White Pine Blister Rust in the Interior Mountain West

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Introduction

White pine blister rust is an exotic, invasive disease of white, stone, and foxtail pines (also referred to as white pines or five-needle pines) in the genus *Pinus* and subgenus *Strobus* (Price and others 1998). *Cronartium ribicola*, the fungus that causes WPBR, requires an alternate host - currants and gooseberries in the genus *Ribe*s and species of *Pedicularis* and *Castilleja* (McDonald and others 2006, Zambino and others 2007) - to complete its life cycle. White pine blister rust was discovered in western North America in 1921. It is thought that the disease was accidentally introduced on infected eastern white pine (*Pinus strobus*) nursery stock shipped to Vancouver, BC from Europe in the early 1900s but the specific details are unclear. Since then, the disease has spread throughout the distributions of most western white pines. Although all of the North American white pine species are susceptible to white pine blister rust (Bingham 1972, Hoff and others 1980), it was once thought that the remote, dry habitats occupied by the noncommercial, high elevation white pines would not support rust establishment. Unfortunately, white pine blister rust can now be found in many of these areas.

Over the past decade, members of the Central Rockies White Pine Health Working Group have collaborated to monitor the spread and establishment of white pine blister rust in the high elevation white pines of the Interior Mountain West - the broad region that encompasses USDA Forest ServiceIntermountain (Utah, Nevada, and southern Idaho), Southwestern (Arizona and New Mexico), and Rocky Mountain Regions (Colorado, Wyoming, South Dakota, and Nebraska), and the eastern portion of the Northern Region (central Montana and North Dakota) (see Fig. 2). The infection front lies within this region and a large portion of its susceptible white pine population has not been challenged by the disease. This publication provides some background on the high elevation hosts and synthesizes current information onthe distribution and impacts of white pine blister rust in these more recently infested areas. A summary of current and ongoing efforts for managing the disease is also provided.

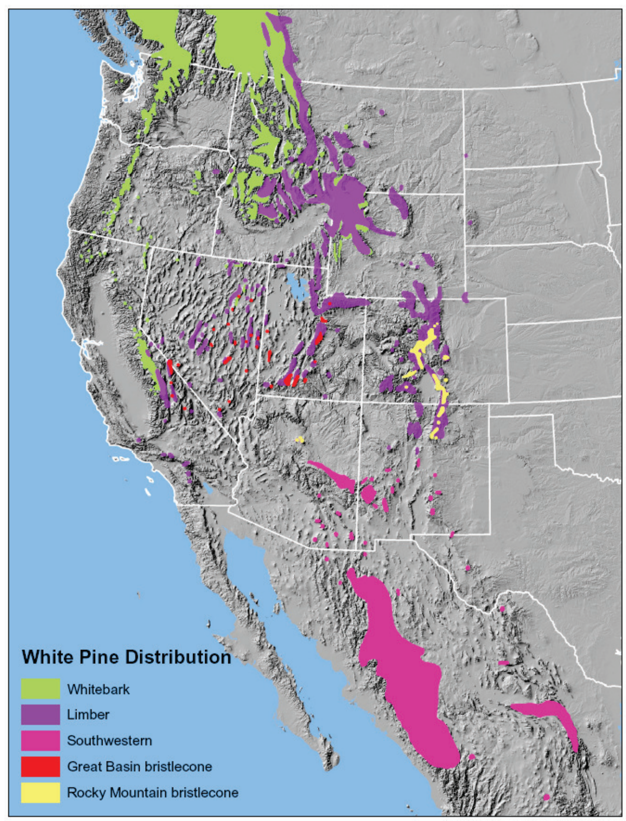

Figure 1. Distribution of high elevation white pine species that grow in the Interior Mountain West.

