Issue No. 20: Spring / Summer 2011

Nutcracker Notes

Whitebark Pine Ecosystem Foundation

Cody's back yard
Photo by Cyndi Smith

WPEF meeting site
Cody, WY
September 2011

WPEF
P.O. Box 17943
Missoula, MT 59808

Whitebark Pine Ecosystem Foundation

Nutcracker Notes, **Issue No. 20; Spring/Summer 2011**

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Our Mission: The Whitebark Pine Ecosystem Foundation (WPEF) is a science-based nonprofit organization dedicated to counteracting the decline of whitebark pine and enhancing knowledge of its ecosystems.

Membership Information and an application is found at <www.whitebarkfound.org>

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Diana F. Tomback and
WPEF-Canada's Randy Moody

Director's Message
Diana F. Tomback

10th Anniversary and Strategic Planning

This year marks the 10th anniversary of the official beginning of the Whitebark Pine Ecosystem Foundation (WPEF). This important milestone will be celebrated at our annual members' meeting on September 16 and 17 at the Draper Museum of Natural History, Buffalo Bill Historical Center, in Cody Wyoming. So, ten years ago a ragtag and admittedly naïve group of researchers and managers from academics and various federal agencies brought forth upon the Western lands an organization passionate about whitebark pine ecosystems and dedicated to raising awareness of their widespread decline. Soon, an equally passionate membership formed, both individual and institutional, providing the moral support and modest funding required to keep the organization afloat—occasionally supplemented by a more substantial windfall donation.

With this grassroots base, in the past ten years the WPEF has made some important contributions to the whitebark pine mission: we devised and promoted sampling methods to assess whitebark pine health, funded restoration projects, held a tremendously successful workshop in West Yellowstone and a symposium at the University of Montana, published two issues of Nutcracker Notes a year (a major vehicle for information and networking), partnered with Montana and Oregon ski areas, provided technical expertise to all who request input, hosted ten highly successful fall science programs and fieldtrips in different parts of the range of whitebark pine, participated in various whitebark pine workshops and gatherings in the U.S. and Canada, more recently advocated for all the high elevation white pines with the U.S. Forest Service leadership, and now have a sister chapter in Canada. All this was accomplished with a volunteer director, a volunteer Board of Directors (BOD), and no staff. We have operated on a shoestring and beat the odds (but not the exhaustion), surviving primarily on passion for the issue and a sense of mission.

Yet, it has become very clear to the BOD over the last two years that this all-volunteer model must change. This message was also effectively delivered at the "wrap-up" session of the High Five Pine Symposium last June. People suggested that the WPEF was on the threshold of making greater progress, but could not with its current operational model. On April 15 this year, the BOD had our first facilitated strategic planning session to help determine how we need to change. Marcia Hogan, a professional facilitator retired from the Lolo National Forest, led the BOD through a three hour session to determine how to make what is generally known as "The Leap"—the transition between a volunteer organization and an institution with a more formal administrative structure and paid staff. We anticipate that "The Leap" will be accomplished in a series of smaller "Hops," as we institute some changes, particularly in staffing. One of the suggestions is eventually to develop a two 'board' structure, with a citizen operating BOD and a scientific advisory board. We, in fact, are looking for more citizen-interest and input, and help. We are also trying to "tap" our membership to help provide scientific expertise. If you know of energetic individuals with a passion for whitebark pine that matches ours, please e-mail us their names and contact information.

WPEF in Washington, D.C.

The resounding success and message of last June's conference, "High Five Symposium: The Future of High-Elevation Five-Needle White Pines in Western North America," generated notice. As follow-up to this event, Dr. Robert Mangold, Director of Forest Health Protection, USDA Forest Service, and the keynote speaker at the symposium, invited me to talk on behalf of the WPEF to the Forest Service leadership in the Washington Office about the importance of the High Five pines and the growing threats to their survival. I asked Bob Keane--a pioneering expert on whitebark pine restoration—to join me, in order to convey a more balanced message—one of alarm but also one of hope. Through the help of Gary Man, Forest Health Specialist in the Forest Health Protection office, we had an ambitious schedule planned for us for February 24 and 25.

Our day began with an invitation to attend the morning "Standup." We were truly pleased to have a brief, impromptu conversation about whitebark pine with Forest Service Chief Tom Tidwell, who was formerly a Regional Forester for Region 1, and very knowledgeable about whitebark pine. Our joint seminar in the Yates Building was well-attended, with representatives from the National Park Service, U.S. Fish and Wildlife Service, American Forests, and the Nature Conservancy in addition to many Forest Service personnel. One message we emphasized was the importance of incorporating management of these pines in national forest plans.

