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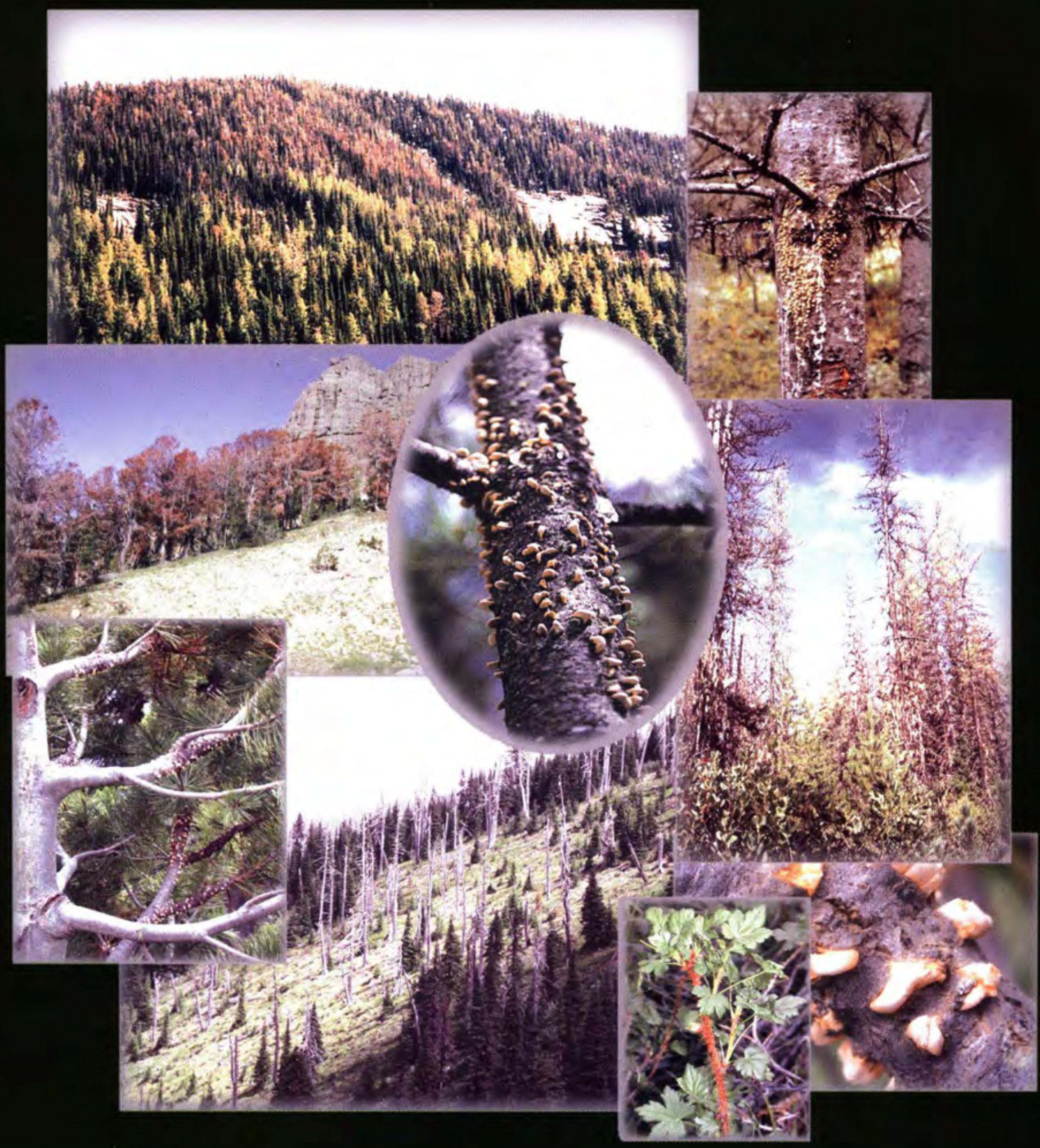
Managing for Healthy White Pine Ecosystems in the United States to Reduce the Impacts of White Pine Blister Rust



"A century since its introduction to North America from Europe, white pine blister rust has come to be recognized as one of the most catastrophic plant disease epidemics in history. It has yet to stabilize, continuing to spread and intensify. The damage done to its hosts and ecosystems is approaching that of the infamous chestnut blight. The nine native white pine hosts comprise major timber producers, important watershed protectors, keystone ecological species, and the oldest trees on earth. All are highly susceptible and some have been damaged severely in parts of their native range, as well as where they have been planted as exotics." From Bro Kinloch ICPP98 paper No 4.4.5S

