on genotypes than species in biogeographic modeling and ecological forecasting." With the growing awareness of climate change and its potential effects on tree species such as whitebark pine, the above statement underscores the long-term need for appropriate genetic studies to determine native gene pools.

Because of the diversity of BLM whitebark pine populations, especially those disjunct stands on the range margin of the species, we recommend that, as funding becomes available, the BLM conduct a range-wide genetic survey of whitebark pine populations on BLM lands, emphasizing those disjunct, potentially unique stands along the range margins and at lower elevations. We recommend that this work follow the methodology developed by Potter et al. (2015) in their range-wide study of ponderosa pine. The USFS in the Pacific Northwest (Region 6) has done similar work in its whitebark pine populations. The USFS National Forest Genetics Laboratory in Placerville, California, would be a preferred cooperator because of its extensive experience. This work would identify unique populations that may require priority restoration efforts, and would provide the basis for developing refined Species Distribution Models for the different genotypes.

Development of genomic techniques for rapid testing of trees for genetic resistance to blister rust would save years of greenhouse work and would make proactive restoration planning far easier and less costly. Research should improve the restoration process by providing vital information on state-of-the-art techniques and protocols that will hopefully make restoration efforts more effective and economical. For instance, are genetic markers available for white pine blister rust, or can they be developed?

Livestock Grazing

Many areas in whitebark pine ecosystems were grazed by huge herds of sheep and cattle in the late 1800s and early 1900s. The recognition of unacceptable levels of disturbance to soils, vegetation, and watershed health has resulted in some grazing reductions (Willard 1990). However, domestic livestock grazing continues in many areas, often in noncompliance with allotment guidelines, and its effects on whitebark pine are largely unstudied.

Seedling Establishment

Survivorship and photosynthetic efficiency of 1-year-old whitebark pine seedlings at treeline was positively correlated with forb and tree cover in field manipulations, except under alleviated water stress (Maher, Germino, and Hasselquist 2005). Young whitebark pine, Engelmann spruce, and subalpine fir did not have a negative response to surrounding vegetation. More research is needed on survival of seedlings, planted seeds, and the conditions that correlate with successful establishment.

Density Management

SDIs are currently being developed for whitebark pine (J. Long and J. Shaw, pers. comm.) (Figure 3.11) from FIA plot data. Their application to thinning and stand vigor has yet to be investigated. Thinning trees that are severely infected with white pine blister rust is sensible, but thinning trees of unknown resistance levels increases the potential loss of rust-resistant, cold hardy or mountain pine beetle–resistant stock. More research is needed on density management and stand dynamics.

Climate Change

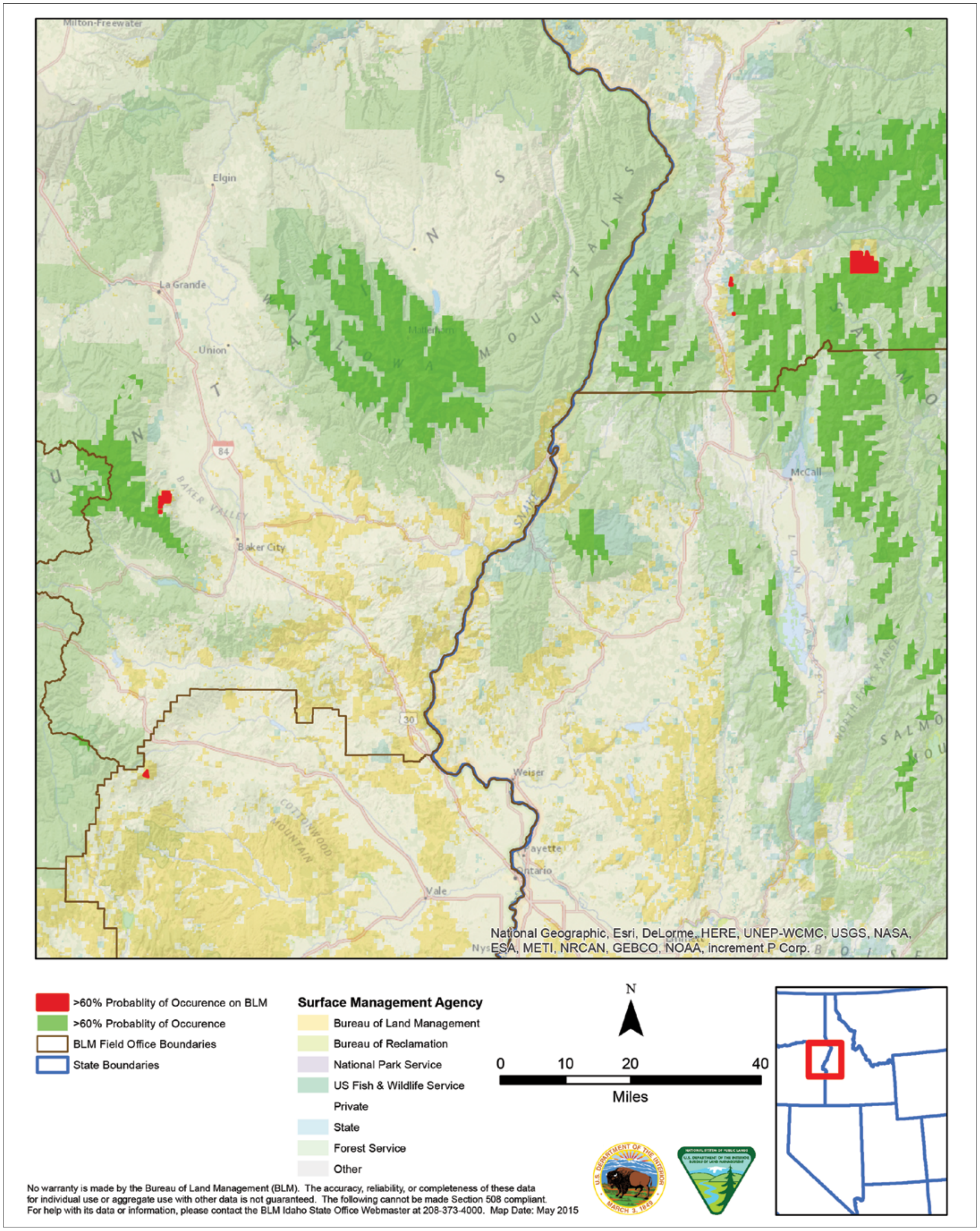
Managers will need to understand how climate change influences the life cycle of the blister rust fungal pathogen *Cronartium ribicola* and seed and cone insects. Research reports on how climate change affects fire frequency and intensity and the life cycle of mountain pine have been discussed briefly in this document. This work is ongoing, and further work is encouraged.

