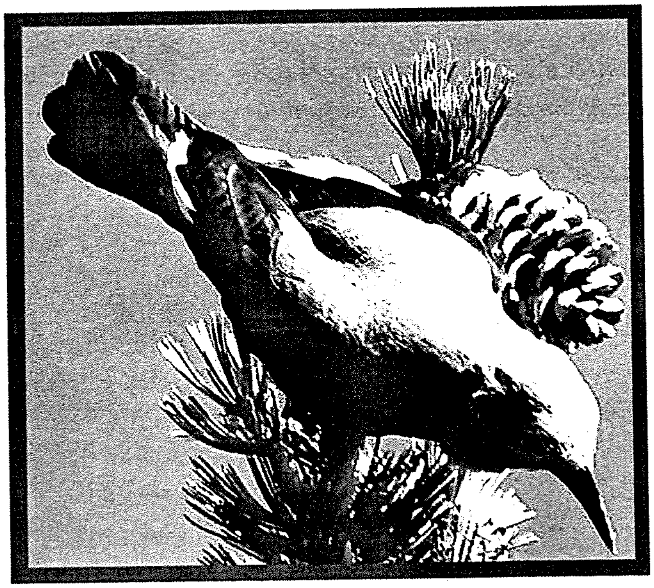
Fall Winter 2004

Nutcracker Notes

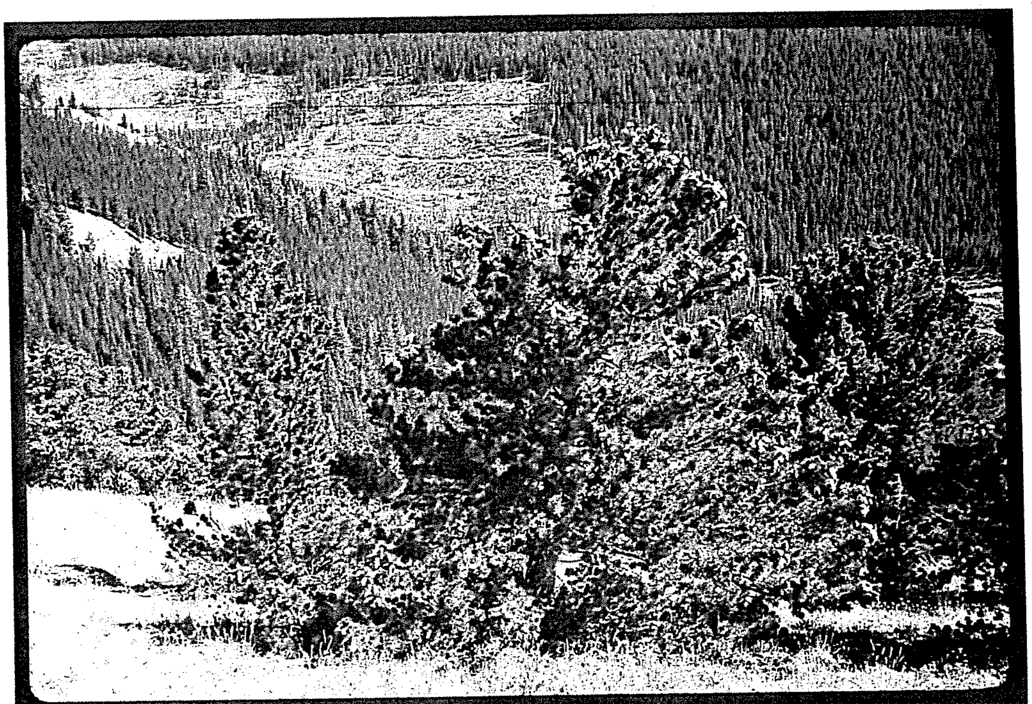
Whitebark Pine Ecosystem Foundation

Featuring Limber Pine



Clarks nutcracker on limber pine. James Blodgett

Limber pines and whitebark pine (left) on Red Mountain north of Lincoln, MT. Steve Arno



Issue 7

Topics

WPEF
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Limber pine communities viewed in 1900 (top) and 1981 (bottom) in the forest-Great Plains transition zone west of Choteau, MT. Livestock grazing and fire suppression evidently allowed pine communities to expand. From George Gruell. 1983. *Fire and Vegetative Trends in the Northern Rockies: Interpretations from 1871-1982 Photographs.* USDA Forest Service, General Technical Report INT-158.

Whitebark Pine Ecosystem Foundation's Mission:

Counteract the decline of whitebark pine, a keystone species of high-mountain ecosystems in western North America.

Director's Message

Diana Tomback

Thanks to our stalwart supporters who again renewed their memberships, and a warm welcome to new members! It is your grassroots support that lends power to our organization—providing a mandate for our efforts.

Our concerns about the ongoing losses of whitebark pine and other five-needled white pines relate in part to the issue of western forest biodiversity. These pines are integral to whole ecosystems, interacting in multiple ways with other forest trees and undergrowth, as well as with microorganisms and animals—both invertebrates and vertebrates. These ecosystems comprise unique sets of species and ecological interactions. We are all aware of the more conspicuous among these community interactions, such as the seed dispersal mutualism between Clark's nutcracker and both whitebark pine and limber pine, and the use of whitebark pine seeds as an important food source for bears. But, more information is being uncovered yearly concerning other interactions involving five-needled white pines, including their facilitation of succession and interactions with undergrowth species. There is much, however, that we do not know about the community inhabitants—for example, about the microorganisms or arthropods—and their interactions. Yet, five-needled white pines are declining rapidly throughout their range, killed by blister rust and the recent upsurge in mountain pine beetles. As these ecosystems decline, we not only lose some part of our western biodiversity, we also lose opportunities for understanding their components and function.

Incrementally, by our accomplishments as an organization, we hope to make progress towards reversing these declines. For example, the methods workshop that we held from June 28 to June 30, 2004, in West Yellowstone, "Monitoring Whitebark Pine for Blister Rust," was a solid success by all accounts. The attendance was the maximum we could support, at 80 attendees from locations throughout the range of whitebark pine, including Canada. The instructor contribution was extensive, with more than 25 professionals and technicians providing either talks, field

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WPEF Happenings

$20,000 Available for Whitebark Pine Restoration

WPEF is soliciting proposals for whitebark pine restoration projects targeted for summer 2006. We hope to provide matching funds of up to $20,000 for one or two short-term projects in regions where whitebark pine is heavily impacted by blister rust or successional replacement.

We will select the most feasible and urgent projects and use them to write an umbrella proposal. WPEF would contribute funding, and we have an offer of matching funds from the Albert and Tricia Nichols Foundation.

The proposal format is as follows:

- Title, proposing agency, and contact information
- Justification of project (very important)
- Location of project
- Project description including size of area to be treated and methods used
- Schedule of project
- Overall project budget, and requested budget
- Source of other matching funds (in addition to contribution from WPEF)
- Likelihood of project completion in 2006, if funded

Funding may be requested for silvicultural thinning, prescribed fire, collecting seeds, growing and planting seedlings, or other aspects of restoration.

Proposals should be 1-3 pages single-spaced. Please send them to WPEF Director Diana Tomback—address on p. 3, or (dtomback@carbon.cudenver.edu)—by March 1, 2005. We will prioritize proposals and write an umbrella proposal for a deadline by the end of the year. We should know whether we are successful in our fund-raising efforts by early in 2006. This should provide adequate time for planning funded work. For more information, check the WPEF web site (www.whitebarkfound.org).

Educational Program Designer Needed

WPEF is looking for a volunteer to design a broad based educational program about the ecology and values of whitebark pine ecosystems and needs for restoration. This program would target many audiences including but not limited to schools, different groups of outdoors enthusiasts, environmental organizations, and natural resource managers and specialists. Many fine educational materials and some school-oriented programs are already available, but WPEF wants a comprehensive, coordinated program to reach a broad array of audiences. WPEF can provide seed money to initiate this effort, in which the volunteer will develop a grant proposal that solicits funding of an educational program by one of several foundations or agency grant sources. If you are interested in this assignment, contact WPEF editor Steve Arno—address on p.3, or (arnos@mcn.net).