In 1776, one of the American colonists' grievances was that the King reserved the best trees in American forests as masts for his navy. These desirable trees were eastern white pines. Almost a century later, it was the mature forests of eastern white pine in the great north woods of the Lake States that inspired the mythical Paul Bunyan stories. As settlers moved west, development was fueled by millions of acres of western white pines in the Inland West. John Muir wrote reverently of the largest pine with the longest cones in the world, the sugar pine of the Cascade and Sierra Nevada Mountains. Before Yellowstone's grizzly bears go into hibernation, they gorge on the unusually large, nutritious seeds of whitebark pine. On the upper slopes of the White Mountains of the Great Basin grow the oldest trees in the world, bristlecone pine. What ties all these forest ecosystems together? It is the 9 species of 5-needle "white pines," which are critical to the health of these and many more ecosystems. This report describes the urgent need to protect, sustain and restore these species from a non-native invasive pathogen: white pine blister rust.

Photos on cover (clockwise beginning at top): Landscape view of whitebark pine mortality; typical rust canker on trunk of sugar pine; western white pine mortality; close-up of rust blisters; alternate host (Ribes) plant; forest converting to firs after whitebark pine mortality; sapling with multiple branch infections; recent whitebark pine mortality; (center photo) rust canker on southwestern white pine sapling.

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Managing for Healthy White Pine Ecosystems in the United States to Reduce the Impacts of White Pine Blister Rust

Executive Summary

In this report we outline the urgent need for vision, focus, and leadership to manage a non-native invasive disease that threatens the stability and survival of white pine ecosystems in 40 of our 50 states. All nine of our native white pine species are at risk and include some of the oldest, most majestic, and ecologically or culturally significant pine species in the United States. White pines play critical roles in forest development and integrity. Without white pines these forest communities would be altered dramatically. Historically, white pines thrived because of their ability to regenerate in openings created by fire, outgrow their competitors, and resist many native insects and pathogens. All species of white pine are susceptible at all ages to a non-native fungus which causes white pine blister rust.

Figure 1. Western white pine mortality.

White pine blister rust is caused by a non-native invasive pathogen, *Cronartium ribicola* that was introduced to North America from Europe almost a century ago. Despite significant efforts to contain it, this fungus has continued to spread (Fig. 1) and may be poised to invade the last uninfected white pine ecosystems, including the ancient bristlecone pine forests of the Southwest.

Much has been accomplished since the discovery of this disease, from understanding the basic biology of the pathogen and its hosts and identifying natural disease resistance in sugar pine, western white pine and eastern white pine to developing improved planting stock and initiating breeding programs with other species. We now realize that blister rust is a permanent resident of North America. Therefore, our efforts have shifted towards facilitating the survival of white pine species in the presence of the disease and minimizing its ecological, economic and aesthetic impacts.

This plan is designed to establish direction to <u>restore</u> white pines where they have been catastrophically decimated, to <u>sustain</u> white pines where the rust is present but not yet devastating, and to <u>plan</u> mitigating actions when the rust spreads into areas where it is not yet present. Unless we take a bold and scientifically sound approach, we risk losing a significant component of our native forests, and with it, considerable irreplaceable biodiversity, as well as genetic and cultural resources. This effort will require the application of existing management tools and continued research and development using integrated genetics, pathological, silvicultural, disease management and ecosystem restoration strategies over several decades.

The USDA Forest Service, with its expertise in forest health protection, forest management, and ecosystem and disease research, is uniquely positioned to implement this plan, a blueprint to ensure white pine survival through management, restoration, research, and public involvement.

Integrated Strategy to Protect, Sustain, and Restore White Pines. The survival of white pines and their ecosystems in North America depends upon a combination of traditional and innovative scientific and management strategies:

- **Genetic Strategies.** The best solution known to save white pines from white pine blister rust is to enhance numbers of rust resistant white pines (Fig. 2) in appropriate ecosystems. It is critical to protect existing white pines that have survived the effects of this disease and foster their regeneration in order to broaden the base of genetic resistance. The identification of resistant trees in species such as whitebark pine and bristlecone pine is also necessary where we do not yet have well developed breeding programs in place.

Figure 2. Rust resistance testing.