Photo by Terry Spivey, USDA Forest Service, Bugwood.org

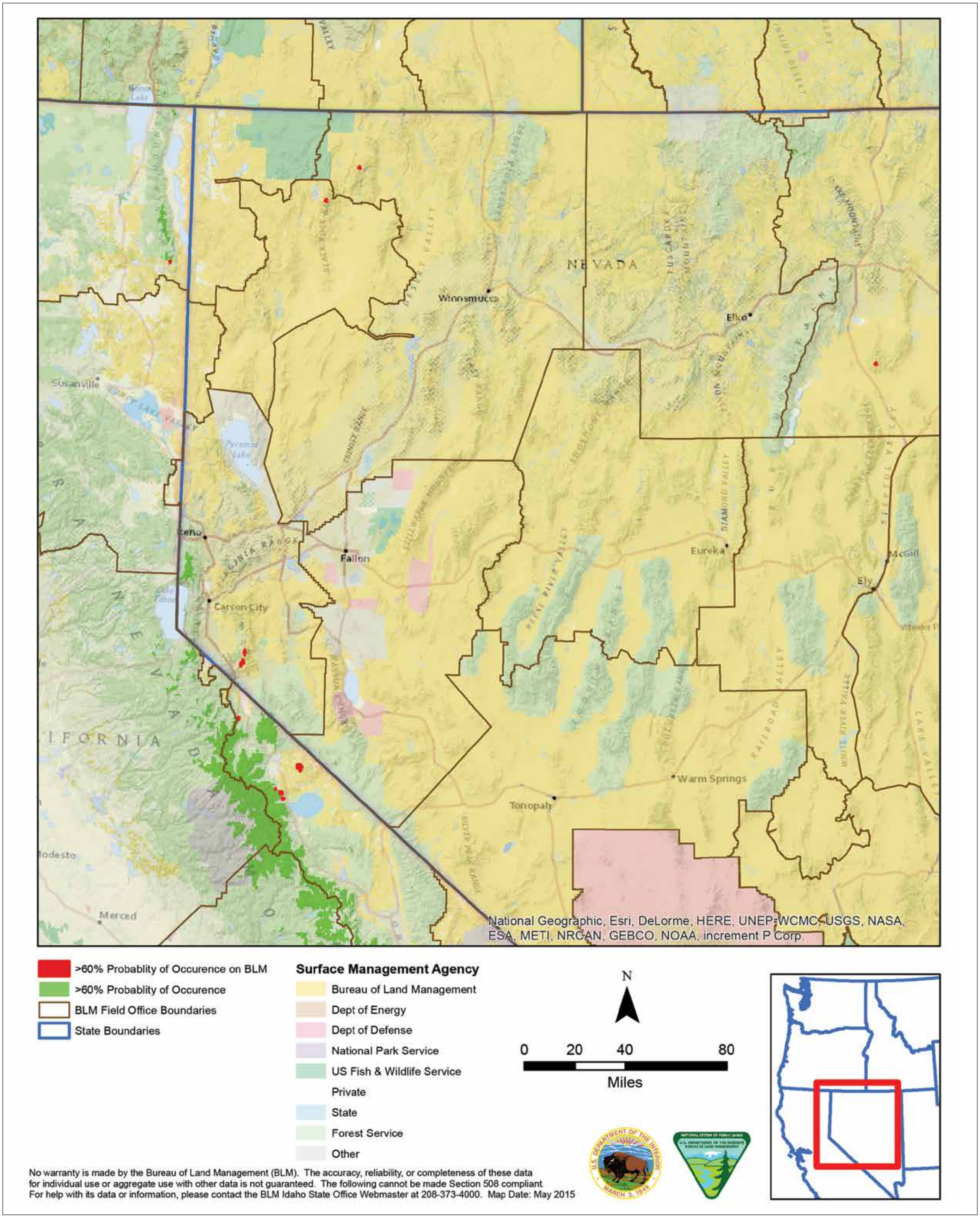
Appendixes

Appendix 1

Maps Showing Probability of Occurrence of Whitebark Pine on BLM Lands in Eastern Oregon and Western Idaho and in Eastern California and Nevada



BLM-Oregon (eastern) and BLM-Idaho (western) whitebark pine occurrence map (red polygons) based on a 60% probability threshold from a bioclimatic model. Green polygons represent all lands where whitebark pine occurs at a probability of 60% (Warwell, Rehfeldt, and Crookston 2007).



BLM-California (eastern) and BLM-Nevada whitebark pine occurrence map (red polygons) based on a 60% probability threshold from a bioclimatic model. Green polygons represent all lands where whitebark pine occurs at a probability of 60% (Warwell, Rehfeldt, and Crookston 2007).

Appendix 2

White Pine Blister Rust Damage Codes for Ranking Severity of Infection, and Mountain Pine Beetle Activity Rating for Whitebark Pine

Rust Severity Code for **large** trees, **GREEN** (live) trees only **(> 5 in. dbh)**

X = unable to see the top well enough to tell
S = Severe
> 66% of crown dead,
and/or bole canker in lower portion of tree,
or if bole canker will likely kill > 66% of the cone-producing area
M = Moderate
33%–66% of crown dead
or several (> 6) large dead branches or flags,
or bole canker in upper portion of tree that will cause only partial top kill
L = Light
< 33% of crown dead or a few small dead branches,
or occasional flags (< 6)
0 = No rust seen

Rust Severity Codes for **small,** live WBP **(< 5 in. dbh)**

D = Dead due to blister rust
DU = Dead for unknown reason (no obvious rust, etc.)
S = Severe (same as for larger trees)
> 66% of crown dead (or top kill),
and/or **lethal** canker in lower portion of tree,
or on a branch < 6 in. from bole
M = Moderate (same as for larger trees)
L = Light (same as for larger trees)
on very small trees, may see only a dead, swollen branch (often at the end of twig),
or flag > 24 in. from bole
0 = No rust seen; clean tree

Mountain Pine Beetle Activity Ratings

Mass attack = boring dust or pitch tubes surround most of the root collar or bole and/or the phloem and sapwood are discolored and beetle galleries and larval mines are visible around most of the bole following bark removal. Foliage may be green.

Strip attack = successful attacks confined to half or less of the tree's circumference.

Pitch out = trees with five or more large pitch tubes with little or no red, oxidized frass. No successful galleries under the bark.

Live or no attack = trees with no frass and fewer than five pitch outs.

Photo by Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database/USDA NRCS. 1995. Public Domain

Appendix 3
Monitoring Report for Health Status of Five-Needle Pines on Wyoming BLM Lands (Reprint)

Prepared by Erin Shanahan, May 14, 2015

In 2013 and 2014 baseline data were collected to assess the overall health status of five-needle pines (whitebark pine and limber pine) on Bureau of Land Management (BLM) properties within the Greater Yellowstone Ecosystem (GYE). In portions of Wyoming, eight mapped units were identified as having a five-needle pine component. Mapped units contained both permanently established transects (for future revisit) and rapid assessment transects. (See Table 1.)

Of the 2,366 live trees surveyed, 107 were positively documented as whitebark pine (*Pinus albicaulis,* or "WBP") and 261 as limber pine (*Pinus flexilis*). Due to the absence of cones and their location in mixed stands of both WBP and limber pine, the species of the remaining 2,005 live five-needle pines was recorded as unknown ("UNK"). All five-needle pines were examined for white pine blister rust (blister rust, or "BR") infection and sign of mountain pine beetle ("MPB") infestation.

Using an unadjusted, combined ratio estimator with a secondary variance component to determine the proportion of five-needle pines infected with blister rust on BLM lands in the GYE, we found that 0.156 ± 0.054 (95% CI [0.045,0.268]) of five-needle pines were infected with blister rust. For whitebark pine only, the proportion of trees infected on BLM lands was 0.302 ± 0.17 (95% CI [0.00,0.703]). The confidence interval width for this estimate is reflective of the small sample size for whitebark pine. About 5% (0.048) of the live five-needle trees had sign of mountain pine beetle, and of the 786 dead trees, 712 (0.91) had galleries on the bole. The understory (< 1.4-m tall) five-needle densities varied (0–441) across the eight mapped units, with a total of 1,272 observed. Of these, the incidence of blister rust was low (0.02).

Table 1. Numeric summaries of total trees recorded for each transect type for combined data from 2013 and 2014 field seasons. Total refers to the count of trees pooling across transects and map units.