One Hundred Attend WPEF's Workshop

Ward McCaughey, WPEF Asst. Director

The Whitebark Pine Ecosystem Foundation hosted a tremendously successful workshop, "Monitoring Whitebark Pine for Blister Rust," June 28-30, 2004 at the Holiday Inn in West Yellowstone, Montana. The basic objective was to present and teach methods for quantifying the status of blister Biologists at Waterton and nearby Glacier National Park are cooperating in studies of rust resistance and planting techrust in whitebark pine communities and monitoring changes over time. Land managers need to obtain valid estimates of the status of blister rust activity as a basis for planning restoration actions. WPEF designed this workshop to fill that need.

The standardized data collection system allows comparisons between data gathered by different people and across geographic regions. A second objective was to incorporate comments by participants to refine and develop a final set of methods for universal use to provide consistency.

One hundred participants were registered, including organizers and trainers. Attendees came from 18 National Forests across the West and Forest Service research stations, 3 U.S. National Parks, Parks Canada, 5 universities, Alberta Sustainable Resource Development, 2 environmental education programs, and included 3 retired research scientists.

In the first phase of the workshop speakers explained some basics including why monitoring is needed, distribution of white pines and rust, blister rust identification, and rust resistance screening. The next phase presented different components of the proposed sampling methods. This was followed by methods instruction in whitebark pine stands on Sawtell Peak near Island Park, Idaho. Thunder showers threatened us, but the rain held off until we were done! The final phase was compiling suggestions from attendees to improve and finalize the methods.

WPEF thanks the co-sponsors that made this workshop possible: USDI National Park Service, Rocky Mountain Cooperative Ecosystems Study Unit; Greater Yellowstone Coordinating Committee; USDA Forest Service, Rocky Mountain Research Station, and Northern Region; and Continuing Education at the University of Montana. Comments indicated that a good learning experience was had by all.

Fifty Join WPEF Conclave at Waterton

Steve Arno, WPEF editor

Amidst glorious fall colors in late September, WPEF Board Member Cyndi Smith hosted a memorable whitebark pine conclave at Waterton Lakes National Park, just across the border in Alberta. In addition to yellow-gold aspen and alpine larch, an azure lake and sky, and a congregation of elk in the rut, we were treated to tours of nearby stands of both whitebark and limber pines where we discussed restoration projects.

Cyndi, Conservation Biologist with Parks Canada, also arranged a mini-symposium featuring a dozen short presentations on studies and projects in whitebark pine and limber pine ecosystems at many locations in Canada and the United States. Speakers and other participants totaled 50 or more with Canadians and Americans about equally represented. WPEF esteemed chair, Professor Diana Tomback provided a riveting account of her long backcountry journey to establish plots in whitebark pine habitat on remote burns in the Bob Marshall Wilderness. Daily treks involved thousands of feet of elevation gain, toting backpacks overloaded with sampling gear, alternately hot and soaking-wet conditions, and living in a dusty or slimy ash substrate. Despite the depravations she is ready to return for re-measurements in coming years.

More than 30 joined the half-day hike into a whitebark pine/subalpine fir stand perched high above Waterton Lake. Here, as mist and clouds slowly gave way to clearing skies, the park's fire management officer, Randall Schwanke, explained his plans for a prescribed burn. This is intended to help whitebark pine regenerate and overcome the combined scourges of successional replacement linked to fire exclusion and depredations of blister rust and mountain pine beetle. Watching the expressions among our group as we lunched among whitebark pine snags and solitary veterans on the 7000-foot ridge, it was easy to see the enthusiasm for restoring this beleaguered habitat.

That afternoon many of us accompanied Cyndi and Randall to a foothill limber pine site along the Rocky Mountain Front a few miles north of Waterton Lake. We climbed through aspen groves and patches of invading Douglas-fir before reaching the wind-trained and stunted limber pines atop a rocky hill overlooking Alberta's Great Plains. Limber pines in this part of the Park are heavily damaged by blister rust and being squeezed out by fir in the absence of prairie fires. Biologists at Waterton Lakes and nearby Glacier National Park are cooperating in studies of rust resistance and planting techniques for both limber and whitebark pines. At the limber pine site we discussed opportunities for restoring fire to create more open conditions that might facilitate establishment of rust-resistant regeneration. Waterton Lakes National Park has nearly all elements of the native ecosystem—even bison may be allowed to range free within park boundaries in the foreseeable future. Biologists want to prevent disintegration of the whitebark and limber pine communities.

Cyndi Smith's excellent arrangements and stewardship set a pattern WPEF hopes to replicate in future annual meetings. A comparable conclave is being discussed for September 2005 in the Flathead Valley of northwestern Montana. Look for full details in the next issue of Nutcracker Notes, arriving in May. ■

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instruction, or both. Included in the materials distributed were the Microsoft Access database CD and manual developed by Brent Frakes and David Pillmore from Rocky Mountain Network Inventory and Monitoring of the National Park Service. Debbra Graham from Continuing Education at the University of Montana did a splendid job of organizing the workshop. They deserve our sincere thanks for the time they invested. We also owe a debt of gratitude to our sponsors for providing funding and support for the workshop, which helped keep registration costs down: the Greater Yellowstone Coordinating Committee; USDA Forest Service, Fire Sciences Laboratory, Rocky Mountain Research Station, Missoula; USDA Forest Service, Northern Region, State and Private Forestry, Forest Health Protection; USDI National Park Service, Rocky Mountain Cooperative Ecosystems Study Unit, and The University of Montana Continuing Education.

Our annual members' meeting was held September 25-26 in Waterton Lakes National Park. It included a very well attended scientific session and field trips and half day hike. The weather started out cold and cloudy but turned into a fine, bright autumn day for the hike. Our thanks to board member Cyndi Smith, who is Conservation Officer for the Park, for organizing this excellent gathering.

As for our projects this year, the WPEF is working on a major restoration initiative, as well as a set of methods for limber pine, and a set of by-laws for the organization, as well as other initiatives reported here in Nutcracker Notes. There are several opportunities for member participation. One, which I wish to highlight here, is the need for a Director of our Ski Area Partnership Program. If anyone has a few hours to donate for an excellent and rewarding cause, please contact me. ■

Limber Pine – A Chat

Ronald M. Lanner, Emeritus Visiting Scientist
Institute of Forest Genetics, Placerville, CA

On my desk is a favorite paperweight, a branch stub I severed from a huge *Pinus flexilis* (limber pine) snag in the Sinks area of Logan Canyon, Utah a couple of decades ago. The sawn surface is hard and polished and rose-colored with resin saturation; and it has 713 annual rings in the five inches between its pith and outer ring. It originated eight feet up the trunk of a tree that must have been close to a thousand years old when it died. It is heavy in the hand and aromatic enough – after all these years – to bring back many pleasant days afield in limber pine groves fringing Great Basin mountain tops and subalpine meadows.

Whether in the Great Basin, the Rockies, or the Sierra Nevada, limber pine is a tree not to be forgotten. It is persistent, trees over 1650 years old having been found in New Mexico, Colorado, and Idaho, and a 2000 year old in Nevada.. It can be massive, especially in its common multi-trunk clumps. Its upswept major limbs with their many-forked verticalized branches would be unique in North America if not for those of *P. albicaulis* (whitebark pine). I interpret this crown form as a naturally selected structure that makes the cones easily visible to nutcrackers, with stiff enough branches for nutcrackers to perch on while foraging. True, nearly all white pines have upswept upper limbs: but the "bird pines" among them spread that habit throughout the crowns of open–grown trees.