- **Silvicultural Strategies.** Enhance planting of rust resistant white pine seedlings in openings created by natural disturbances and silvicultural methods. Creating openings near surviving white pines will enhance planting and regeneration opportunities. Tools such as prescribed burning, pruning, thinning, alternate host control (demonstrated to be effective in the Northeast), and hazard rating projects will be used to improve survival of planted pines (Fig. 3).

Figure 3. Pruned western white pine plantation.

- **Research and Information Needs.** Even though much of the basic biology of the pathogen and its hosts is known, vital research is still needed to understand the intricate mechanisms and inheritance of host resistance in order to incorporate them effectively into breeding programs. Long-term performance of seedlings with improved resistance, as well as the epidemiology of the disease affecting these seedlings, will be monitored. The role of different species of *Ribes* (Fig. 4) in maintaining and spreading disease also needs further study.

Figure 4. Uninfected Ribes.

- **Public Outreach and Partnerships.** Federal, State, Tribal, and non-governmental organizations, and the public will work together to protect, restore, and sustain these ecosystems.

The Resource: White Pines and Their Ecosystems

Nine species of white pines are native to U.S. forests: eastern white pine (Fig. 5), western white pine, sugar pine, whitebark pine, limber pine, southwestern white pine, Rocky Mountain bristlecone pine, Great Basin bristlecone pine, and foxtail pine. White pines occur naturally in 40 of our 50 states, from seashore to timberline and from isolated desert mountain ranges to extensive inland forests. These pines include some of the oldest, most majestic, and most culturally significant trees in the United States. An ancient bristlecone pine in eastern California is believed to be the oldest living thing on Earth at over 4,700 years of age.

Figure 5. Eastern white pine.

The great size and superior wood quality of mature eastern white, western white, and sugar pines made them the chief prize of lumbermen as they worked westward across the continent.

White pines play an important role in maintaining watershed health and wildlife habitat as well as providing commercial products and desirable recreational experiences. White pine ecosystems contain white pines as a significant or dominant part of their coniferous tree cover and play critical roles in forest development and integrity. Examples of white pine ecosystems range from mixed-conifer ecosystems where white pines are a minor to moderate component, to white pine-dominated ecosystems where they are the major tree species, to harsh high-elevation sites where white pines are the only conifers that can survive.

Historically, white pines thrived in many forests because of their ability to regenerate in openings created by fire, outgrow their competitors, and resist many native insects and pathogens. Today, white pine ecosystems are being transformed and impoverished by the combined effects of white pine blister rust and lack of openings for regeneration (Fig. 6). Without fire or other openings, white pines fare poorly and are replaced by other species that can regenerate beneath the pine canopy. In many cases in western forests, a few conifer species, such as grand fir and Douglas-fir, will become dominant resulting in forests that are less diverse, densely overstocked, especially fire-prone, and more susceptible to insects and disease. Eastern white pine is also favored by fire and other openings, although it is more shade tolerant. However, with limitations on active management, Lake States pine forests convert into disease prone, unthrifty hardwood stands.

Figure 6. This whitebark pine ecosystem has been impacted extensively by blister rust and bark beetles.

The Disease: White Pine Blister Rust and Its Impacts

White pine blister rust, a fungus native to Asia, was introduced to the eastern and western coasts of North America around the turn of the 20th century on infected white pine nursery stock grown in Europe. In spite of a complicated life cycle requiring the presence of gooseberries or currants (*Ribes* species) as well as pines, the pathogen has spread into 38 states (Fig. 7), causing substantial damage and mortality in seven of the nine native white pine species. Infected trees may lose much of their canopy, where cones are produced, years before death occurs. Two white pine species, the long-lived Rocky Mountain and Great Basin bristlecone pines, remain untouched by this disease, but for how long?

Ecological Impacts

The effects of blister rust go far beyond the loss of individual trees. There is a cascading effect on associated plant and animal communities throughout affected ecosystems. Natural regeneration and intermediate age classes have been rapidly killed by blister rust resulting in dramatic changes to normal successional pathways. In some cases, the impact of blister rust combined with lack of regeneration opportunities threatens to eliminate the white pines as functioning components of forest ecosystems. This outcome has significant negative impacts for watershed health, wildlife habitat, and the ability of these ecosystems to respond to changes brought on by fire, insects, pathogens and other agents of change. For example, western white pine was once the dominant species on five million acres in the Inland Northwest.