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Hosts

White pines are well distributed within the forested areas of the Interior Mountain West (Fig. 1). Pine hosts in this region include whitebark pine (*Pinus albicaulis*), limber pine (*P. flexilis*), Rocky Mountain bristlecone pine (*P. aristata*), Great Basin bristlecone pine (*P. longaeva*), and southwestern white pine (*P. strobiformis*). These species grow at high elevations and are especially important because of their unique ecological and cultural characteristics. They provide cover and regulate snow and runoff on steep, rocky sites where little else can grow; their seeds are an important food source for corvid bird species, small rodents, grizzly bears, and other animals; and they are some of our oldest and largest pines.

Whitebark pine is widely distributed in two broad sections within western North America – from the Coast Range of British Columbia into the Cascade and Sierra Nevada Mountains and from the Canadian Rockies to the Middle Rocky Mountains of Wyoming. Scattered outlying populations occur within and around these sections. The species is a major component of high elevation, timberline forests of Idaho, Montana, and western Wyoming. The seeds of whitebark pine are large and wingless and enclosed in a cone that does not open upon ripening. Clark's nutcrackers extract the seeds and serve as the primary dispersal mechanism. A number of scatter-hoarding birds and small mammals contribute slightly to seed dispersal. Many species of wildlife, such as red squirrels and grizzly bear, rely on whitebark pine seeds as an important part of their diet. Blister rust-infected whitebark pines were first observed in the Coast Range of British Columbia in 1926 and in the Northern Rocky Mountains n 1938 (Childs and others 1938). Mortality caused by the disease is greatest in whitebark pine stands of the Northern Rockies where infection levels are variable but frequently greater than 70 percent (Kendall and Keane 2001, Schwandt 2006). The incidence in the more recently infected Greater Yellowstone Ecosystem is estimated to be 25 percent (Greater Yellowstone Whitebark Pine Monitoring Working Group 2006).

Limber pine is widely distributed in the west from Alberta and southeastern British Colombia to New Mexico, and southeastern California with isolated populations in North Dakota, South Dakota, Nebraska, eastern Oregon, central Arizona, and southwestern California (Burns and Honkala 1990). Limber pine has a very wide elevational distribution as well, ranging from 2,850 feet in North Dakota to 12,500 feet in Colorado (Burns and Honkala 1990). In the Northern Rocky Mountains, limber pine generally occurs at lower elevations. In the Southern Rocky Mountains, limber pine has a very wide elevational range, from the grassland-forest ecotone at 5,250 ft to the subalpine-alpine ecotone at 11,482 feet and everywhere in between (Schoettle and Rochelle 2000). Limber pine seeds are wingless (or nearly wingless) and rely on the Clark's nutcracker for dispersal. In contrast to whitebark pine, limber pine cones open upon seed maturity. Its seeds also provide food for squirrels and may therefore affect prey populations of the Canada lynx. Limber pine tends to be one of the first species established after fire on dry sites and can facilitate the establishment of other species that eventually replace it on the more mesic sites. This species can tolerate very harsh, exposed sites and can reach ages over 1,000 years. Infected limber pines were first observed in central Montana in 1944 (Riley 1944), southern Idaho in the 1940s (Krebill 1964), and central Wyoming in 1959 (USDA Forest Service 1959, Brown 1967).

Southwestern white pine is distributed in the mountains of western Texas, New Mexico, Arizona, and southwestern Colorado, but most of its distribution is in Mexico. Limber pine and southwestern white pine hybridize where their distributions overlap, so distribution and range information is somewhat unclear. The species generally occurs as a minor component of mixed-conifer and spruce-fir stands, and higher elevation ponderosa pine stands, but may become dominant on high elevation, cool sites. In New Mexico and Arizona there are more than 30 geographically isolated populations. Like limber and whitebark pine, southwestern white pine seeds are essentially wingless, but the seed dispersal mechanisms are not fully understood. White pine blister rust was discovered on southwestern white pine for the first time in 1990 in southern New Mexico (Hawksworth 1990). Since then, the disease has been observed in the northern and western parts of the state (Conklin and others 2009) and more recently in Arizona (M.L. Fairweather personal communication). The disease has not been reported on southwestern white pine in Colorado, Texas, or Mexico to date.