This crown form, which entails repeated forking and steeply upward growth, brings up two issues over which I have made a nuisance of myself for some years. I have suggested that the forking habit is a response to terminal-bud murder by *Pissodes strobi* (white pine weevil), with lateral shoot replacement. An entomologist friend of mine thinks a related weevil causes repeated forking in *Pinus contorta* (lodgepole pine). Checking out forks by dissecting them and observing the process through a growth cycle would be an ideal study at the M.S. level. The branch upsweep doesn't kick in until the tree is out of the sapling stage. Another good study possibility would be dissection and anatomic analysis to see if these pines have a heightened ability to form compression wood, or if the upsweep is due to a strong negative geotropism mediated by some other mechanism.

Limber and whitebark pines share some other attributes as well, because both are mutualists of Clark's Nutcracker,

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Tidbits about Limber Pine

Contrasting Limber and Whitebark Pines

Forest Habitat Types of Montana (Pfister and others 1977) notes the following differences between limber and whitebark pines in the U.S. Northern Rockies. Whitebark pine is widely distributed at high elevations all across these mountains. Limber pine is common *below* the general conifer forest zone on the east slopes of the Continental Divide and extends up to middle elevations on droughty sites, especially on limestone. Whitebark pine is a common part of high-elevation forests and its stagnant saplings and dead standing snags often can be found among forests several hundred feet lower on the mountains. Limber pine is rarely a component of dense forests, and seldom regenerates in stands dominated by other species.

Seed cones of whitebark pine are purple and disintegrate on the tree, leaving only broken scales on the ground, while cones of limber pine turn from green to brown and remain intact on the tree and then on the ground for a few years. Pollen cones of whitebark pine are pinkish purple and persist for months on the tree, while those of limber pine are yellow.

Limber Pine and Bears

Kate Kendall provides the following information about bear use of limber pine: Are seeds of limber and whitebark pines of equal interest to bears? The answer is yes and no. The seeds of both trees are essentially identical in their high nutritional value; but limber pine seeds are harder for bears to collect. Limber pine seeds fall from the maturing cones and scatter on the ground. Whitebark pine seeds are cached by hundreds of thousands in squirrel middens, where they are easy for bears to access. Not much is known about how bears obtain limber pine seeds. They might snatch cones from tree branches before they are fully ripe and ready to cast their seeds onto the ground.

References on Limber Pine

Bob Keane offers the following reading list: Those interested in learning more about limber pine will find Steele's chapter (pp. 348-353) in the *Silvics of North America* (Burns and Honkala 1990) a great start. It summarizes the ecology and management of the species. Richardson's (1998) book on pines of the world is also an excellent source on limber pine and its relationship to other pines. Ron Lanner's (1996) book is an engaging read that explains the mutualistic relationship between nutcrackers and pines. Readers can also find information on the following web site: http://www.nrmsc.usgs.gov/research/limber.htm

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Limber Pine Ecology and Threats it Faces

Anna W. Schoettle, Ecophysiologist
Rocky Mountain Research Station, Fort Collins, CO

Limber pine has a broad latitudinal range, and its elevation range is wider than that of other western conifers. In the northern Rocky Mountains, limber pine is generally found at lower elevations. Farther south it grows at high elevations along side or below the bristlecone pines. In some areas of the southern Rockies limber pine grows from the short grass steppe up to the upper tree line at the continental divide. This species can be very long-lived on dry sites, with trees in excess of 1500 years old reported in Colorado and over 2000 years in Nevada and California.

Limber pine is in the subsection *Strobi*, but it is similar to whitebark and other stone pines (subsection *Cembrae*) in depending on nutcrackers and other corvids for dispersal of the large, generally wingless seeds. As a consequence of bird dispersal limber pines often grow in clusters of individuals. Similar to whitebark pine, seeds of limber pine can be an important food source for birds, bears, squirrels, and small rodents. In contrast to the stone pines, limber pine cones open when dry and the seeds germinate easily under greenhouse conditions.

The most extensive threat to limber pine is the exotic disease white pine blister rust caused by the fungus *Cronartium ribicola*. This lethal rust has been affecting limber pine in the Northern Rockies and down into southern Wyoming and eastern South Dakota since the 1970s and was identified in northern Colorado in 1998 and southern Colorado in 2003. Because of the rust, limber pine communities are challenged by potentially diminishing seed availability and dispersal, delayed maturation and reproduction slowing the spread of resistant genotypes, high mortality of saplings, and added stress on seed trees from bark beetles. Results from ongoing studies of these relationships may also have application to whitebark pine.

While the selective pressure exerted by the rust on limber pine is not uniform across its distribution, the coincidence of the distributions of *Ribes* and limber pine suggests that rust infection may become extensive. The impacts of the rust may depend on the limber pine habitat type. Limber pine forms nearly pure ("climax") stands on dry rocky sites while on moist sites it is limited to an early successional status. Limber pine dominates the driest sites because the physical environment is too harsh for more competitive

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Insect and Disease Status of Limber Pine

Contributed by Blakey Lockman, Jim Hoffman, Marcus Jackson, and Ken Gibson
USDA Forest Service, Forest Health Protection

Bark Beetles

At present, mountain pine beetles (*Dendroctonus ponderosae)* are at outbreak levels on a regional scale. Currently they are killing tens of thousands of limber pine trees throughout much of the species' range. In many areas east of the Continental Divide limber pine communities expanded as a result of fire exclusion (see photos on inside front cover) onto sites where the species might be more susceptible to stress. Undoubtedly, the extended western drought of recent years has impacted limber pine and other pine species, and has aided the expansion of beetle populations. For the next several years, additional trees will be killed until much of their suitable host material is gone, or until environmental conditions change—for example, a return of extremely cold winter temperatures.

Dwarf Mistletoe

Limber pine dwarf mistletoe (*Arceuthobium cyanocarpum*) is not a regionally important agent, but is locally severe in certain stands or areas. Combined with drought effects, mistletoe cankers weaken trees rendering them less resistant to bark beetle attacks. Although this is an aggressive dwarf mistletoe, it is a native pathogen. Limber pine has evolved with this parasite; thus it is not a threat to its overall survival.

Needle Disease

Dothistroma needle disease (*Dothistroma septospora*) has been locally severe in certain areas of central Montana in the mid-1990's, causing overall decline and outright mortality. Trees with greater than 90% defoliation were more likely to die in subsequent years during drought than trees with lower levels of infection. This is a native fungus that responds to favorable environmental conditions, so damage from this disease may become cyclical, and continue to have local importance.

Blister Rust

White pine blister rust (*Cronartium ribicola*), a non-native pathogen, has expanded out of the northwestern range of western white pine and is causing significant mortality in limber pines and other 5-needle pines throughout the distributions of these tree species. This fungus causes branch and stem cankers that eventually lead to top kill or death of most infected trees. The native trees have not evolved with this

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Limber Pine - A Chat continued from Page 6. . . .

and the birds have had a lot to say about what these trees will look like, and where they will grow. Both bear stalkless cones filled with large, nutritious, flightless seeds, all of which increase the chance of being harvested – thus cached and nominated for germination – by nutcrackers.

An important character the nutcrackers have determined is that limber pines usually form all-aged stands. For example, the grove that yielded my paperweight had an age spread of 24 to 1000 years, if my estimate of the big snag is in the ball park. That phenomenon is typical of all bird pines in the white pine subgenus that I know of, and seems to indicate a multi-generational sense of place that persists in the nutcracker mind-set. The clumping of stems is also largely nutcracker-determined, as clump members are very often survivors of the same seed cache. And that too is shared by whitebark pine. So is the status of both pines as pioneers on burns and other clearings, though both are also often "planted" beneath an overstory of aspen in the case of limber pine, and lodge-pole pine in the case of whitebark.