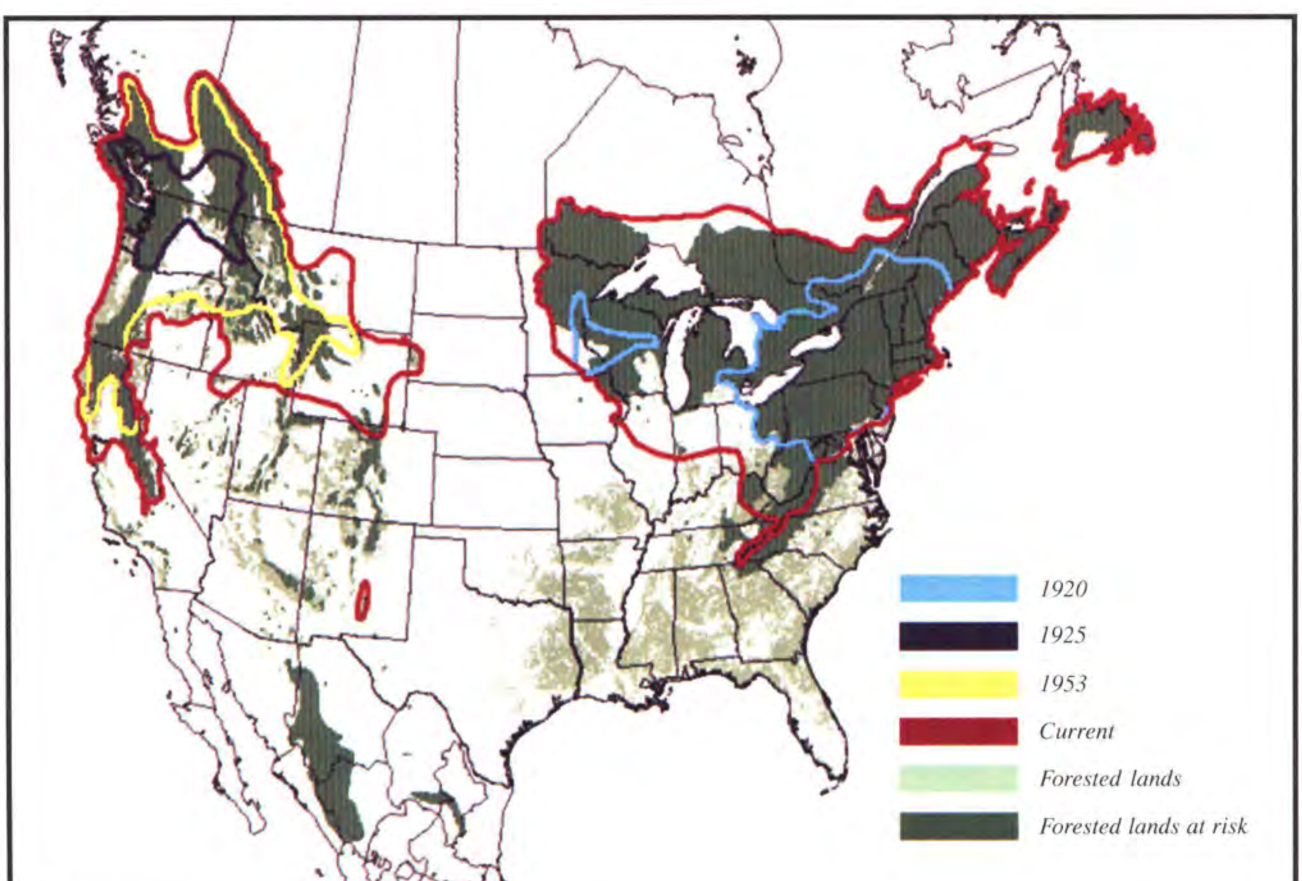

Figure 7. History of white pine blister rust spread.

Today, less than ten percent of that area has a significant western white pine component. Where western white pine have been killed by blister rust or removed to "pre-empt" blister rust losses, the forest becomes dominated primarily by Douglas-fir, grand fir, western red cedar and hemlock (Fig. 8), species which are more susceptible to root diseases, bark beetles, windthrow and drought. The increased mortality caused by these agents, along with changes in species and stand structures and subsequent fuels buildup, has led to a pattern of increased risk of catastrophic fire. Loss of white pine also means less old growth trees, and less large wood for fish, wildlife habitat and nutrient cycling.