Great Basin bristlecone pine occurs in eastern California, Nevada, and Utah. It grows high in the mountains from 6,760 feet in Nevada up to 12,000 feet in California. The species has a remarkable ability for surviving under adverse conditions and is slow-growing and very long-lived. For example, one tree in Great Basin National Park in eastern Nevada is estimated to be 4,950 years old – the oldest living single organism in the world. Even though the distribution of Great Basin bristlecone pine overlaps with other susceptible white pine species no infected trees have been observed to date. It is the only five-needle pine species in the United States that remains uninfected.

Rocky Mountain (RM) bristlecone pine's distribution is almost entirely within the state of Colorado with a small portion extending into northern New Mexico, and an outlying population in central Arizona. This species was distinguished from Great Basin bristlecone pine in 1970 (Bailey 1970). RM bristlecone grows from 9,000 to 12,040 feet in elevation and can be very long-lived, reaching life spans of over 2,600 years old. It is primarily a subalpine species but it can also grow in and amongst ponderosa pine (*P. ponderosa*) and piñon pine (*P. edulis*). Like limber pine, it forms long-lived stands on dry exposed slopes and ridges and regenerates after fire though colonization is slow (Coop and Schoettle 2009). This species has winged seeds that are wind-dispersed but are also dispersed by nutcrackers and other corvids. White pine blister rust was first observed on Rocky Mountain bristlecone pine in 2003 near Mosca Pass in the Great Sand Dunes National Park and Preserve, Alamosa County, Colorado (Blodgett and Sullivan 2004, Burns 2006).

Impacts of White Pine Blister Rust in the Interior Mountain West

White pine blister rust impacts all phases of the regeneration cycle. The disease affects trees of all ages and sizes and could potentially eliminate white pines from certain ecosystems and landscapes. Young trees are especially susceptible and cone potential is greatly impacted on infected large trees when most or all of the cone-bearing branches are killed. Although the impacts of the disease are similar in the high elevation and low elevation white pine species, there are some important differences. The white pine species of the Interior Mountain West grow high in the mountains with broad valleys separating populations - this limits gene flow and changes the dynamics of disease spread.

It appears likely that aeciospores can disperse very long distances in upper level air currents to eventually infect pines (Frank and others 2008). Opportunities for such long distance spread are rare since climatic conditions must be favorable at both the source location and the target location at the appropriate time (Frank and others 2008).

Conditions suitable for intensification are also infrequent, but thought to be associated with large-scale weather systems that create conditions favorable for infection throughout the crown, as opposed to the diurnal events that occur near the ground in the low elevation species (Jacobi and others 2002). Because of this, it is not unusual for severe decline to result without a stem infection when numerous branch infections occur throughout the crown. Additionally, susceptible *Ribes* species and white pines occur together throughout the Interior Mountain West so there is no reason to assume the remaining ecosystems will escape infection.

A mountain pine beetle epidemic is occurring throughout the west and unfortunately mature white pines are particularly suitable hosts. The combined effects of mountain pine beetle and white pine blister rust have caused extensive mortality in whitebark pine in the Northern and Intermountain Regions. In the Rocky Mountain Region, mountain pine beetles are devastating some limber pine and Rocky Mountain bristlecone pine stands. Mountain pine beetles threaten ancient trees and sites with confirmed resistance to blister rust. Bark beetles kill mature cone-bearing trees reducing regeneration potential. Forest recovery is further impaired by white pine blister rust, which rapidly kills small trees.

Current Distribution of White Pine Blister Rust

The distribution of white pine blister rust was summarized for the Interior Mountain West in 2003 (Geils and others 2003) but since has expanded to several new locations. A map of the current known distribution of white pine blister rust is displayed in Figure 2. The most notable new outbreak areas are in southern Idaho, eastern Arizona, western and northern New Mexico, and Colorado. New information on the distribution of the disease is reported below by sub-regions.