The remainder of the visit included meetings with the Deputy Chiefs, the U.S. Fish and Wildlife Service, the NGOs American Forests and The Nature Conservancy, and focused discussions with Dr. Mangold and others. This trip was productive, raising awareness of the High Five pines in general, and the precarious status of whitebark pine in particular. It has led to important contacts, new collaborative efforts, and interactions, as well as raised awareness of the WPEF. Rather than an end to itself, we feel that this visit will require follow-up, to keep this issue on the "front burner."

Upcoming

The WPEF and American Forests are in the process of drawing up a memorandum of understanding to work together on a campaign to raise money for restoration of the high five pines. American Forests was established in 1875; it is the oldest non-profit group in America devoted to conservation. Last year, in the lead-up to the High Five symposium, *American Forests* magazine devoted a full color spread to whitebark pine. The WPEF will serve in a scientific advisory capacity for this campaign, as well as provide support with outreach and networking.

The proceedings volume for the "High Five Symposium: The Future of High-Elevation Five-Needle White Pines in Western North America," held June 28-30, 2010, on the University of Montana campus, is on a fast track. Page proofs were just made available to contributors. Publication is anticipated sometime this summer rather than fall. Publication of a proceedings earlier than originally anticipated must be a landmark accomplishment!

As we have noted previously, the U.S. Fish and Wildlife Service is currently undertaking a 12-month status review to determine whether whitebark pine should be listed under the Endangered Species Act. We anticipate that the results of this review will be available this summer.

The 2011 field season is nearly here. Each field season presents opportunities for U.S. and Canadian managers and researchers to accomplish surveys and restoration activities and projects for whitebark pine. Although the damage and mortality from white pine blister rust and mortality from mountain pine beetle are on a scale that is almost incomprehensible, every project we accomplish helps insure a future for whitebark pine. The same applies now to the rapidly deteriorating populations of limber, southwestern white, and foxtail pine in parts of their respective ranges. None of us can afford to rest on our laurels.

Please consider joining us for what promises to be an excellent WPEF conference, field trip, and anniversary celebration in colorful Cody, Wyoming, this September.

WPEF-Canada

Randy Moody; randy@keefereco.com

The Whitebark Pine Ecosystem Foundation of Canada has been active in recent months planning ways to build awareness, and waiting with bated breath to hear the results of the SARA (Species at Risk Act) review process. To build awareness we plan on supporting field intiatives, launched a web site and are planning to host our own meeting this summer.

The BC Ministry of Forests Seed Centre recently donated several seed-lots to be planted at several sites throughout the province including Whistler Mountain, Manning Park and near Fort St. James. This is an exciting, albeit small, step forward in getting some restorative planting on the landscape. Many of our members will be involved in these plantings, some of which are to be promoted as public events to raise awareness and get some restoration work completed.

We have recently launched our own Canadian website at whitebarkpine.ca or from the link on the whitebarkfound.org website. Although the site is embryonic at the moment, it has some great content. Check out the video of Boo the grizzly bear at Kicking Horse Resort eating whitebark pine cones.

We are holding our first ever meeting in Lillooet BC on July 14 and 15. The format will be the standard approach of presentations on the first day followed by a field day. The Lillooet area has what may be some of the most intact whitebark pine ecosystems in Canada with lots of healthy whitebark trees. If you have never explored the Lillooet area, consider this a fantastic opportunity to see the aftermath of the large wildfires that swept through the area in recent years and some fantastic geology. We are still building our list of presenters and are hoping to hear from some new research by local grad students on grizzly bear - whitebark use and a large community based restoration project conducted by the Lillooet Tribal Council. For more information contact Randy Moody (randy@keefereco.com) or Don Pigott (ypprop@shaw.ca). ■

Announcing WPEF's 10th Annual Meeting: Cody, Wyoming, September 16-17, 2011

Whitebark pine, the quintessential high-mountain tree in much of western North America is disappearing. Once a keystone species hosting a remarkable ecosystem, whitebark pine is now suffering disease, beetle outbreaks, and ecological and climatic changes, all appearing linked to human activities. Formal endangered status is being considered by both USA and Canada.