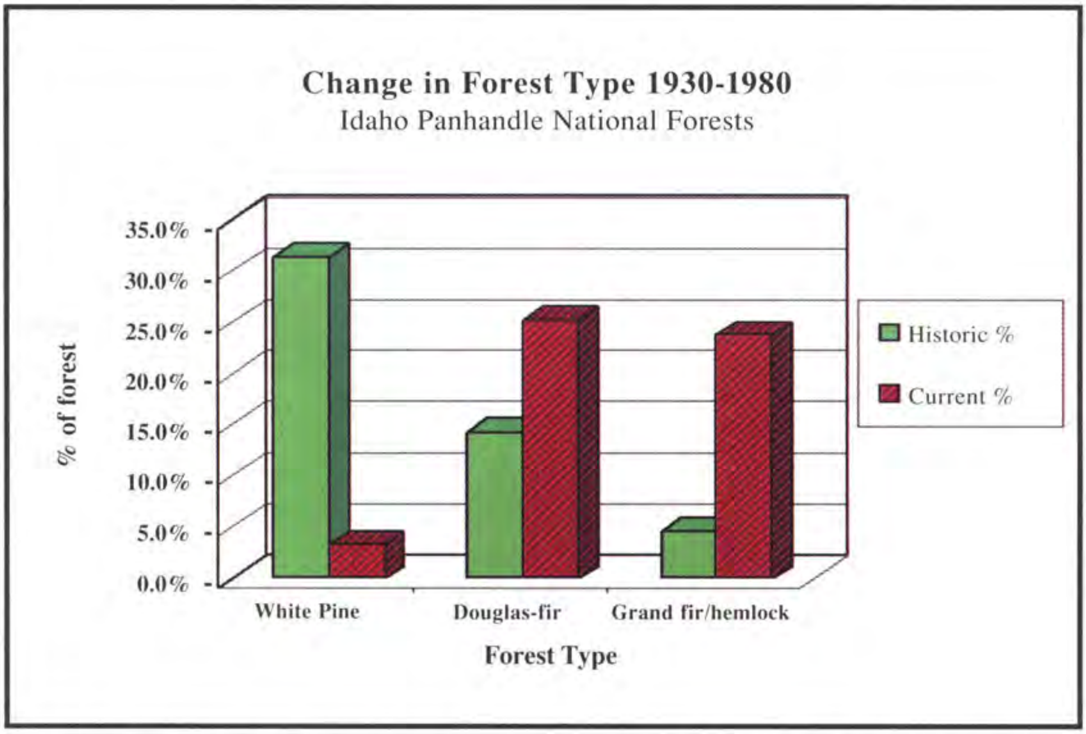

Figure 8. The acreage of white pine in one part of the Idaho Panhandle National Forest was once larger than the state of Rhode Island and is now less than 1/10th of that. Similar changes have occurred throughout the west.

Other white pines, such as sugar pine, southwestern white pine and eastern white pine grow in mixed species stands where they diversify forest composition, making these ecosystems more resilient to changes wrought by drought, fire, and insects and diseases. The large seeds of these species are also important food for wildlife. Mortality of these pines is resulting in more homogeneous forests, changes in fire regimes, and reduced wildlife diversity.

Bristlecone, foxtail, limber and whitebark pines are among the few conifers adapted to arid and high elevation environments. They are sometimes the only tree species present in the most austere parts of these ecosystems, or act as windbreaks for other species to grow. They contribute to the regulation of snow accumulation and soil stabilization. Many animals depend on these trees for food and shelter. For example, whitebark pine seeds are a critical food source for Clark's nutcrackers (Fig. 9), pine squirrels, black bears and grizzly bears, as well as a number of small, seed-eating birds and mammals.

Figure 9. Clark's nutcracker is an essential component in whitebark pine ecosystems.

Economic Impacts

Historically, eastern and western white pines were the mainstays of the lumber industry throughout their ranges (Fig. 10). They were prized for their rapid growth and clear, straight-grained wood that commanded premium prices, often more than double that paid for other species in the region. On good sites, western white pines grew to more than 150 feet tall and 36 inches in diameter. Mixed western white pine stands commonly produced 50,000 board feet per acre, while the best mixed fir stands on the same sites today are projected to produce only half that much.

Figure 10. Marketable white pines are in decline.

Although bristlecone, foxtail, limber and whitebark pines are not typically used for lumber or pulp, their presence enhances the rugged beauty of many of our national parks (Fig. 11), forests, and wilderness areas. Devastation of these species, as seen today in the stands of dead and dying trees in Crater Lake, Glacier, and North Cascades National Parks, erodes the scenic grandeur of these treasured landmarks and may affect the tourist economies of adjacent communities.