Category	Permanent Transects Count	Proportion	Rapid Transects Count	Proportion
Total map units	8		36	
Total transects	8		137	
Total trees	146		3,006	
Total dead trees	7		779	
Total WBP	12		96	
Total Live WBP	12/12	(1.000)	95/96	(0.990)
Total Live WBP with BR	4/12	(0.333)	24/95	(0.253)
Total WBP with MPB	0/12	(0.000)	5/96	(0.052)
Total Limber Pine	20		246	
Total Live Limber Pine	20/20	(1.000)	241/246	(0.980)
Total Live Limber Pine with BR	9/20	(0.450)	85/241	(0.353)
Total Limber Pine with MPB	0/20	(0.000)	6/246	(0.024)
Total UNK trees	114		2664	
Total Live UNK trees	114/114	(1.000)	1891/2,664	(0.710)
Total Live UNK trees with BR	15/114	(0.132)	457/1,891	(0.242)
Total UNK trees with MPB	2/114	(0.018)	141/2,664	(0.053)

Earlier, in 2004, an interagency whitebark pine long-term monitoring program was established to detect and monitor changes in the health of whitebark pine populations across the GYE due to infection by blister rust, attack by mountain pine beetle, and damage by other environmental and anthropogenic agents. Data for this monitoring program are collected from 176 transects in 150 stands of whitebark pine across the GYE. Currently, the proportion of live, whitebark pine trees > 1.4-m tall infected with blister rust is 20%–30%. This range includes the confidence interval for the estimate. Infection is defined as a single canker to multiple on a given tree. From this ground-based monitoring approach, we report that as of 2013 about 27% of whitebark pine has died in the GYE since 2004. Mountain pine beetle infestation was evident on 833 (0.58) of the 1,443 dead trees. Understory counts on the 176 transects totaled more than 8,000 trees and ranged from 0 to > 600 on a given transect. Blister rust infection was low in this size group.

On six of the eight mapped BLM units, we found whitebark pine to be a minor stand component in conjunction with limber pine and other conifer species. Whitebark pine on the monitoring program transects are typically found in mixed and pure stands of whitebark pine and other species. Limber pine is rarely encountered in the monitoring program stands. During the two seasons of data collection on BLM-managed lands, cone production was almost nonexistent for trees on all of the eight mapped units, as 2012 had evidently been a mast year. Elevation ranges for BLM transects went from 5,900 to 9,400 feet, whereas the span for the monitoring program transects starts at 7,800 feet and goes up to 10,400 feet.

The rate of infection in whitebark pine populations on BLM-managed lands is similar to rates reported for whitebark pine in other areas of the GYE. At least two (Commissary Ridge and Pine Grove/Deadline) of the eight mapped units were located within close proximity to several of the monitoring program transects. Though infection proportions were similar in both areas, we noticed that blister rust infection appeared to be fairly recent throughout most of the eight mapped units on BLM lands. This was deduced based on the fact that most infections were located in the canopies of infected trees and there was an absence of flagging in association with these branch cankers.

Although mountain pine beetle related mortality in five-needle trees was relatively higher on BLM trees than the monitoring program trees (0.91 compared with 0.58), there was a higher incidence of mountain pine beetle on the monitoring program transects (0.71) compared with the BLM transects (0.52; monitoring program = 126/176, BLM = 76/145). One reason for this difference could be that the most recent mountain pine beetle outbreak seems to have more heavily impacted five-needles in some of the southern portions of the GYE close to where the BLM transects are located. Regeneration densities are fairly comparable for both BLM and other GYE areas.

Appendix 4
Scion and Pine Pollen Collection and Handling

Scion Collection and Handling

The following is a list of guidelines for selecting and collecting scion material to be used in future grafting projects.

1) Collect scion material from the upper third of the tree crown **ONLY**. Female flowers are most often produced in the upper third of the tree crown.

2) Collect scion material in the spring while the tree is still dormant. Collect scion material from wood that grew the previous summer (1-year-old material). **To ensure dormancy, all scion must be received at the Coeur d'Alene Nursery (CDA Nursery) by the close of business on March 20.**

3) Ensure that scion measures 6–8 in. long to prevent dessication and allow enough material for grafting. Most grafting is done with 2-0 rootstock (two growing seasons). Scion caliper should match rootstock caliper as closely as possible, and this varies by species and year. In most years, the target scion calipers average 1/8 in. for western larch, 3/16 in. for whitebark pine, 3/16 in. – 1/4 in. for western white pine and lodgepole pine, and 1/4 in. – 5/16 in. for ponderosa pine. For thicker branched species, you may need to collect secondary and not primary branches. **Do not force the scion to fit in the bag by trimming needles or bending the scion.** If a 1-gallon ziploc bag is not big enough, use the 2-gallon ziploc bags now available.

4) Wrap the cut end of the scion material in wet paper towels. **Do not put snow in the bag.** Depending on the species, 10–20 pieces of scion from the **SAME donor tree** can be wrapped in wet paper towels (i.e., it is unnecessary to wrap each piece of scion individually).

5) Consult David Foushee (208-765-7394, *dfoushee@fs.fed.us*) at the CDA Nursery if you have questions about quantity of scion needed per individual, or other questions.

6) Include two tags with each ziploc bag filled with scion, one on the inside and one attached to the outside. The tags should include one of the sets of information shown below:

   a) White Pine Parent Trees from Wild Stand Collections

      Species
      Cycle Number
      Tree Number
      Collection Type (BO = Breeding Orchard, CB = clone bank)
      Township, Range, Section
      Elevation
      Area Name
      Forest and District Name
      Full Name of Collector
      Date of Collection

b) Collections from Field Tests, Plantations, and Tree Improvement Areas (all species)

Species
Breeding Zone
Phase (I or II)
Cycle Number (for white pine)
Stand and Tree Number
Pedigree Number
Collection Type (BO = breeding orchard, CB = clone bank, SO = seed orchard, VR = vertical resistance study, etc.); purpose for the collection; where it will be out-planted.
Plantation, Field Test, or Tree Improvement Area Name; if from a Tree Improvement Area, identify where the material was collected: early selection trial (EST), clone bank (CB), or seed orchard (SO)
Replication (block), Row and Column of the Plantation, Field Test, or Tree Improvement Area
Forest and District Name
Full Name of the Collector
Date of Collection

7) Create tags/labels before collecting scion in the field, for greater ease and to minimize mistakes in recordkeeping. Organizing the scion collection bags by how material is collected in a field test (e.g., serpentine fashion) will also speed up the collection process.

8) Place ziploc bags in coolers with frozen blue ice packs during the day when scion is being collected at the site. **Do NOT use dry ice.**

9) Scion material may be stored for 2–3 weeks in a refrigerator set at 34– 38 °F. Scion may be stored for 1–3 months at 32 °F. **We recommend, however, shipping the scion within 24–48 hours after field collection.**

10) Ship scion in coolers to keep the material at a cool temperature and to ensure that the material stays in good condition. An ice pack in the bottom of the cooler will keep the material cool during transport. If you cannot bring the material to the CDA Nursery, then you should ship it with an overnight express carrier. Avoid shipping on a Thursday or Friday, since doing so risks delaying delivery until the following week; material may not be kept in a cool environment over the weekend and become damaged. Remember, this material is living tissue that needs to be handled with extreme care. **Please notify the CDA Nursery before shipping scion by calling 208-765-7394 or -7375 (front desk), so the nursery can be ready to process it immediately. If delivering the scion material in person, be sure to make the delivery during posted business hours for the nursery** (7:30 a.m. – 4:00 p.m., Pacific time, Monday–Friday).