Do foresters still get confused over the similarities of these pines? The differences are in the details, not in the big picture. Limber pine cones are woody, and last several years on the ground before they rot. They are big enough to kick around, and do not shatter. Whitebark pine cones are usually broken up into their components of scales and cores by nutcrackers and squirrels, so there's nothing left to kick around. In spring, limber pine sports bright yellow pollen cones, while those of whitebark pine are a lovely crimson. Both species' saplings have smooth gray bark with pink highlights, but as they age whitebark develops chalky scales and limber pine furrows followed by gray and pinkish scales.

Limber pine is a gift from Mexico, whitebark from Asia. I have argued elsewhere that the typical "wind pine" *Pinus ayacahuite* (Mexican white pine) is the ancestor of *P. strobiformis* (southwestern white pine), which is in turn ancestral to limber pine; and that the mediators of this process were jays in the south followed by nutcrackers in the north. These species form a complex stretching 3700 miles from Guatemala to Alberta, and many of their key characters grade into each other.

Less speculative because it is backed up by considerable genetic analysis is the origin of whitebark pine in northeast Asia from the bird pine *P. sibirica* (Siberian stone pine). Thus the similarities of limber and whitebark pines result from convergent evolution, and are not evidence of a close genetic link. One might argue that the Asian branch is older

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than the Mexican, because whitebark pine has more sophisticated nutcracker-selected cone traits than limber pine, and because, unlike whitebark pine, some limber pines still produce winged seed.

The use of limber pine seeds as a food has been well documented for birds and small mammals. But they have also been eaten by people, despite the frustration some may have experienced in shelling them. Settlers in Idaho and Wyoming made some use of them as a snack, but most intriguingly, the large number of grinding stones discovered some years ago at Alta Toquima Village high on Nevada's Toquima Range suggested widespread use by Native Americans in the distant past. It appears there is still much to learn about this strikingly beautiful pine.

Continued from Page 6. . . .

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Limber Pine Ecology continued from Page 7....

trees. These limber pine stands tend to be open-growing and, in the absence of the rust, support continual recruitment. Severe mortality caused by blister rust on dry sites could transition the sites to treeless vegetation communities with implications for soil stability, snow accumulation, hydrology, and wildlife habitat.

While limber pine is most common on rocky ridges and dry slopes it can also be found in small populations scattered widely through forests in the central and southern Rockies. On these more mesic sites, limber sometimes serves as a nurse tree mitigating harsh open conditions after a severe fire or other disturbance, and facilitating establishment of Engelmann spruce, subalpine fir, or Douglas-fir. Mortality from rust might alter succession pathways on these sites.

Despite limber pine's wide range and patchy distribution, it shows little genetic differentiation and remarkably low morphological variation along the elevation gradient. Limber pine has a high degree of variation in physiological traits yet consistent drought tolerance and avoidance behavior. Therefore physiological plasticity or broad physiological tolerances may contribute to limber pine's wide distribution. Extensive adaptive variation studies have not yet been established and therefore seed transfer rules for limber pine do not exist.

The frequency and distribution of rust-resistance traits has not been thoroughly explored for limber pine, but historical studies and field observations suggest that resistance is low. Evidence of hypersensitive reaction ("major gene resistance", MGR) to the rust has been found in one of five bulk seed lots tested. Individual tree seed collections are currently being compiled for limber pine for future studies.

Some field assessments of incidence and intensity of rust infection have been conducted throughout the Rockies (see other articles in this issue). Aging cankers has been problematic for this and other high elevation white pines due to their long needle lifespans (9-10 years). If it is incorrect to assume that the young needles are the only infection sites, canker ages could be off by as much as 8 years. Likewise, when assessing the risk of successful infection or infection efficiency knowing the receptivity of older leaves to infection is critical since approximately 80 percent of the foliage in a mature limber pine tree is greater than one year old. Limber pine is slow growing and the latent period between infection and canker formation in the field may be different from other, faster growing white pines, further complicating the estimation of time of infection.

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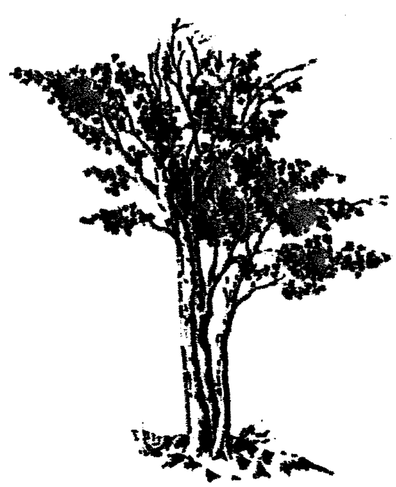
Limber pine is also susceptible to impacts by mountain pine beetle and mistletoe. The contribution of rust-caused stress to an increase in sensitivity to these and other stresses such as drought and competition will have to be studied to fully assess the impacts of the disease.

Limber pine is out-competed by other trees and requires disturbance to gain a foothold on sites suitable for other conifers. The distribution of white pine blister rust overlaps with about half of the distribution of limber pine and is still advancing. While the rust probably will not eliminate limber pine, it is likely to impact its population dynamics, distribution on the landscape, and functioning of the ecosystems. The rust may cause local population extinctions as well as greatly reduce genetic diversity of limber pine. Our incomplete understanding of the ecology, genetic structure, adaptive variation and rust resistance of limber pine constrain our ability to develop and implement conservation programs. ■

Insects continued from Page 7....

fungus and thus have not built up resistance within their populations. Consequently, this is the single biggest threat to limber pine health and survival range wide.

Finally, to add insult to injury, white pine blister rust is using limber and whitebark pines to "bridge" into previously uninfected five-needle pine host ranges throughout the central and southern Rocky Mountains. In 2003 Rocky Mountain bristlecone pine (*Pinus aristata*) was found infected with white pine blister rust adjacent to infected limber pines in southcentral Colorado. This was the first report of bristlecone pines becoming infected in nature. Previously the species was thought to be of low risk for infection because greenhouse tests showed it has fairly high resistance to the blister rust disease. ■



White Pine Surveys in California

Joan Dunlap, Blister Rust Resistance Program, Region 5, USDA Forest Service, Camino, California

In 2004, with funding from USDA Forest Service Health Protection, the Pacific Southwest Region (Region 5) began field studies to evaluate high-elevation white pines for the incidence and severity of white pine blister rust. In California, the incidence of white pine blister rust is well documented for sugar pine (*Pinus lambertiana*); however, the presence and impacts of the pathogen on high elevation five-needled pines are not well known. The objectives of our field studies are to determine the current range and levels of rust, and to establish plots for long-term monitoring in limber (*Pinus flexilis*), foxtail (*Pinus balfouriana*), Great Basin bristlecone (*Pinus longaeva*), whitebark (*Pinus albicaulis*), and western white (*Pinus monticola*) pines. Field work consists of reconnaissance surveys and plot establishment throughout the geographic range of the California white pines. Simultaneously, we will develop a database to collate current and future information on white pines and blister rust, as well as link these to data from other geographic areas.

In 2004 we began surveys and established monitoring plots in all high-elevation white pines except western white pine. Twelve limber pine plots were established in scattered locations distributed over its geographic range, from the southern Sierra Nevada to the Santa Rosa Mountains in Riverside County. No blister rust was observed in any of the 12 plots. Plots located in stands of Great Basin bristlecone pine, the oldest known conifers in the world, in the White Mountains also did not reveal any blister rust. However, in northern California, blister rust on foxtail pine were confirmed in the two plots on the Klamath National Forest. And, in the Sierra Nevada, 13 of 24 plots in whitebark pine stands had infected trees. Preliminary data analyses show that the incidence of rust on northern populations of foxtail pine was 18 and 30%, and on whitebark, rust incidence in plots with infected trees ranged from 8 to 71%. These findings suggest a need for more surveys in the range of these species and where blister rust hazard is predicted to be high. Field work will continue through 2005.