In light of these impacts, and the key role white pines play in maintaining ecosystem health and resilience, the following integrated strategy has been developed to protect, sustain and restore white pine ecosystems.

Figure 11. Remnant whitebark pines add beauty to national historic treasures such as Crater Lake.

Integrated Strategy to Protect, Sustain and Restore White Pines

Widespread cooperative efforts to save white pines were initiated in 1909 in both eastern and western North America. These efforts, largely focused on eliminating the alternate host, *Ribes* (Fig. 12), were not effective in stopping the

Figure 12. Blister rust infected Ribes.

spread of blister rust. Also, the number of *Ribes* plants was not shown to affect the amount of infection in the west, although they were demonstrated to have a long-lasting effect on infection and survival of trees in Maine. By the late 1960s, the combined effects of blister rust, harvesting, fire and bark beetle-caused mortality devastated the white pine forests in many areas across North America. In the West, most western white pine management was abandoned.

Fortunately, by the 1960s, USDA Forest Service scientists identified rust resistant western white pine, eastern white pine, and sugar pine trees. Rigorous selection of disease resistant trees, breeding for disease resistance, and application of silvicultural treatments such as thinning and pruning infected branches effectively captured the genetic resistance, offering an effective strategy for growing white pines in the presence of blister rust. This began a pivotal shift in focus from direct control of the alternate host (reducing exposure to the rust pathogen) to breeding for rust resistance (Fig. 13) and using silvicultural strategies to augment restoration. In the past 40 years, genetic breeding programs have produced