Shipping address:
David Foushee
USDA Forest Service
Coeur d’Alene Nursery
3600 Nursery Road
Coeur d’Alene, ID 83815-5279

Pine Pollen Collection and Handling

1) Locate trees and assess for pollen development. Flag elite trees ahead of time to facilitate relocation before actual pollen collections take place. Record as much pollen identification information on the outside of the bags ahead of time, to speed up actual field collections.

2) If you are collecting pollen from the same trees or the same locations in different years, when to monitor for ripeness can be based on past experience with adjustments made for that year's climate. An "indicator" tree close to your office can also be used, based on past experience with that tree's ripeness relative to target trees in the field. It is always better to be a little early and have to make a second visit than too late and have to wait until next year.

3) Hopkin's Bioclimatic Law can be used to estimate pollen ripeness dates for trees in new locations relative to locations where ripeness dates are known. In general for the northern Rockies, pollen ripens:

- 4 days later for each 1 degree latitude northward; 4 days earlier for each 1 degree latitude southward
- 4 days later for each 5 degrees longitude eastward; 4 days earlier for each 5 degrees longitude westward
- 4 days later for each 400-ft increase in elevation; 4 days earlier for each 400-ft decrease in elevation

This should be used as a general guideline only because of microsite differences such as aspect, cold air drainage, and the genetics of the tree (early ripeners vs. late ripeners).

4) Monitor catkins for signs of ripening. Be aware that you have about 24–36 hours to collect mature pollen before pollen flight. Things to keep in mind:

- Catkins turn from green to yellow in white pine and from reddish-purple to yellow in ponderosa pine.
- Trees ripen from the bottom up, unless there are cold air drainage problems (e.g., Hog Meadows).
- You can perform a squeeze test. (Squeeze a catkin between thumb and finger. If the liquid is yellow and/or cloudy, the pollen is not ripe. If the liquid is clear, pick the catkins).
- **If nearby neighbors are shedding pollen, and there is a risk of pollen contamination at the target elite tree due to air movement, do not collect pollen.**

5) Place catkins in paper lunch bags or pollen bags. Seal seams with tape to avoid contamination with other pollen collections. Collect two–three bags of catkins per tree and do the following:

- Fill bags 1/3–1/2 full with catkins only—**NO NEEDLES**.
- Double-fold the top of the bag shut, and staple closed. Do not fold bags so far down that the catkins are packed together with no "breathing room." Seal the stapled fold with tape.

6) **To avoid pollen contamination when moving from one elite tree to the next, sterilize all collection tools (snippers) and hands with rubbing alcohol and allow sufficient drying time before proceeding with the next collection. A new pair of disposable surgical gloves is recommended for hands in lieu of repeated skin contact with alcohol.**

7) **Do not collect catkins in the rain or in wet, extremely humid conditions. Doing so greatly increases the chances of mold growing on the catkins before the pollen can be processed at the nursery. Mold decreases pollen yield and viability.**

8) Use red tape, or staple red flagging to the top of the bag to indicate "red tag" pollen lots that need to be processed for use that same field season. Also, write "red tag" on the bag.

9) Record collection and identification information with a waterproof marker.

   a) Single-tree collections in stands (white pine)

Record the following information on the bag:

Indicate if this is a "red tag" lot.
Collection Date _____/_____/_____
Species Code __________________
(2 alpha, WP)
TWN______ RNG______ SEC______ ELEV________
Cycle Number__________________
Family Number_________________
Collected by_______________________________________

   b) Plantation Collections (ponderosa pine)

Record the following information on the bag:

Indicate if this is a "red tag" lot.
Collection Date _____/_____/_____
Species Code __________________
(2 alpha, PP)
Plantation Code________________
(4 alpha, e.g., LONE, COND, LUBR)
Breeding Zone__________________
Family Number_________________
Pedigree Number________________
Elite Tree Rep_______Row_______Col_________
Collected by_________________________________

10) (Temporary storage.) Keep bags cool and dry, out of direct sunlight while in the field. If unable to ship pollen within 24 hours, hang bags on a clothesline in a garage or warehouse, with clothespins, and be sure to shake the bags twice a day to ensure air circulation and minimize mold formation. Ship bags within 48 hours of collection.

11) Transport pollen collections in a cardboard box that is loosely packed with crumpled newspaper. Cut 2-in. diameter holes around the sides of the box for aeration. Tomato or apple boxes work well.

12) Ship pollen to Coeur d'Alene Nursery. Notify David Foushee (*dfoushee@fs.fed.us*, 208-765-7394) before shipping. Ship to arrive during posted business hours, 7:30 a.m. – 4:00 p.m., Pacific time, Monday–Friday.

Shipping address:
David Foushee
USDA Forest Service
Coeur d'Alene Nursery
3600 Nursery Road
Coeur d'Alene, ID 83815-5279

Appendix 5

Whitebark Pine Plus-Trees in Idaho, Montana, Oregon, and Wyoming

These trees show few to no symptoms of blister rust, and their progeny will be tested for rust resistance. Cone collections and rust resistance screening at the USFS Coeur d'Alene Nursery is ongoing.

Site Name	Tree ID	Field Office	Seed Zone	WGS84_X (long.)	WGS84_Y (lat.)	Aspect (deg)	Elevation (ft)
IDAHO PLUS-TREES							
Marshall Mountain	mmt373	Cottonwood	BTIP	-115.856	45.3874	332	7,969
Marshall Mountain	mmt374	Cottonwood	BTIP	-115.856	45.3854	288	8,090
Marshall Mountain	mmt375	Cottonwood	BTIP	-115.855	45.38493	280	8,155
Marshall Mountain	mmt376	Cottonwood	BTIP	-115.855	45.38296	247	8,140
Marshall Mountain	mmt377	Cottonwood	BTIP	-115.853	45.38157	292	8,208
Marshall Mountain	mmt372	Cottonwood	BTIP	-115.857	45.37578	240	8,028
Marshall Mountain	mmt371	Cottonwood	BTIP	-115.846	45.37428	349	8,438
Geertson Ridge	Gee890	Salmon	BTIP	-113.696	45.24092	268	9,134
Geertson Ridge	Gee893	Salmon	BTIP	-113.697	45.24053	297	9,077
Geertson Ridge	Gee892	Salmon	BTIP	-113.696	45.24259	281	9,200
Geertson Ridge	Gee891	Salmon	BTIP	-113.694	45.24391	287	9,258
Geertson Ridge	Gee899	Salmon	BTIP	-113.716	45.22885	254	7,861
Geertson Ridge	Gee898	Salmon	BTIP	-113.713	45.22941	183	8,014
Geertson Ridge	Gee897	Salmon	BTIP	-113.708	45.23321	156	8,420
Geertson Ridge	Gee896	Salmon	BTIP	-113.708	45.23445	186	8,600
Geertson Ridge	Gee900	Salmon	BTIP	-113.721	45.22259	177	7,270
Poverty Flat	Pov306	Challis	BTIP	-114.368	44.30389	153	9,430
Poverty Flat	6995	Challis	BTIP	-114.361	44.30763	60	9,306
Poverty Flat	7002	Challis	BTIP	-114.358	44.32006	12	9,415
Poverty Flat	7001	Challis	BTIP	-114.363	44.31652	186	9,416
Poverty Flat	7000	Challis	BTIP	-114.362	44.31566	179	9,407
Poverty Flat	6990	Challis	BTIP	-114.349	44.30224	80	8,799
Poverty Flat	6998	Challis	BTIP	-114.363	44.31104	109	9,362
Poverty Flat	6997	Challis	BTIP	-114.362	44.31033	99	9,326
Poverty Flat	6991	Challis	BTIP	-114.36	44.3053	66	9,303
Poverty Flat	6996	Challis	BTIP	-114.363	44.30971	70	9,394
Poverty Flat	7004	Challis	BTIP	-114.356	44.31794	77	9,411
Poverty Flat	7003	Challis	BTIP	-114.355	44.31652	165	9,376
Poverty Flat	6999	Challis	BTIP	-114.362	44.31456	170	9,388
Poverty Flat	6994	Challis	BTIP	-114.361	44.30644	71	9,319