Crews also visited limber pine stands in southern California in anticipation of seed collections for blister rust screening, seed banking for species conservation, and population genetic analyses. In 2004, cones were collected from one stand; other collections will be made as opportunity arises. In cooperation with the Pacific Northwest Region of the Forest Service, the Pacific Southwest Region's Genetic Resources Group has also planted a small number of limber pines along with other white pines on the Klamath National Forest to evaluate them for partial rust resistance—also known as slow rust resistance—due to multiple genes. We also plan new collaborations with the Pacific Southwest Research Station, Institute of Forest Genetics at Placerville, as we learn more about blister rust distribution in California, its impact on limber and other white pine species, and the nature and frequency of host resistance mechanisms. ■

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Assessing Rust Resistance in Limber Pine Seedlings: A Test Under Way

Angelia Kegley, USDA Forest Service, Dorena Genetic Resource Center, OR; and
Holly S. Kearns and William R. Jacobi, Colorado State University, Fort Collins

Seedlings grown from limber pine and bristlecone pine seed collections made in Boulder County, Colorado, are being tested for susceptibility to white pine blister rust. The limber pine seedlings were 3 years old and bristlecone pine two years old when transported to Dorena, Oregon, near Cottage Grove.

The objectives of the inoculation test are to compare performance of limber pine and bristlecone pine exposed to three spore densities, and to compare their susceptibility to that of three other previously studied species—western white pine, sugar pine, and whitebark pine. The study design for the limber and bristlecone pine seedlings was a randomized complete block with three replications of three treatments. Thirty limber pine seedlings were used in each block by treatment combination for 90 total seedlings per treatment. Twenty-four bristlecone pine seedlings were used per treatment block for a total of 72 seedlings per treatment.

Ribes leaves infected with blister rust at the telial stage were collected from forested areas and placed on wire frames above the seedlings in the inoculation chamber on September 18, 2003. The seedlings were exposed to 3 different inoculum densities—low (3,000 basidiospores/square cm), medium (6,000), and high (9,000-10,000). Monitoring slides were placed in 5 positions within each replication and treatment. Agar plates to monitor basidiospore germination were also randomly placed within each replication.

On July 19, 2004, the seedlings were assessed for needle lesions (spots) and stem symptoms. Preliminary observations suggest limber pine seedlings are more susceptible than bristlecone pine seedlings. The trees will be reassessed periodically and a full report will be available in 2005. ■

Planting Trials for Limber Pine at Waterton Lakes National Park

Cyndi Smith and Celina Praymak, Parks Canada

At Waterton Lakes National Park in southwestern Alberta, limber pine *(Pinus flexilis)* inhabits primarily the lower mountain slopes, where it forms pure stands or is associated with inland Douglas-fir *(Pseudotsuga menziesii* var. *glauca)*. The undergrowth is often a combination of bearberry (*Arctostaphylos uva-ursi*), foothills rough fescue (*Festuca campestris*) and common juniper (*Juniperus communis*) (Achuff *et al.* 2002). Limber pine populations in the park are declining due to damage from white pine blister rust (*Cronartium ribicola*), mountain pine beetle (*Dendroctonus ponderosae*), drought (Kendall *et al.* 1996, Achuff 1997), and successional replacement linked to fire suppression (Schoettle 2004).

If stands become severely depleted, revegetation may be the only means of restoring these populations, but the potential survivorship and long-term success rate of revegetation methods are largely unknown. As revegetating with seedlings costs more than direct seeding (due to the 2-3 years of nursery effort involved) we wanted to experiment with planting seeds and seedlings. Perhaps direct seeding, even if the survival was poorer, would be cost-effective.

Two sites were chosen, approximately 300 m apart, on a low ridge at 1650 m elevation. This ridge was patchily burned during a lightning-caused fire in September 1998. Site A is open with burned and unburned areas. Several small (< 1m) limber pine escaped burning. The ground cover is common juniper and bearberry, with several grass and forb species. Site B is similar to the burned area in site A, with patchy, sparse vegetation composed of grasses and bearberry. It has burned snags, many of which are limber pine, but no living limber pine and no aspen suckers or shrubs. Both sites are exposed to full sun.

The seeds and seedlings planted were obtained from Glacier National Park's plant nursery in West Glacier, Montana. The seeds were collected in September 1999, on the Blackfeet Indian Reservation about 50 km southeast of the planting site. Seeds were collected from trees that were potentially blister rust resistant, as they were the only healthy trees in a stand with high blister rust infection. The collected seed was sent to the USDA Forest Service nursery in Coeur d'Alene, Idaho, for propagation.

In October 2003, 272 seedlings were planted in 68 clumpsat Site A and 73 seedlings were planted in 33 clumps at Site B. Similar numbers of seeds were also planted in clumps at the 2 sites. Seeds and seedlings were planted under the following paired treatments: burned vs. unburned; protected vs. unprotected; near vegetation vs. in the open; and 1, 3, or 5 seeds or seedlings per clump. Protection from herbivory and pilfering consisted of using photo-biodegradable plastic netting over the seedlings, and hardware cloth over the seeds.

The seeds and seedlings were monitored weekly from May 7 to August 31, 2004. Data were collected for each clump including the number of seedlings and the height of the tallest seedling. The overall health and vigour of the seedling clump was then rated. Where seeds had been planted, the number of seedlings emerged was recorded, and these were subsequently measured and their health rated.

First-year germination for the seeds was 33 percent at Site A, and 31 percent at Site B. Of the seeds that germinated, 24 percent at Site A and 50 percent at Site B suffered mortality by the end of August. Several weeks of intermittent rainfall in 2004 proved beneficial for the majority of seedlings planted. Most seedlings remained healthy throughout the monitoring season, with many exhibiting substantial bud growth in June. Several that appeared sick or recently dead at the beginning of the year also went on to produce buds later in the season.

At the 2 sites a total of 68 seedling clumps were healthy, 26 appeared unhealthy, and 10 were dead or dying. There was no significant difference between the survival rate of protected versus unprotected seeds and seedlings. All protected seedlings appeared undisturbed, though needle loss was common when the netting was removed for measurement purposes. Exposure and cache size similarly had little effect on the success rate of seeds and seedlings.

We are unable to draw any conclusions yet whether planting seeds or seedlings might be better, as additional seeds may yet germinate. Further analysis will be undertaken, and monitoring will continue in 2005.

***Acknowledgements*: Anna Schoettle (Research Plant Ecophysiologist, USDA, Fort Collins, CO), Joyce Lapp (Restoration Ecologist, Glacier National Park, MT), Sara Dedekam (Nursery Supervisor, Glacier National Park, MT), Graeme Poll (intern, WLNP), Reese Halter (Global Forest Society, Banff, AB).**

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Genetic Resistance to Blister Rust in Limber Pine

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Major gene resistance (MGR) to white pine blister rust (*Cronartium ribicola*) was first reported in sugar pine almost 35 years ago (Kinloch et al., 1970). Since then, MGR has been demonstrated experimentally in three other western pines: western white, southwestern white, and limber (Kinloch & Dupper, 2002). MGR has yet to be found in whitebark, foxtail, or the bristlecone pines, but further research is needed before we can conclude that none exists. At present, we are looking for evidence of MGR in the latter species, and refining our understanding of it in southwestern white and limber pine.

MGR is controlled by a single dominant gene that confers immunity to seedlings that have at least one copy of the resistance allele. Differential phenotypes are expressed within a few days or weeks after needle infection. *Susceptible* responses are characterized by bright yellow (chlorotic) spots at the site of inoculation (blister rust spores infect through stomates). Chlorosis spreads through needles toward the base as the fungus ramifies within host tissues. Needles become slightly swollen in cross section, and infected spots appear to glow.

Definitive evidence of infection occurs within a few weeks or months after inoculation, when fungal spores (*spermatia*) emerge in orange droplets from colonized stem tissue, near the base of infected needles from which the fungus penetrated the stem. As the fungus grows, the stem swells and surrounding bark develops an orange hue.