Colorado and Wyoming: In Wyoming, white pine blister rust was first discovered in Yellowstone National Park on *Ribes* in 1944 (USDA Forest Service 1950) and then on whitebark pine in 1950 (USDA Forest Service 1951). The disease front has slowly progressed east and south since then. Infected pines were reported on the Shoshone National Forest in 1966 (Brown 1967), the Bighorn National Forest in 1959 (USDA Forest Service 1959, Brown 1967), and Laramie Peak, Medicine Bow National Forest, in 1969 (Brown 1978). An examination of limber pine on Pole Mountain in the early 1980s revealed very light infection levels (B.W. Geils, unpublished data). The most comprehensive survey of central and south-central Wyoming was recently completed (Kearns and Jacobi 2007) and the disease was reported in the Medicine Bow and Sierra Madre (Kearns and Burns 2005) Mountains of southern Wyoming for the first time. Incidence of WPBR is greatest in northern Wyoming and in areas where the disease has been present for decades. The incidence of WPBR is currently low in the Medicine Bow and Sierra Madre Mountains.

White pine blister rust was discovered on limber pine on the Roosevelt National Forest in northern Colorado just below the Wyoming border in 1998 (Johnson and Jacobi 2000). These new infections were likely the result of southward spread from Wyoming (Brown 1978). Other parts of Colorado had not been surveyed extensively until 2002 when field crews discovered infected trees on the San Isabel National Forest in the Sangre de Cristo and Wet Mountains of southern Colorado. Infections in southern Colorado were found primarily on limber pine, but infected Rocky Mountain bristlecone pines were also observed for the first time in their native range in the Great Sand Dunes National Park and Preserve (Blodgett and Sullivan 2004). The incidence in southern Colorado is generally low but isolated infection centers have been discovered in other parts of Colorado since then. The disease was discovered 4.5 miles southeast of Estes Park in 2005 (R. Beam and J. Klutsch, unpublished data); 4 miles north of Nederland in 2006 (J.T. Hoffman, unpublished data); and on Pikes Peak in 2009 (K.S. Burns, unpublished data).

Southwestern Mountains (Arizona and New Mexico): White pine blister rust was discovered on southwestern white pine in the Sacramento Mountains of southern New Mexico on the Lincoln National Forest in 1990 (Hawksworth 1990). Subsequent surveys identified the disease in several other locations farther north in New Mexico, including the White Mountains in 1991, Capitan Mountains in 1994, and Gallinas Peak in 1999 (Conklin 2004, Geils and others 1999). More recently, blister rust was discovered in western New Mexico on the Gila National Forest in 2005 and in northern New Mexico in the Jemez Mountains in 2006 and Zuni Mountains in 2007 (Conklin and others 2009).

In the past it has been assumed that conditions in much of Arizona were unfavorable for rust establishment but infected southwestern white pines were observed on the Fort Apache Indian Reservation and the Apache-Sitgreaves National Forest in 2009 (M.L. Fairweather, personnel communication). More in-depth surveys will be needed to determine how extensive the outbreak is in Arizona.

<u>Great Basin and surrounding areas (Nevada, Utah, southern Idaho)</u>: Although some populations remain uninfected, white pine blister rust has been present on National Forests in Idaho since the 1960s (Brown and Graham 1969, Krebill 1964). A small population of limber pine in Craters of the Moon National Monument and Preserve in southern Idaho was discovered to be infected in 2006. Infected limber pines were identified at Emigration Pass in Bear Lake County, southeastern Idaho in 2002 (B. Geils, unpublished data). In Nevada, blister rust was discovered in whitebark pine and western white pine (*P. monticola*) in the western part of the state in 1997 (Smith and others 2000) and was confirmed in whitebark pine in northeastern Nevada in 2002 (Vogler and Charlet 2004). Blister rust has not been reported in Great Basin bristlecone pine or limber pine in Nevada or Utah. Infected *Ribes inerme* leaves were observed in Carbon County, Utah, in 2005 (B.W. Geils and D.R. Vogler, unpublished data), but the disease has never been reported on pine hosts in that state.