Site Name	Tree ID	Field Office	Seed Zone	WGS84_X (long.)	WGS84_Y (lat.)	Aspect (deg)	Elevation (ft)
MONTANA PLUS-TREES							
Sweetgrass	swe381	Hauvre	CLMT	-111.137	48.85406	81	6,777
Windy Pass	6341	Dillon	CLMT	-111.967	45.68635		8,000
Windy Pass	6342	Dillon	CLMT	-111.963	45.68608		8,000
Axolotl	6343	Dillon	GYGT	-111.903	45.19538		8,600
Axolotl	6344	Dillon	GYGT	-111.901	45.19819		8,600
Axolotl	6345	Dillon	GYGT	-111.887	45.21202		8,600
Medicine Lodge	6347	Dillon	CLMT	-113.055	44.77737		8,700
Upper Horse Prairie	6346	Dillon	CLMT	-113.15	44.90906		8,900
Upper Horse Prairie	6349	Dillon	CLMT	-113.155	44.91204		8,900
OREGON PLUS-TREES							
Hunt Mountain	hunt701	Baker	BTIP	-118.058	44.8808	5	7,200
Hunt Mountain	hunt702	Baker	BTIP	-118.058	44.88016	45	7,303
Hunt Mountain	hunt703	Baker	BTIP	-118.058	44.87918	40	7,421
Hunt Mountain	hunt704	Baker	BTIP	-118.058	44.8776	289	7,462
WYOMING PLUS-TREES							
Commissary Ridge	com005	Kemmerer	GYGT	-110.577	42.0459	88	8,972
Commissary Ridge	com006	Kemmerer	GYGT	-110.575	42.06562	278	9,304
Commissary Ridge	com008	Kemmerer	GYGT	-110.569	42.08903	77	9,330
Commissary Ridge	com007	Kemmerer	GYGT	-110.569	42.09004	32	9,310
Commissary Ridge	com001	Kemmerer	GYGT	-110.573	42.06961	90	9,353
Commissary Ridge	com002	Kemmerer	GYGT	-110.573	42.08523	181	9,298
Commissary Ridge	com003	Kemmerer	GYGT	-110.574	42.08512	229	9,287
Commissary Ridge	com004	Kemmerer	GYGT	-110.57	42.08237	347	9,367

BTIP – Bitterroots - Idaho Plateau
CLMT – Central Montana
GYGT – Greater Yellowstone - Grand Teton

Appendix 6
Cone Collecting Guidelines

1) Place cages over immature cones in early summer, generally mid to late June.
2) Cones mature/ripen in late summer. The method to determine method seed ripeness is to:

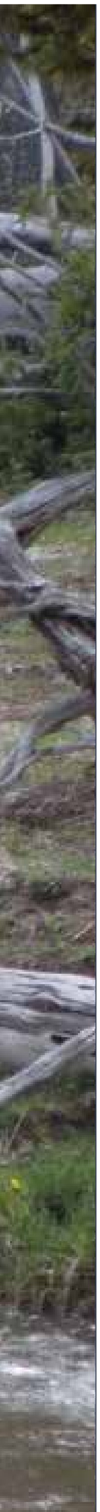
    a) Cut cones in half longitudinally (or sections) with a cone cutter to reveal the half section faces of seven to eight seeds. This is an easy method for inspecting the embryo.
    b) Cut seeds longitudinally and confirm that the embryo fills 90% or more of the embryo cavity (Burr, Eramian, and Eggleson 2001). A cavity that is filled 75% or better may also yield acceptable germination rates.
    c) Repeated visits to determine cone ripeness are time-consuming, but because cones are caged, collections can occur after seed maturation.

3) Once cones are ripe, remove cages, collect cones, and put cones in burlap sacks.

    a) To prevent cone infection from insects or pathogens, place tarps beneath collecting areas, so no cones touch the ground.

4) Store cones in burlap sacks or equivalent breathable material.
5) For plus-tree collections, you must keep all cones from the tree in their own unique sacks.
6) Keep sacks underfilled, approximately 1/3–1/2 full, with the tie closure within 3 in. of the top, to allow adequate ventilation.
7) Sacks must have tree cone collection tags (identification number, locations, admin unit, etc.) inside the bag and also tied to the outside.
8) It is critical to store sacks of cones in a dry, well-ventilated environment until the cones are shipped to nurseries and the seed extracted.

Photo by John Esworthy



Appendix 7

Whitebark and Limber Pine (Five Needle Pine) Management Guidelines for Wyoming BLM, August 2011 (Reprint)

Attachment 2 of Instruction Memorandum: WY-2011-041

These guidelines are developed to provide direction on how to manage both whitebark pine and limber pine found on BLM lands in Wyoming. The silvicultural prescriptions are to be used as guidelines to meet the objectives of the maintenance and restoration of five needle pine on the landscape. The objectives are: 1 - to maintain these stands on the landscape in the face of changing climate and insect (mountain pine beetle – MPB) and disease (white pine blister rust – WPBR) epidemics that are severely impacting these species, 2 - to maintain genotypic diversity on the landscape and 3 - to provide both the source and opportunity for these species to naturally migrate or change their species ranges as climatic conditions change in the future. Field Offices need to evaluate the objectives of projects that involve five needle pines to ensure that the long term objectives of maintaining these sensitive species on the landscape are appropriately evaluated along with other management objectives.

Reference materials that can be used for documentation of potential management actions can be found at: *http://web.wy.blm.gov/930/forestry/pines/index.htm*

Wyoming BLM is working with Utah State University to develop Stand Density Index Charts for both whitebark and limber pine. When these are completed they will be valuable tools with which to manage these stands. All Stand Density Index (SDI) materials can be found at: *http://web.wy.blm.gov/930/forestry/SDI/index.htm*

General Guidelines:

Cone (Seed) Collection: There are significant regional whitebark and limber pine seed collection efforts underway to identify white pine blister rust (WPBR) resistant trees. The cone collection efforts are central to five needle pine restoration for three reasons: 1 - blister rust resistance testing, 2 - restoration plantings, and 3 - *ex-situ* gene conservation.

Preliminary seed tree selection involves finding and marking trees that are nearly free of both WPBR and mountain pine beetle (MPB) infestation. Trees need to be marked and located with a Global Positioning System (GPS) so that they can be relocated for further collections if testing determines that these trees are WPBR resistant. This information will be stored on a GIS data layer at the District level. The entire process, from cone collection to rust resistance determination, takes approximately 5 years, so these trees need to be protected from both natural and human disturbance until the determination is made. If the testing shows WPBR resistance, these trees will be permanently marked and used as a seed source. These trees are identified as “plus” trees. All trees either tentatively or positively identified as “plus” trees need to be protected by pheromones or insecticides (see next page).

Whitebark pine seed collection procedures can be found in the online five needle pine references. Limber pine, because of its different cone structure, does not normally require the caging that whitebark pine does and can be collected as soon as the seed is ripe. In high pine mortality areas (limited seed source), where there is significant predation from squirrels and birds, caging of both species is necessary. Collections for both species is normally done, dependent on site and climatic conditions, in late August or early September when their embryo cavities are found to be at least 80 percent full.