In *resistant* responses, phenotypes may initially appear similar to susceptible ones (expanding chlorotic spots). Shortly, however, fungal growth is stopped by death of host tissues around the spot margin, effectively walling off the pathogen. Spots become sunken, dull brown, and cease to expand. Cell necrosis is an active host resistance response, resulting from cellular interactions triggered by fungal infection. In plant pathology, this is referred to as a *hypersensitive reaction*, and is documented as an effective resistance mechanism in many agricultural crops.

MGR is generally an all-or-nothing immune response, sometimes referred to as *complete resistance*. Individuals that have the dominant resistance allele do not become infected beyond the initial inoculation site, the pathogen does not establish in the stem, and no fungal sporulation occurs. Other, less dramatic resistance mechanisms also occur. Mechanisms of *partial resistance* (sometimes referred to as *slow rusting*) allow the fungus to establish in the host, and may even permit sporulation, but otherwise impede or halt the development of the pathogen, thereby allowing the host to survive to sexual maturity.

Several such mechanisms are documented in sugar pine (Kinloch & Davis, 1996), including *bark reaction* (the pathogen grows normally in needles but is resisted at the point where it enters a branch or stem, resulting in abnormal, sunken cankers) and *blighting* (infection develops normally in branches, including sporulation, until infected branches die prematurely, preventing the pathogen from infecting the stem). Similar reactions with diverse phenotypes and timing are documented in western white pine (Hoff et. al, 1980). As yet, their inheritance is unknown, but is presumed to be complex, resulting from interactions among two or more genes with minor effects.

At the Institute of Forest Genetics we are working closely with Forest Service Region 5's Genetic Resources Program to understand genetic resistance to blister rust. For limber pine and high-elevation white pines, blister rust resistance research and screening have just begun, yet there is growing concern about the health of forests in which these species dominate (Samman et al. 2003). An understanding of how these pines will respond to blister rust is critical to sustaining white pine ecosystems. To date, research with limber pine seed from several sites in the western United States has revealed MGR in one bulk seedlot from northern Colorado (Table 1).

Table 1. Frequency of MGR in limber pine, based on limited samples and a wide geographic range in western North America. The gene conferring MGR is designated R, since inheritance of genes for resistance to blister rust in limber pine is not yet characterized. (Mosca Pass data were scored by the authors in 2004; data from other sites are from file archives at IFG)

able 1. Frequency of MGR in limber pine, based on limited samples and a wide geographic range in western **[N]orth America.** The gene conferring MGR is designated R, since inheritance of genes for resistance to blister rust in [li]mber pine is not yet characterized. (Mosca Pass data were scored by the authors in 2004; data from other sites are from [th]e archives at IFG)

Seed Source		No. of	Year	Year(s)	No.	Results[1]				R-gene
Location	**State**	**trees**	**collected**	**inoc.**	**inoc.**	**S**	**R**	**?**	**D**	**freq.**
Glacier NP	MT	1	1995	1996	43	43	0	0	0	**0.00**
Arapaho NF	CO	Bulk lot	1999	1999 & 2000	140	109	18	13	0	**0.06**
Mosca Pass	CO	Several	2003	2004	45	43	0	0	2	**0.00**
Bismarck Lake	AZ	1	1984	1999 & 2000	196	192	0	4	0	**0.00**
Onion Valley	CA	1	1967		77	77	0	0	0	**0.00**
White Mtns.	CA	1	1967		70	67	0	2	1	**0.00**
				Total:	**571**	**531**	**18**	**19**	**3**	—
				Percent:	**—**	**93%**	**3%**	**3%**	**1%**	—

[1]**S**, diffuse chlorotic spots on needles, with subsequent stem infection; **R**, discrete hypersensitive spots on needles, with no subsequent stem infection; **?**, needle and stem reactions unclear; **D**, test seedling died before needle symptoms or stem infection could be assessed.

The presence of MGR in limber pine, though limited by sample size and lack of family-level collections, holds promise for protecting and restoring limber pine threatened by blister rust. A lack of resistance in affected populations will prove devastating to infected seedlings, which succumb quickly. We expect that extensive family-level collections—which we are now soliciting from cooperators—will yield more promising results from other areas.

Sugar and western white pine are inoculated in the cotyledon stage the same year seed are sown, yielding similarly robust and generally unequivocal phenotypes. Limber and southwestern white pine can also be inoculated at the cotyledon stage, but their spot phenotypes and symptom development are more difficult to interpret. Unfortunately, foxtail, whitebark, and bristlecone pines require more time and intensive scrutiny for successful screening. In most cases, results cannot be interpreted until the second season after inoculation.

The work in progress may require another decade before we can assert that high-elevation white pines can be reliably screened operationally. We are confident of protocols for sugar and western white pines, and we are becoming more familiar with expression of resistance in limber and southwestern white pines. However, we face a long learning curve before we can successfully interpret host reactions for species that are still poorly characterized. There is no time to waste.

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Developing a White Pine Blister Rust Hazard Model

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In 1910, *Cronartium ribicola* (J.C. Fisch.), the causal agent of white pine blister rust (WPBR), was introduced to western North America. *C. ribicola* is a heteroecious rust capable of infecting all North American white pines (five-needled pines) and utilizing *Ribes* species, currants and gooseberries, as alternate hosts. WPBR through its disruption of vascular tissues and bark affects white pines by reducing their growth and reproductive potential, eventually killing the pine host and, in turn, affecting community structure and composition by removing the host from the community (Kendall and Arno 1990).

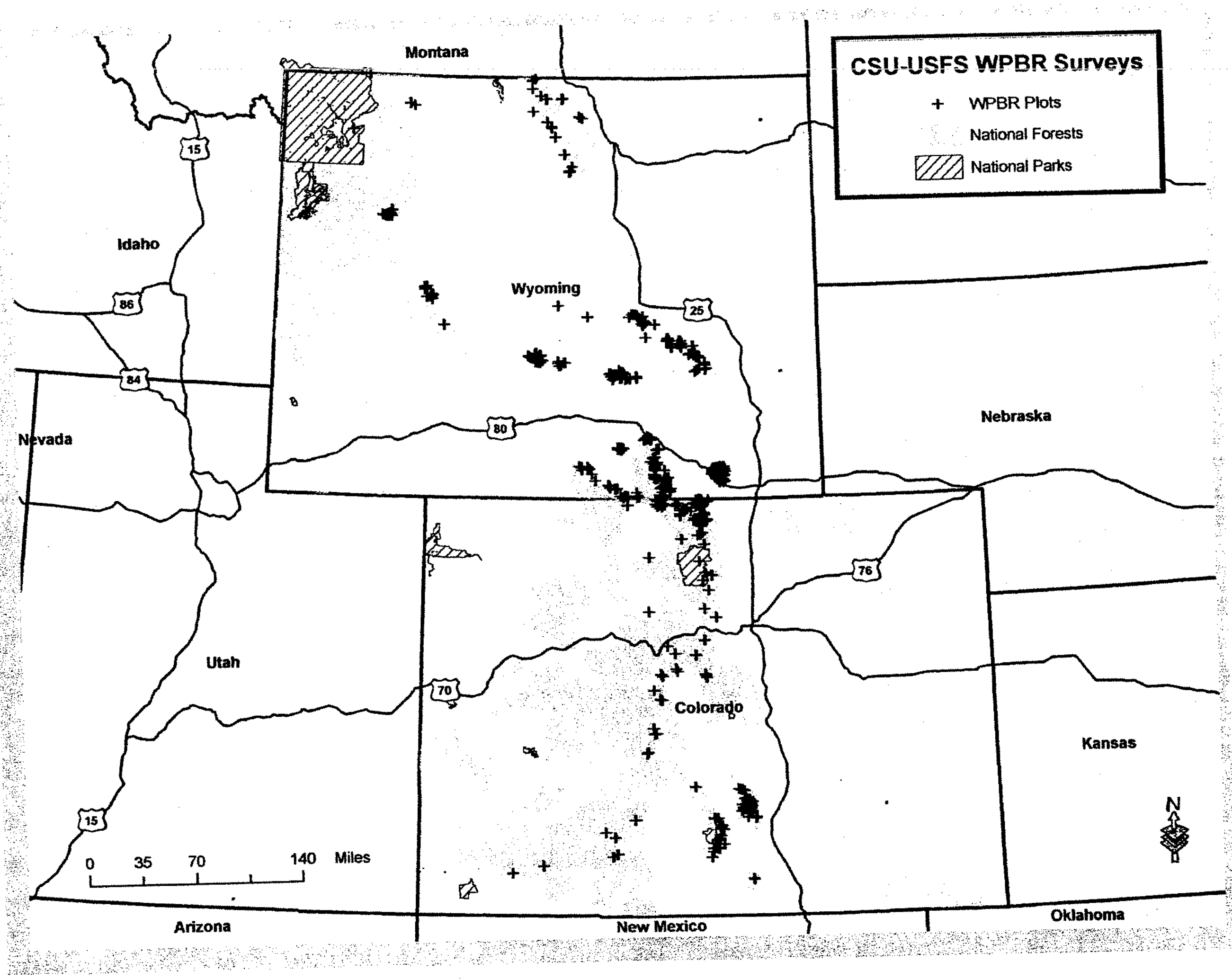
WPBR has been present in northwestern Wyoming since the 1940s and in central Wyoming since the 1970s (Brown 1978), but has only recently been observed in Colorado. The disease was first reported in Colorado in 1998 affecting limber pines (*Pinus flexilis*) with the area of highest infection located within approximately 18 km of the Wyoming border (Johnson and Jacobi 2000). In 2003, isolated WPBR infestations were discovered in the Wet and Sangre de Cristo Mountains of southern Colorado, more than 300 miles away from other known infections. Limber pines are infected in these new areas, but the first natural infections on Rocky Mountain bristlecone pine (*P. aristata*) were also discovered (Blodgett and Sullivan 2004), heightening concern about rust spreading throughout populations of limber, southwestern white (*P. strobiformis*), and bristlecone pines in the southern and central Rockies (Johnson and Jacobi 2000).