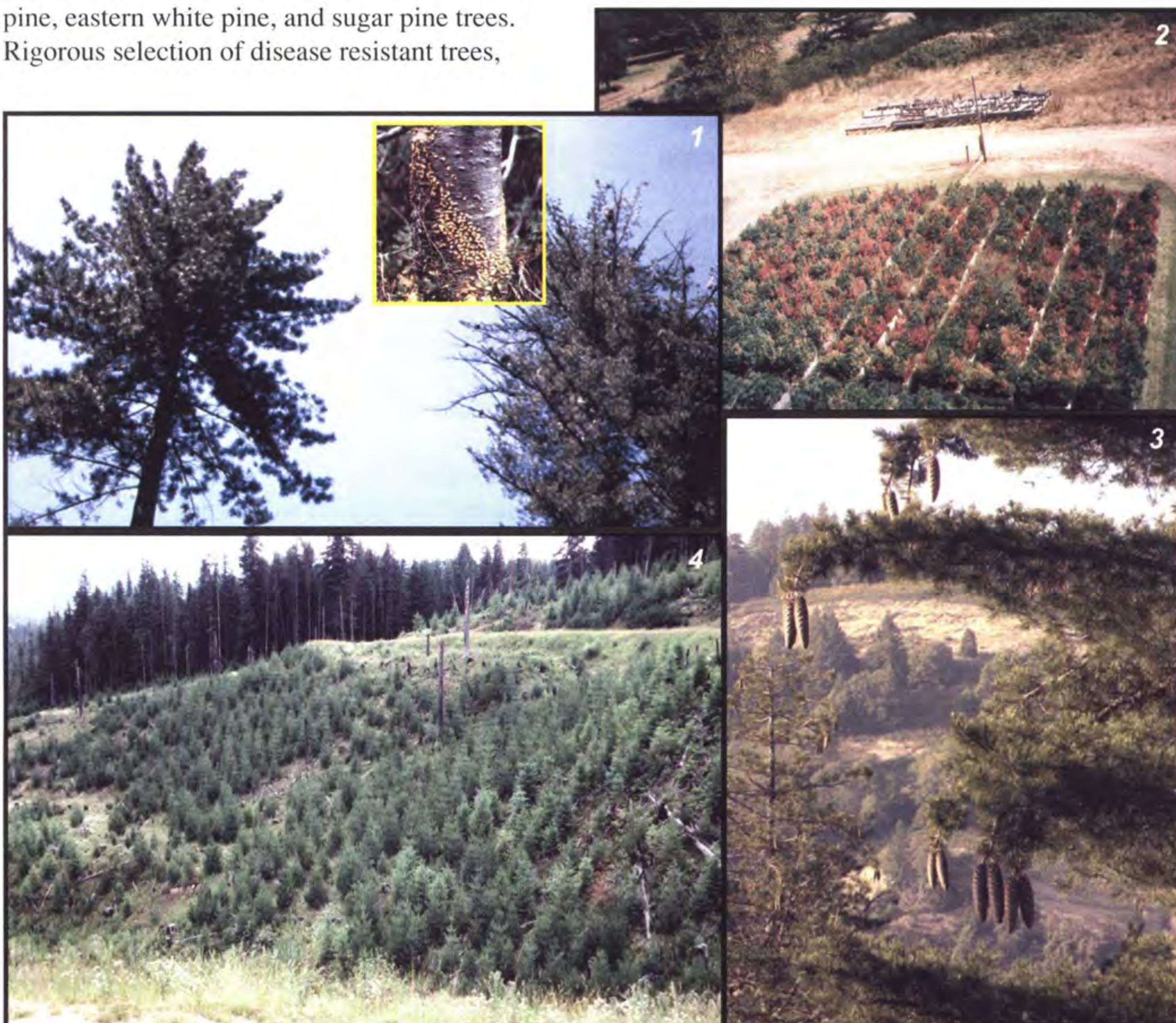

Figure 13. 1) rust-resistant sugar pine (inset - blister rust cankers), 2) testing for rust resistance, 3) sugar pine seed orchard, 4) rust-resistant plantation.

rust resistant seedlings that have been effective in maintaining a small but significant component of these three species in disease-affected forests.

We realize that blister rust is now a permanent resident of North America, affecting even the high-elevation and drier forest ecosystems that we once thought would escape infection. Our goal in managing white pine forests is to promote the establishment and growth of white pine trees, stands and populations that will thrive while coexisting with blister rust. We have the expertise and technological tools necessary to reach this goal. This effort will require an integrated approach using genetic, silvicultural and disease management strategies. The intent will be to restore white pines where they have been catastrophically affected by rust infection (e.g., western white pine in the Inland Northwest), to sustain white pines where the rust is present but not yet devastating (e.g., parts of the range of southwestern white pine [Fig. 14]), and to plan and prepare for potential spread of the disease where the rust is not yet present (e.g., the bristlecone pines (Fig. 15) in California, Nevada, Utah, Colorado, and New Mexico). Restoring white pine ecosystems contributes to the main goals of the "Healthy Forest Initiative" and the "National Fire Plan" by improving and restoring forest ecosystem conditions. To enhance natural pine resistance, we will focus our efforts on the following four general work areas.

Figure 14. Infected southwestern white pine.

Figure 15. Bristlecone pine.

Genetic Strategies

The most effective strategy available to combat this disease is to capture and deploy plants with natural genetic resistance to the rust. Although natural resistance is infrequent, we are working with the natural disease resistance present in white pines to identify resistant trees that can be used as parents of new generations of trees. Genetic conservation and breeding programs have already made considerable progress towards maintaining sugar pine and western white pine as viable components of ecosystems. The breeding programs continue to discover and develop rust resistant varieties of white pines. In California, a total of 1,329 proven rust resistant sugar pine seed trees have been identified, and two seed orchards are established.

In the Pacific Northwest, resistance breeding programs support 40 seed orchards. The Rocky Mountain Region has identified more than 3,100 rust resistant western white pine trees and planted 96,255 acres with blister rust resistant white pine seedlings. A breeding program is also established for eastern white pine and programs for whitebark pine and southwestern white pine are in the early stages of development.

Where blister rust is present, researchers and land managers can accelerate the following actions of the established breeding programs:

- Locate and protect potentially resistant trees, and test seedlings from these trees for resistance.
- Characterize resistance mechanisms and inheritance of observed resistance.
- Evaluate test plantations to confirm the durability of resistance.
- Breed a new generation of white pines with a mixture of known resistance mechanisms.
- Plant rust resistant seedlings or seed wherever possible.
- Manage areas around identified resistant trees and stands to allow openings for regeneration.
- Conduct long-term monitoring to assess the survival of natural regeneration compared to planted resistant stock.

Figure 16. Pruned western white pine plantation.

- Maintain broad-based breeding programs to prevent the loss of potentially important sources of genetic variation.

For white pine species where no disease resistance has yet been discovered, such as high-elevation white pine species, land managers can:

- Collect seed from disease resistant trees to "bank" genetic diversity within species and populations. This is a stopgap measure to ensure that potentially valuable white pine genotypes at risk in the wild will be maintained until we can reduce the threat. Concurrently, test seedlings of these selected trees for resistance.
- Implement a conservation strategy (Fig. 16) to protect the remaining trees and enhance regeneration.