Because of the workload associated with identification of potential "plus" trees as well as the seed collection, it is recommended that Field Offices develop BPS submissions in conjunction with the "Seeds for Success" program assist in funding these activities.

Seedling Planting: Seedlings from these trees have a fairly low survival rate ranging from less than 30 to approximately 70 percent. Seedlings should be planted in the autumn, to avoid summer drought stress, at approximately 200-250 seedlings per acre with the goal to have a 3 to 5 year survival of 85-100 trees per acre. There should be no overstory competition within 20 feet. The planting design should be a patchy pattern with densities similar to that of nearby stands. Microsite placement is critical. The transplants should be placed in a protected microsite in moist to the touch soil on the north side of a log, rock, or stump. Gophers feed on roots and bury trees, so avoid planting the seedlings in areas of deep soils and swales where they burrow. Competing vegetation such as grasses and sedges should be removed from the immediate vicinity of the planted seedling. Avoid planting seedlings within 2 feet of bear grass (*Xerophyllum tenax*). On more mesic sites, grouse whortleberry (*Vaccinium scoparium* Leib. ex Coville) appears to be beneficial to establishment when growing in association with whitebark pine and should be retained. Lower elevation xeric sites may not have these vegetative components. Current recommendations for planting with WPBR resistant seedlings include, 1 - sites where WPBR mortality exceeds 20 percent and, 2 - WPBR infection is more than 50 percent.

Pheromone Usage: Pheromones, especially verbenone, can be used to protect against MPB attack. Recent work in Idaho on whitebark pine shows a 20 percent increase in survival over a control population when verbenone is used. Because of costs, this use is only feasible in high value recreation/visitor areas or on trees either tentatively or positively identified as plus trees.

Insecticide Usage: Carbaryl is commonly used to provide protection from MPB. This insecticide when properly applied by spraying can provide almost 100 percent protection from MPB attack for up to 2 years. Trees must be accessible to compressor driven spray equipment, limiting this application to trees in close proximity to roads.

Pruning: Pruning can be used to extend the life of a five needle pine. Pruning should be done by hand, leaving the branch collar (swollen base of the limb) intact. This should only be used on limbs where the WPBR canker is more than 4 inches from the bole (trunk) of the tree. Because pruning is labor intensive it should only be used to: 1 - to protect high value individual trees in high visibility sites such as recreational/ski areas or, 2 - in a small isolated stand with few cone bearing trees and no existing seed source for regeneration. Pruning will not change the WPBR resistance of an individual tree or stand, but will extend the life span and potential reproductive life of the tree.

Range Management Applications: The historic bison range in Wyoming closely approximates the range of lower treeline limber pine in Wyoming. The Nature Conservancy along the Front Range has used the following range management technique to replicate bison/limber pine interactions with success. Where feasible, this technique can be used on Wyoming BLM lands.

Place water developments and salt stations in close proximity to limber pine stands. This will provide thermal cover for livestock. Their usage of the limber pine stands will raise the crown heights due to rubbing, reduce ground cover including tree reproduction, and reduce flammable fuels within the stand. The long term objective (50 + year) is to approximate an open limber pine stand that resembles historic bison/limber pine interactions.

Wildland Fire Management: Wildland fire has been an integral component of the five needle pine ecosystem. At high elevations, low to moderate intensity fires reduce competing vegetation and reduce fuel loadings. Small areas of high intensity fires create open areas for Clark's nutcracker seed caching activities and therefore create areas where whitebark pine can regenerate naturally. However, when subalpine fir has expanded extensively into, and provides a closed canopy fuel load below them, these stands can burn large areas of five needle pine habitat and reduce or eliminate the available seed source. The potential for natural reseeding of these stands *via* the Clark's nutcracker is subsequently reduced. Some researchers have found a 40 year lag time between fire and the re-establishment of whitebark pine on these high elevation areas.

Less is known about the wildland fire effects on the lower elevation five needle pines: Information available suggests fire return intervals ranging from 100 to 1,000 years and most fires were probably low to moderate intensity.

At high elevations wildland fire should be allowed to play a role in maintaining these high elevation five needle pine ecosystems. A combination of mechanical thinning and prescribed fire can also be used to create the patchy mixed severity fire effects in these stands, replicating natural fires. Altering the mixed conifer stands below these high elevation stands may be necessary to break up and reduce the canopy cover by creating patches of younger aged (less flammable stands), and reducing the basal area/SDI of the mature mixed conifer stands to reduce fire behavior before it burns into the high elevation stands. Because many of the Wyoming BLM high elevation whitebark and limber pine exist in small isolated stands, careful evaluation of fire potential must be done to ensure that these disjunct stands are not eliminated from the landscape.

At lower elevations, prescribed and wildland fire can be used at low to moderate intensities to reduce accumulated fuels and thin the stands. The best description of this is to "take some and leave some," so that the stand can remain on the landscape and provide for gene conservation and ecosystem services.

General Silvicultural Information for Five Needle Pine Stands: Whitebark and limber pine occur over a range of ecological gradients and vegetative associations. This enables the forester to select from a variety of silvicultural prescriptions that will meet desired goals for the management of these species. It is important to remember that both species of five needle pines are very slow growing, often requiring 50 or more years to reach maturity and produce a cone crop. Small size is a poor indicator of recent establishment.

The five needle pines generally do not show strong apical dominance. Because of this, different types of thinning around these trees can influence their growth form. Thinning on all four sides will encourage a more spread out, multi-forked tree, while thinning on two or three sides will encourage a straighter less forked tree. In mixed stands thinning on two or three sides would encourage the tree to have a straighter, taller growth form to allow it to get higher in the canopy and access more light for growth. In more open monoculture stands thinning around all four sides of either single or multi-stemmed trees would encourage a more open branching crown, increasing cone production.

The 5 needle pines, especially the whitebark pine, evolved in a mutualistic relationship with Clark's nutcracker. The whitebark pine and to a lesser extent limber pine require the Clark's nutcracker to disperse their seed. **Research has indicated that the nutcracker prefers areas with a minimum basal area of 22 ft^2, and a cone production of approximately 285 per acre. In areas with a BA of less than 22 ft^2, or a production of less than 120 cones per acre, there is a rapid decline in the frequency of the nutcracker, until at less than 53 cones per acre; Clark's nutcracker activity becomes negligible. This results in a significant decline in the probability of seed dispersal. The current scientific recommendation is that a threshold of approximately 400 cones per acre is needed for a high probability of nutcracker presence for seed dispersal.**

Important factors in any silvicultural practice are the identification of potential WPBR resistant trees and building the on-site prescription around them. Individual stands also vary in their resistance to WPBR due to local genetic material. WPBR often takes 25-35 years to kill a mature tree and but only 5 years to kill a sapling. WPBR severely reduces cone crop production, often eliminating a living tree from the reproductive pool by killing the cone producing limbs long before the tree actually dies.

When undertaking thinning operations in five needle pines that have white pine blister rust infections, take the most heavily infected trees while retaining those trees showing no sign of infection or minor infections on limbs that are away from the bole of the tree. Many trees that have a level of rust resistance will have a low level of infection on one or more limbs, but show little movement towards the bole of the tree. Removing all trees that have minor infections can take partially rust resistant trees out of the genetic pool, reducing future stand resistance.

These five needle pines are among the least resistant to the MPB, so often the best strategy may be to manage them to reduce the mortality risk. Research has indicated that whitebark pine stands need to have their basal area be below 45 ft^2 to be at least partially resistant to Mountain pine beetle. Thinning to reduce the potential for widespread MPB mortality also has the advantage of reducing the competition among the remaining trees and increasing resource availability. Field observations have documented MPB attacking 3” to 5” diameter trees.