A landscape-scale hazard rating system for limber pine and bristlecone pine that will identify areas where Colorado white pines are threatened by WPBR is being developed through a cooperative agreement between Colorado State University and the USDA Forest Service Forest Health Management and Rocky Mountain Research Station. WPBR epidemiology is strongly affected by genetics, profusion of inoculum, nearness and distribution of hosts, and microclimate (Geils et al. 1999). Development of a hazard model will rate the risk of WPBR infection to Colorado white pines and supplement our understanding of fundamental disease processes involving spread, climate, and alternate hosts. Aside from increasing our comprehension of underlying disease processes, the ultimate goal of developing hazard rating models is to aid forest managers in forest planning and management practices.

Surveys of limber and bristlecone pines have been conducted to assess WPBR hazard in a landscape context and to further clarify the relationship between *C. ribicola* infection and various features of the site and associated vegetation. Based on the field data collected on over 400 plots in Wyoming (Figure 1), a series of models that predict the likelihood of rust establishment and rust incidence and severity over time will be developed. Wyoming will serve as the model for Colorado as WPBR has been present in Wyoming white pine populations for over 25 years. Surveys have also been conducted in many areas of Colorado and these data will be used to assess and validate the models developed from Wyoming field data. In addition to the white pine survey plots, over 750 plots have been established throughout Colorado and Wyoming to examine *Ribes* distributions, densities, and associated site factors. Empirical relationships will be determined to predict expected rust incidence and severity based on epidemiological factors (microclimate, *Ribes* and white pine distribution and abundance, and time since pathogen establishment) and site/stand characteristics (elevation, habitat type, physiographic class, associated vegetation, local climate, and soil conditions).

Achieving an understanding of how each of these variables, and possibly others, affects the incidence and severity of WPBR, should allow better prediction of the risk of WPBR to Colorado white pines. The final products will include predictive models and a GIS-based map with WPBR hazard defined for the white pine populations in Colorado that will allow land managers to focus monitoring and control efforts on those areas with the highest risk of infection.

Figure 1. Limber and Rocky Mountain bristlecone pine study areas in Wyoming and Colorado