Silvicultural Strategies

Historically, fires created large openings, which permitted natural regeneration of white pines. Today, land managers can plant rust resistant white pine seedlings in the openings created by large fires. However, we are unlikely to make significant progress without active management, removal of invading species and/or prescribed fire. We need to implement silvicultural tools to create the openings necessary for white pine regeneration. The following actions are necessary to implement gains made in enhancing natural blister rust resistance through the breeding programs:

- Use rust hazard assessment models to select the best sites for planting and maintaining white pines.
- Regenerate stands with harvests that create suitable openings for white pines while saving uninfected and infection-tolerating seed trees to promote natural genetic resistance.

- Use prescribed fires to prepare seed beds and reduce competing vegetation.
- Plant resistant seedlings or seed in openings created by natural disturbances such as windthrow, fires, root diseases, or bark beetles.
- Use pruning and thinning where appropriate to remove rust infections to extend the life of planted pines.
- Plant rust resistant seedlings in frost pockets, taking advantage of white pines' superior frost resistance.

Where blister rust is not currently present or not yet causing extensive losses, strategies will focus on encouraging natural regeneration and, under some circumstances, protecting existing stands. These activities must be integrated with other land use objectives such as hazard fuel reduction, and improving or maintaining wildlife habitat (Fig. 17), watershed values and scenic quality. Land managers and researchers can:

- Emphasize the importance of sustaining, protecting, and restoring white pine ecosystems in revisions to National Forest plans.

Figure 17. Whitebark pine seeds are an important high-caloric part of the grizzly bear diet, essential to their survival through harsh winters.

- Conduct periodic surveys to accurately map rust occurrence, monitor spread and intensification of rust incidence, and identify new introductions or changes in rust behavior.
- Develop hazard rating systems and other predictive models to better prescribe the best set of management practices for various white pine sites.
- Use pruning and thinning where appropriate to remove existing rust infections and extend the life of existing regeneration.
- Use locally grown nursery stock to avoid introduction of blister rust into new white pine ecosystems.

Research and Information Needs

Past research and management efforts have provided us with critical knowledge, technologies and strategies that are used today to sustain, protect and restore white pine ecosystems. However, there are still many questions to answer in order to improve our ability to cope with this disease. The following list describes some of the highest priority research and information needs:

- Identify resistance mechanisms, their heritability, and geographic distribution in all white pine species.
- Evaluate the linkage of resistance mechanisms to important survival and growth traits, and identify environmental factors affecting these characteristics.
- Investigate variation in *Ribes* susceptibility and develop species of *Ribes* that will resist rust without impacting commercial gooseberry production.
- Determine impacts of fire, prescribed burns, thinning, and other management activities on numbers and species of *Ribes* that may regenerate from seed banks.
- Examine genetic variation in the rust fungus including the potential for new races with differences in virulence,

aggressiveness and adaptation to different climates.

- Develop techniques needed to successfully regenerate species at high elevation, naturally or from nursery stock or seeds (Fig. 18).
- Develop seed transfer guidelines for all white pine species.

Figure 18. Foxtail seed and pollen cones.

Public Outreach and Partnership

Both internal and external participation and collaboration among Federal, Tribal, State, and private land managers, and non-governmental organizations (Fig. 19) are essential for protection and restoration of the white pines. Forest Service managers and researchers partner in many collaborative efforts to:

- Provide information on forest conditions and encourage participation in forest management.
- Incorporate white pine restoration and sustainability goals into forest plans and field project decisions.
- Provide rust resistance testing capabilities for partners.
- Provide financial and technical assistance to small landowners.

Conclusion

This plan focuses on protecting, sustaining and restoring white pine ecosystems that are either devastated or threatened by a non-native invasive pathogen, *Cronartium ribicola*, the cause of white pine blister rust. It complements the implementation of the Healthy Forest Initiative and the National Fire Plan and their associated strategic documents by developing a sensible approach to restoring fire-adapted resilient ecosystems in the areas where white pine once dominated. It also complements the Western Bark Beetle Report by maintaining and restoring high numbers of white pines in ecosystems that have become dominated by other species that are more vulnerable to bark beetles and root pathogens. Increased collaboration and partnerships among land managers and researchers will facilitate the long-term restoration of white pine ecosystems. These restored white pine ecosystems will have the capacity for self-renewal, recovery and retention of ecological resiliency while meeting current and future needs of people for desirable experiences, products, and services.

Figure 19. Land managers and researchers from all agencies are involved in collaborative efforts to restore white pines.

Team Leaders and Members

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We are striving for the day white pines will coexist with blister rust