In cases of severe MPB infestations, it may be necessary not only to remove of all infested five needle pines but also any mature uninfected overstory to reduce the MPB habitat (larger diameter trees) and reduce the numbers of MPB surviving on site. This may be the only way to protect the advanced reproduction so that the reproduction survives on site to provide for future trees and seed source. This will reduce the Basal Area (BA) and/or Stand Density Index (SDI) below the guidelines in the specific silvicultural operations described below.

Elevational Differences: Limber pine grows across the widest elevational range of any conifer in the Rocky Mountains, ranging from approximately 5,250 feet (1600 m) to almost 11,000 feet (3300 m). The 8,500 foot elevation was selected as the dividing point between high elevation/upper treeline and low elevation/lower treeline limber pine because of its usage in the only peer reviewed document that established elevational differences in limber pine as a research criteria. It is possible that stands meeting the meaning of “high elevation/upper tree line,” i.e. subalpine ridge and mountain tops can be found below 8,500 feet and expert field opinion must be used to determine which category best fits the stand. Whitebark pine generally grows above 8,000 feet in elevation, but potentially can be found at lower elevations. All guidelines for whitebark pine should be used without regard to actual elevation of the stand but rather, the associated species.

Specific Silvicultural Operations, Treatments and Prescriptions for Five Needle Pine Stands:

Stand Type: High elevation/upper treeline predominately whitebark and limber pine stands (Generally found above 8,500 ft. in the subalpine zone).

Desired Conditions/Functions: Maintain and/or restore these stands on the landscape to fill their hydrologic, wildlife and other related ecosystem services. Stand structure will be as resistant as possible to MPB infestations. Maintain WPBR resistant individuals on site and use their seed source for interplanting to maintain five needle pine stands.

Existing Conditions: These stands are severely impacted by both WPBR and MPB. They are also being encroached on by mixed conifer species, especially subalpine fir. These stands range from patchy open woodlands to a more closed canopy structure.

Silvicultural Treatments/Prescriptions:

1. Removal of subalpine fir from the stand to reduce competition for resources. If it is not possible to remove all the subalpine fir, remove the fir in a radius of 20 feet around large five needle pines (or clumps) and remove fir in a radius of at least 10 feet from seedling/sapling five needle pines. Because the five needle pines are very slow growing,

evidence of release may not be exhibited for five (5) plus years. The relative densities should range between 10 and 25 percent of the maximum SDI for newly treated stands and should not exceed 40 percent maximum SDI.

2. Thin stands to make them more resistant to MPB attacks in areas with incipient MPB infestation or threat, reduce the Basal Area of the trees to **less than 45 ft^2 but no lower than a Basal Area of 22 ft^2.** Slash must be disposed of by burning within 1 year or less or by mastication to eliminate the risk of pine beetles currently in the removed trees to survive in the slash. In areas infected with WPBR preferentially thin the trees exhibiting the greatest amount of infection. Attempt to leave different ages and sizes of trees within the stand, but, dependent on proximity to MPB, preferentially leave five needle pine trees of less than 6 inches DBH. The relative densities should range between 10 and 25 percent of the maximum SDI for newly treated stands and should not exceed 40 percent of maximum SDI.

3. Use prescribed fire and natural ignitions where feasible at low to moderate intensities to create openings in the stands for Clark's nutcracker seed caching, to reduce competition from other conifers and to reduce fuel loadings. Ensure that small disjunct stands are protected from high intensity crown fire to prevent their elimination form the landscape when feasible.

4. Identify, monitor, and collect seeds from potential "plus" trees to provide for a future seed source.

5. Use locally collected seed from "plus" trees to inter-plant these stands when WPBR reaches the break points listed above in Seedling Planting section above and there is an absence of uninfected advanced regeneration in the understory.

Stand Type: Mixed conifer stands with a five needle pine component (Generally found above 8,500 ft. and directly below the subalpine zone):

Desired Conditions/Functions: Maintain five needle pine component in the mixed conifer systems. Maintain an appropriate mix of species to maximize whitebark pine seed caching by squirrels for grizzly bear food source. Pine species (lodgepole and five needle pine) densities are low enough to minimize MPB epidemics and keep MPB at endemic levels. Maintain WPBR resistant individuals on site and use their seed source for in-planting to maintain five needle pine stands.

Existing Conditions: These stands are characterized by multiple tree species including lodgepole pine, Engelmann spruce, and subalpine fir and the five needle pines. New, unpublished research presented at the High 5 Symposium in 2010 shows a positive symbiotic relationship between the red squirrel, lodgepole pine, five needle pines, and grizzly bears in Canada and the Yellowstone area.

Silvicultural Treatments/Prescriptions:

1. When working in these stands, reduce the five needle pine Basal Area to approximately 25 ft^2 (**but no lower than 22 ft^2**) and reduce the lodgepole pine Basal Area to approximately **30**-40 ft^2. Preferentially remove the spruce and fir to accomplish other vegetative management objectives. The reduction of pine (five needle and lodgepole) Basal Area to the 55-65 ft^2 range will inhibit the spread of MPB. The relative densities should range between 15 and 25 percent of the maximum SDI for newly treated stands and should not exceed 40 percent of the maximum SDI to inhibit the spread of MPB.

2. Remove competing woody vegetation around existing five needle pines to provide for release.

3. Identify, monitor and collect seeds from potential “plus” trees to provide for a future seed source.

4. Use locally collected seed from “plus” trees to interplant these stands when WPBR reaches the break points listed above in Seedling Planting section above.

5. Most of these stands have a long fire return intervals [sic] that are a mixed severity to stand replacement types [sic]. Prescribed fire should be targeted to those areas (south facing slopes, lower elevations) where the vegetation indicates a mixed severity shorter fire return interval. North facing mesic sites with a crown replacement fire regime should only be spot treated (i.e. removal of slash accumulations/piles) and small openings created in the overstory.

Stand Type: Limber pine growing in association with ponderosa pine and/or Douglas fir, aspen, and mountain shrub (Generally found below 8,500 ft. /lower treeline.)

Desired Conditions/Functions: Maintain healthy forest conditions with an appropriate limber pine component to fulfill ecosystem services and to provide a seed source for post disturbance early seral limber pine establishment to serve as a nurse plant and to provide ecological modification of the site to allow for other species to re-establish.

Existing Conditions: In many cases the limber pine in these stands is an early seral species and will be outcompeted by the ponderosa pine and Douglas fir. Limber pine serves an important function in these landscapes as a nurse tree species and as a site modifier to enable other species to establish. MPB is the primary agent of limber pine mortality in these stands.

Silvicultural Treatments/Prescriptions:

1. Thin stands to make them more resistant to MPB attacks. Reduce Basal Area in pine dominated stands to less than 60 ft^2. Leave a scattering of limber pine in the understory to provide for a seed and genetic source. Emphasize limber pine on exposed slopes and ridges. Maintain maximum SDI of between 25 and 40 percent.

2. In Douglas fir dominated sites, keep some residual limber pine on site for a seed and genetic source after a disturbance. Maintain maximum SDI of between 25 and 40 percent (total SDI for all species).

3. In aspen stands where there is a viable limber pine stand in close proximity to the aspen stand, it is permissible to remove the limber pine from the aspen stand as part of an aspen regeneration/wildlife project. Limber pine that predates the establishment of the aspen stand should be retained for diversity.

4. Limber pine grows in association with mountain shrubs, often being a nurse tree for the mountain shrub community. When needed, thin the limber pine to a tree crown cover of approximately five percent (or a five to ten percent of the maximum SDI) to allow the tree to remain on site to provide for a seed and genetic source while opening up the stand to encourage mountain shrub production. Leave multi-age cohorts on site wherever feasible.