<u>Great Plains and surrounding areas (North Dakota, South Dakota, Nebraska, and Central Montana)</u>: Blister rust infection was reported on limber pines on the eastern slope of the Rocky Mountains in Montana for the first time in 1944 (Riley 1944). Very little information is available on the status of white pines in central Montana but a survey conducted in 2007 found an average incidence of 50 percent in 16 limber pine plots (Burns and others, in review). White pine blister rust was discovered on a single planted limber pine in an urban area in central North Dakota in 1992 (Draper and Walla 1993). The disease was not detected in subsequent white pine surveys of native white pine stands in 1992 and 2007 (Burns and others, in review). White pine blister rust was detected in a small outlying limber pine population in the Black Hills National Forest of South Dakota (Lundquist and others 1992) in 1992. The disease has not been reported in the any of the small outlying limber pine populations located where the Nebraska, Wyoming, and Colorado borders meet.

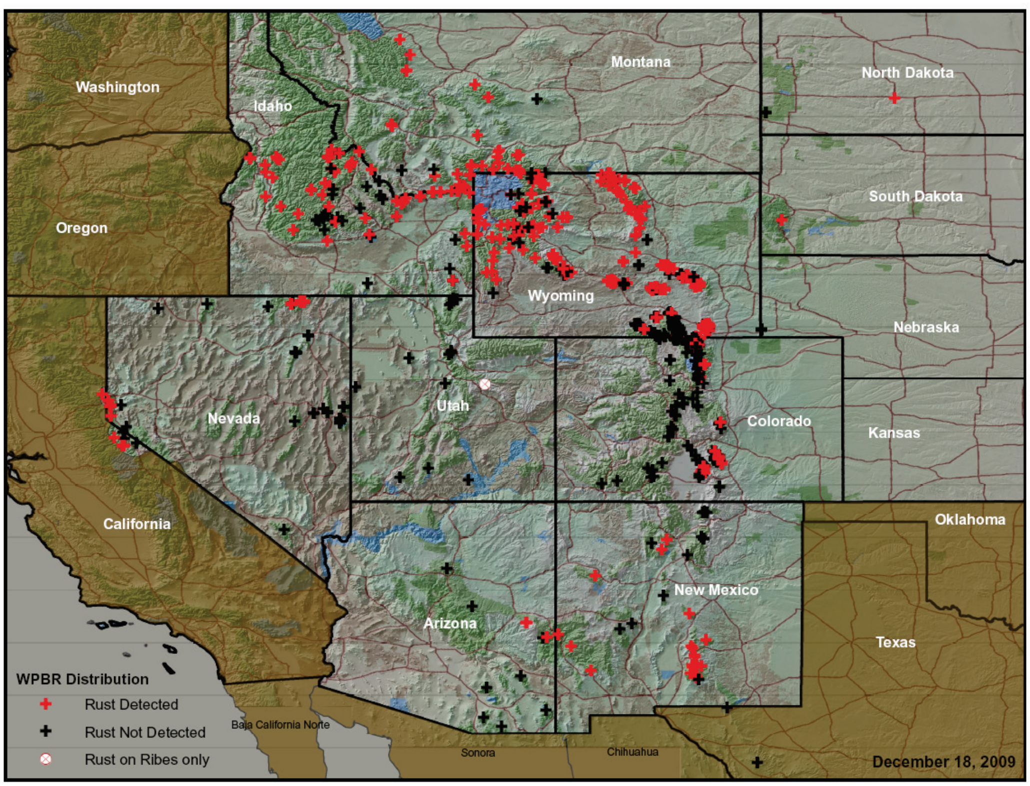

Figure 2. Distribution of white pine blister rust in the Interior Mountain West.