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Whitebark Pine Ecosystem Foundation
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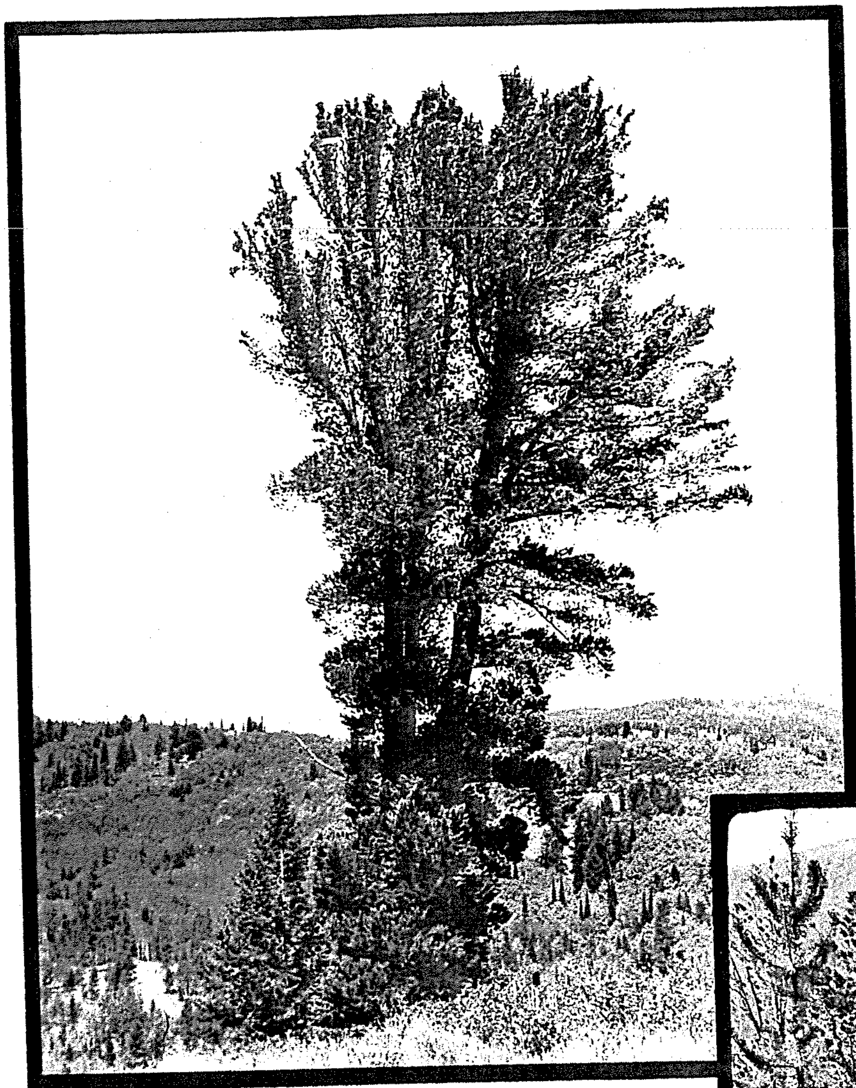
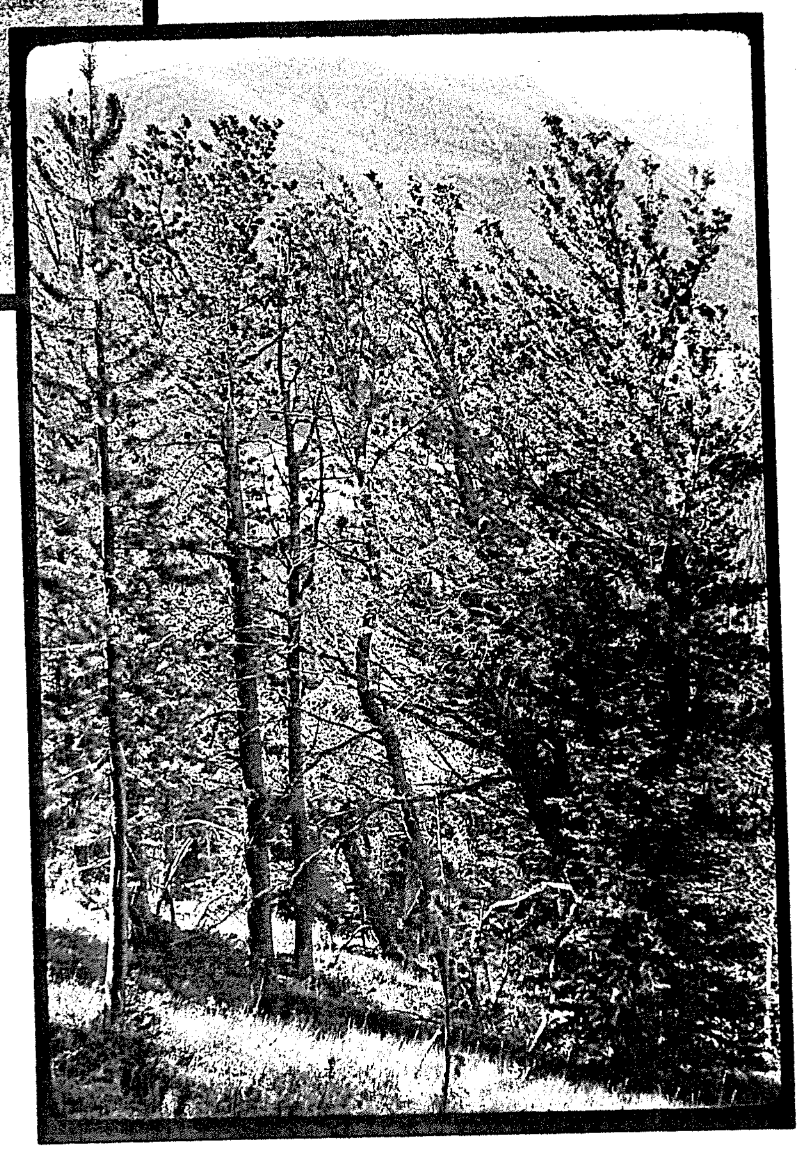
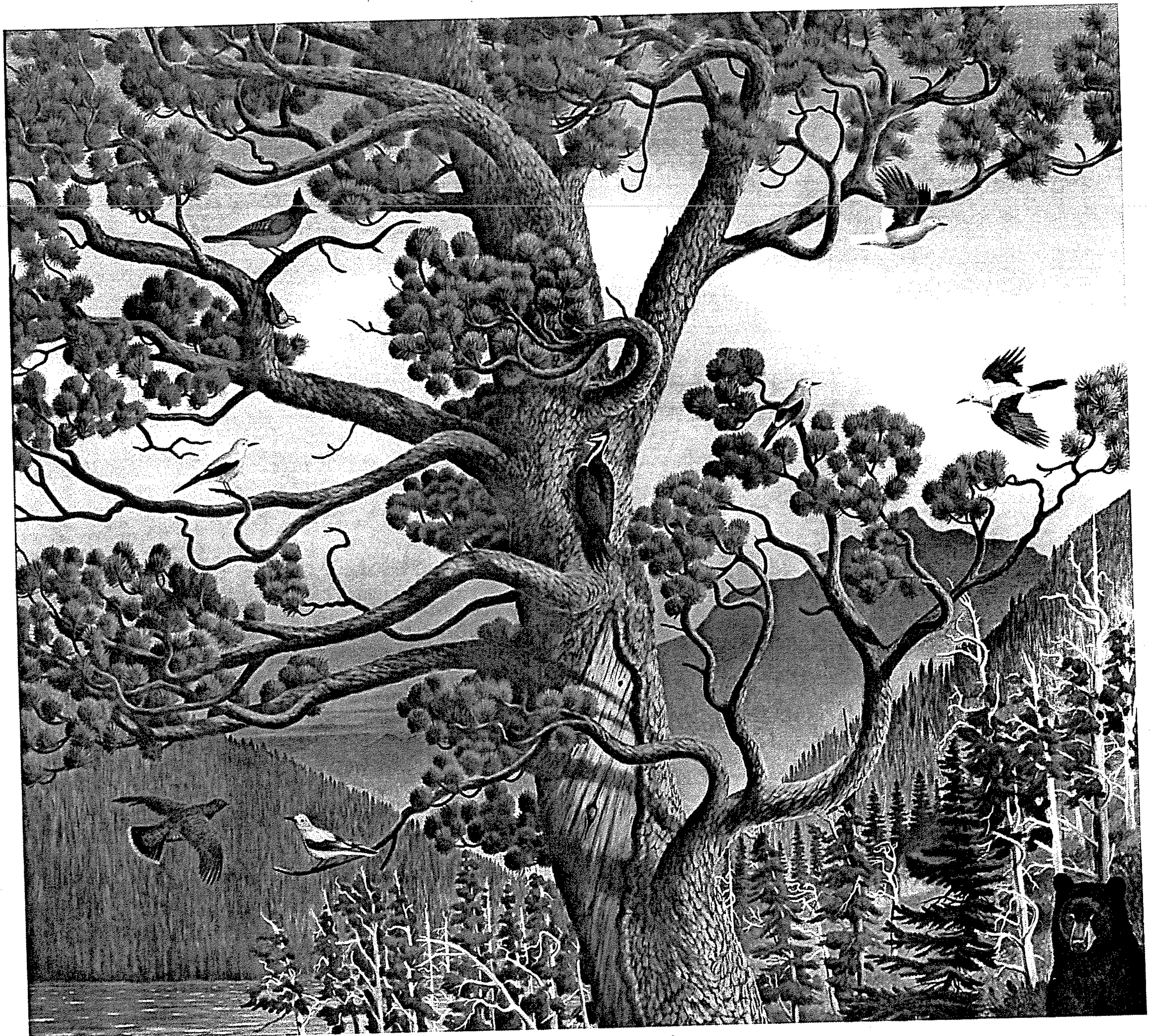


Multi-stemmed limber pine in northern Utah. Ronald M. Lanner

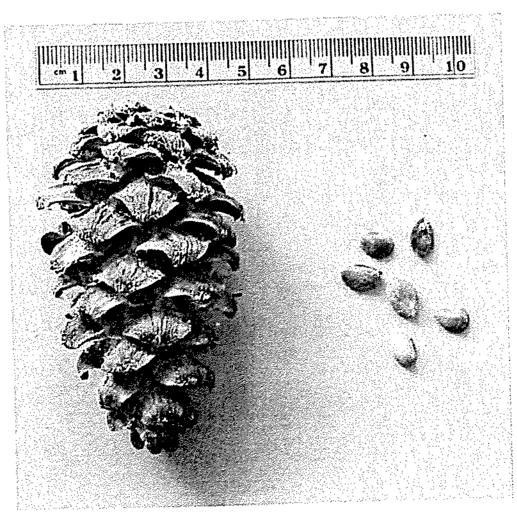


Limber pine (right), whitebark pine (left), and a solitary lodgepole pine (far left) on Red Mountain. Limber pine stems are mostly crooked while whitebark tends to grow nearly straight on moderate sites. Steve Arno



"Tree of Life" A limited edition giclee print by Monte Dolack

Tree of Life was inspired by limber pines on rocky outcrops along Saint Mary Lake, Glacier National Park, MT. To view more paintings and posters by Monte Dolack visit the Monte Dolack Gallery, 139 W. Front Street in Missoula, www.dolack.com or phone 1-800-825-7613.



Limber pine cone and seeds--cm scale. Anna Schoettle