5. Identify, monitor and collect seeds from potential “plus” trees to provide for a future seed source.

6. Use locally collected seed from “plus” trees to inter-plant these stands when WPBR reaches the break points listed above in Seedling Planting section above.

7. Prescribed fire can be used in these stands. Primary objectives of prescribed fire will often be reduction of fuels and re-introducing fire for the benefit of other later seral woody species. Low to moderate intensity fire will assist in maintaining limber pine on site, and should not be directed at limber pine stand eradication.

Stand Type: Limber pine stands growing in riparian areas (Generally found below 8,500 ft.).

Desired Conditions/Functions: Restore or maintain a fully functioning riparian/wetland area as measured by Proper Functioning Condition (PFC, and/or other site specific resource objectives).

Existing Conditions: In some riparian/wetland areas there has been an expansion of upland vegetation including limber pine, Douglas fir, juniper, and sagebrush into these systems. This expansion is detrimental to the functions of the riparian/wetland areas as determined by the Standards for Healthy Rangeland (WY BLM). Limber pine in these areas tends to be faster growing than in upland areas and can impact, in conjunction with the other upland species, the functioning conditions of riparian/wetland areas. Impacts from MPB and WPBR vary widely in these stands, ranging from areas of very high mortality to stands that are just beginning to be impacted. Future outlook is for increasing MPB mortality and increasing WPBR infection/mortality as well as continued expansion into the riparian/wetland areas.

Silvicultural Treatments/Prescriptions:

1. Limber pine does play a significant role in the hydrology of the watershed. It should be left on the landscape in the upland areas away from the riparian zone. Management of these upland stands should follow the silvicultural treatments and prescriptions in the stand type "Lower treeline limber pine stands either in association with juniper species or a monoculture" described below.

2. In areas where PFC or other monitoring studies, assessments, or evaluations indicate: 1 - an excess of upland vegetation exists in the riparian/wetland area, and 2 - conifer expansion is identified as one of the casual [sic] factors affecting the functionality of the system, it is permissible to remove limber pine. The removal of some limber pine and other upland vegetation within the riparian/wetland system will assist in meeting or making progress towards meeting the Standards for Healthy Rangelands (BLM, Wyoming), and/or other site specific objectives. Because the ecology of limber pine is not fully understood, a "leave some take some" approach should be implemented in the riparian/wetland zones as in upland areas.

Stand Type: Lower treeline limber pine stands either in association with juniper species or a monoculture (Generally found below 8,500 ft. in ecotones).

Desired Conditions/Functions: Preserve and maintain these stands on the landscape as woodlands and savannas, with density levels commensurate with reduced risk of widespread MPB mortality. Allow these stands the flexibility to move on the landscape in response to changing climatic and other environmental conditions.

Existing conditions: There has been a lack of research on these stands, and very little is known about the ecosystem services provided. These often occur on steeper, rocky, exposed slopes and have shown movement downslope in the past 100-200 years. MPB is found in these stands at increasing levels of infestation and mortality. WPBR infections and MPB infestations vary widely in these stands, ranging from areas of very high mortality from one or both WPBR and MPB to stands that are just beginning to be impacted. Future outlook is for increasing MPB mortality and increasing WPBR infection/mortality.

Silvicultural Treatments/Prescriptions:

1. Thin stands to make them more resistant to MPB attacks. Stands should be thinned to a Basal Area of 40-45 ft^2 where they form a fairly continuous canopy cover. Preferentially remove juniper species (Utah and Rocky Mountain) to allow for release and to open up the understory for grass and forb establishment and growth. Maintain Maximum SDI of between 25 and 40 percent.

2. On deeper soils at the bottom of slopes and drainages, when needed, thin the limber pine to a tree crown cover of approximately five percent (or a five to ten percent of the maximum SDI) to allow the tree to remain on site as an open woodland and to provide for a seed and genetic source. If maintenance of a higher density woodland is desired, maintain Maximum SDI of between 25 and 40 percent. Leave multi-age cohorts on site wherever feasible.

3. Use the Range Management Application described above to assist in creating an open woodland stand of limber pine.

4. Identify, monitor and collect seeds from potential "plus" trees to provide for a future seed source.

5. Use locally collected seed from "plus" trees to inter-plant these stands when WPBR reaches the break points listed above in Seedling Planting section above.

6. Use low to moderate intensity prescribed and natural fire to assist in thinning of the stands. The best description of this is to "take some and leave some," so that the stand can remain on the landscape and provide for gene conservation and ecosystem services.

Stand Type: Lower treeline limber pine stands growing in sagebrush areas such as former sagebrush meadows and otherwise suitable sage-grouse habitat (Found below 8,500 ft. in ecotones).

Desired Conditions/Functions: Restore open sagebrush flats and meadows for suitable sage-grouse habitats and to protect important habitats from extreme fire behavior.

Existing Conditions: In some transitional sagebrush areas there has been observed expansion, and in some cases invasion, of coniferous vegetation including limber pine and juniper into habitats managed for Sage-grouse. This noted expansion is detrimental to the overall functionality of important Sage-grouse habitats as measured by the Habitat Assessment Framework and associated Standards for Healthy Rangeland (WY BLM). The expansion of Limber pine and other coniferous species in these areas may increase risk for high severity wildland fire and threaten reduction of important Sage-grouse habitat functionality.

Silvicultural Treatments/Prescriptions:

1. Conifer removal efforts must consider and observe the concurrent goals and objectives of the sensitive species of limber pine management and maintain adjacent limber pine sites for local seed source. Projects would be conducted following the silvicultural treatment prescriptions in the stand type "Lower treeline limber pine stands (below 8,500 ft.) either in association with juniper species or a monoculture" described above.

2. In areas where long-term sagebrush steppe and sage-grouse habitat management objectives would require removal of encroaching conifer species, including limber pine, it is permissible to remove conifers from important sagebrush steppe habitats in an effort to support maintain and improve conservation of habitat for Sage-grouse and other sagebrush obligate species.

Stand Type: Limber pine stands growing in surface disturbance areas such as rock/gravel quarries and other mining activity (Generally found below 8,500 ft., but can occur at other elevations dependent on mineral locations).

Desired Conditions/Functions: Reclamation of disturbed limber pine sites including the planting of limber pine seedlings using local seed source and other mitigation methods determined to be acceptable.

Existing Conditions: The development of surface disturbing activities can eliminate all or portions of limber pine stands. These activities may occur in any of the limber pine types, but will be concentrated in the "Limber pine growing in association with ponderosa pine and/or Douglas fir, aspen, and mountain shrub" and the "Lower treeline limber pine stands either in association with juniper species or a monoculture" types. MPB and WPBR vary widely in these stands, ranging from areas of very high mortality from one or both WPBR and MPB to stands that are just beginning to be impacted. Future outlook is for increasing MPB mortality and increasing WPBR infection/mortality.

Silvicultural Treatments/Prescriptions:

1. Limber pine within the project boundaries that are not in the disturbed area will be managed as per the appropriate sivlicultural [sic] treatments/prescriptions listed above as partial mitigation of the disturbance.

2. Disturbed areas will be planted with local seed source seedlings from project area or adjacent stands as per the seedling planting guidelines.

3. If an entire stand is within the disturbance area, off-site mitigation in the form of appropriate silvicultural treatments of adjacent stands, collection of seed, identification of "plus" trees or other acceptable mitigations will be done to offset the loss of a stand in addition to replanting limber pine on the reclaimed area.

Photo provided by the National Park Service, U.S.D.I., Public Domain

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Notes