Current and Ongoing Efforts for Managing the Disease

Despite efforts to control white pine blister rust, the disease continues to spread and intensify. Control strategies have been developed for the commercial species but these strategies have not been tested on the high elevation species and they may not be applicable in the Interior Mountain West. We are taking a proactive approach where possible (Schoettle and Sniezko 2007) and are involved in a variety of projects aimed at improving our ability to manage the disease in the high elevation species of the Interior Mountain West. Examples of current projects are summarized in the following section.

Resistance Screening: Efforts to locate putatively resistant trees (and random trees in uninfected areas) and screen progeny for blister rust resistance are underway for limber pine, Rocky Mountain bristlecone pine, southwestern white pine, and whitebark pine (Kinloch and Dupper 2002, Mahalovich and others 2006, Schoettle and Sneizko 2007, Schoettle and others 2009, Sneizko and others 2007, Vogler and others 2006). Examples of specific disease resistance projects include tests for complete resistance in limber pine families and populations (Schoettle, Sniezko, Burns, Connor) and southwestern white pine (Vogler, Sniezko and Conklin) as well as tests for partial resistance in limber pine and RM bristlecone pine families (Schoettle, Sniezko, Pineda-Bovin, and Burns).

Southern Rockies White Pine Conservation Project: The mountain pine beetle epidemic threatens ancient trees and trees with confirmed rust resistance. Rocky Mountain Research Station, Rocky Mountain Region (R2) and Northern Region (R1) Forest Health Management, several R2 National Forests, Colorado State University, Rocky Mountain National Park, Great Sand Dunes National Park and Preserve, and Dorena Genetic Resource Center have teamed up in a race against the beetles (Schoettle and others 2008). Limber and Rocky Mountain bristlecone pine populations are being protected from mountain pine beetles (using insecticides or verbenone) and seed collections, began in 2003, are ongoing for conservation, restoration, rust resistance screening, and other research applications.

Long-term Monitoring: Long-term monitoring plots have been established throughout the Interior Mountain West to evaluate the impacts of white pine blister rust over time (Burns and others 2009, in press; Conklin 2004).

Meteorology Studies: Researchers are evaluating micro-scale meteorological conditions in pine ecosystems in Colorado and Wyoming and whether they can predict the impact of white pine blister rust (Goodrich, Jacobi, Kearns, and Geils). Longterm meteorological measurements are also ongoing to support studies of climate change and to compliment other genetic and ecological studies (Schoettle).

Planting and Regeneration Studies: The objective of this study is to develop and refine guidelines for planting limber pine seedlings and to survey regeneration to determine current stand characteristics and natural regeneration rates (Casper, Jacobi, Schoettle, and Burns).

Pruning Trials: The feasibility of pruning cankers, excising cankers, and/or lifting crowns for protecting and prolonging the life of high-value trees is being evaluated in limber and Rocky Mountain bristlecone pine in two recreation areas – the Great Sand Dunes National Park and Preserve, southern Colorado and Vedauwoo Campground, and southeastern Wyoming (Crump, Jacobi, Burns, Howell).

Verbenone Trials: The efficacy of using verbenone to protect limber pine from mountain pine beetle is being tested in Colorado. Preliminary results indicate that trees treated with verbenone are less likely to be attacked but success varies by site and a large portion of trees are still attacked so the treatment will probably not be effective over the course of an outbreak (Costello, unpublished data).

Management Guides: New publications are available that summarize options for the management of white pine blister rust for the Southwestern Region (Conklin and others 2009) and the Rocky Mountain Region (Burns and others 2008).

High Elevation White Pine Website: An educational website was created to provide a clearinghouse of information on the high elevation white pines (Schoettle and Laskowski 2006).

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