Join us at the Buffalo Bill Museum Complex in Cody, Wyoming, for updates on knowledge of whitebark pine ecosystems, the latest research, restoration practices, and a whitebark pine field trip hosted by experts, and all taking place in a delightful setting with exceptional opportunity for interchange of ideas and interests. This meeting will:

- Present the latest news, science, and management tips to public lands staff, students, scientists, educators, and others concerned about natural ecosystems.
- Celebrate the 10th anniversary of the Whitebark Pine Ecosystem Foundation and help spur further interest in these ecosystems.
- Provide an exceptional on-the-ground learning experience by visiting whitebark pine communities with interpretation by experts.
- This annual conference also includes a brief annual membership meeting of the Whitebark Pine Ecosystem Foundation which is open to non-members.

Friday, September 16:
Daytime Presentations: More than a dozen presentations from U.S. and Canadian specialists on issues including ecology, decline status, policy developments, and restoration.
Evening Celebration: Conference attendees and the public are cordially invited to a celebration of the 10th anniversary of the Whitebark Pine Ecosystem Foundation. An attractive non-technical illustrated presentation explains the many values of whitebark pine ecosystems, and we will partake of an anniversary cake and refreshments. (Admission is free.)

Saturday, September 17:
Field Trip: We will venture into the spectacular high-country near Cody to see diverse whitebark pine communities and hear from regional experts about impacts, restoration, and other current topics.

Venue
Meeting headquarters is the Draper Museum of Natural History, part of the impressive Buffalo Bill Historical Center in Cody. The Draper Museum has state-of-the-art natural history exhibits exploring human interaction with the Greater Yellowstone ecosystem (see www.bbhc.org/yellowstone/)
Registration will involve a minimal fee (tentatively $10 or 15) collected at the door.
Presentations Coordinator is Liz Davy, who can be reached at: edavy@fs.fed.us or 208-652-1203. Contact Liz if you would like to offer a presentation about ecological aspects, research, or restoration of whitebark pine or limber pine ecosystems.
Accommodations: Vacancies in Cody can be scarce in late summer, so it is advisable to make reservations early (see www.codychamber.org/visit-cody.cfm?id=9)
Further Information: Contact Michael.Murray@gov.bc.ca (250-825-1173)

Cody, Wyoming, the eastern gateway to Yellowstone National Park, is a small Western town with a friendly attitude. The past is always present in Cody Country. Cody is what the West was, a place where the cowboy culture thrives and where the new west begins. The vistas are spectacular, the land is wild, the people are hospitable and the opportunities for outdoor adventure, recreation, education and entertainment are as large and varied as the Wyoming skies.

Cody Country has a well developed hospitality industry with varied lodging opportunities, fine dining, world class museums and western activities. ■

News Briefs
Nutcracker/Whitebark Publications

The U.S. Forest Service's Pacific Northwest Research Station (PNW) recently released an excellent educational publication entitled *Clark's Nutcracker and Whitebark Pine: Can the Birds Help the Embattled High-Country Pine Survive?* This easy-to-read non-technical article is well illustrated and explains in detail new findings about the role of Clark's Nutcrackers in distributing whitebark pine seeds and providing for successful regeneration. It was published as a PNW *Science Finding* (issue 130; February 2011) and can be downloaded from the PNW web site by clicking on publications, and *Science Findings.*

A scientific article covering the same study findings has just been published:
Teresa J. Lorenz et al. 2011. "Cache-Site Selection in Clark's Nutcracker." *The Auk* 128(2):237-247. A pdf version of the article can be obtained from authors Lorenz <lore5748@vandals.uidaho.edu> or Carol Aubry <caubry@fs.fed.us>.

New 5-Needle Pine Working Group

The first meeting of a working group for land managers in the Northern Continental Divide Ecosystem who manage 5-needle pines was held in November 2010. Fifteen people attended representing several land management units and agencies; Glacier National Park, Waterton Lakes National Park of Canada, Flathead National Forest, Lewis and Clark National Forest and the U.S. Geological Survey along with a U.S. Forest Service regional geneticist.
Goals and opportunities for the group were discussed. There was unanimous support for establishing the working group by all who attended. Benefits discussed included information sharing and collaboration on restoration efforts and funding requests. Opportunities for efficiency were identified such as saving travel time and costs by recertifying Forest Service tree climbers with a National Park climbing instructor. There is a lot of enthusiasm and dedication in the group along with many years of personal experience with 5-needle pine management that can be shared and drawn from.

A major discussion topic at the November meeting was the genetic rust resistance breeding program. The regional geneticist provided detailed information on the roles, responsibilities and requirements for units participating in program. The information provided clarified some of the details of the process and renewed the commitment of the units participating in the program.

The next meeting is scheduled for July 14, 2011 at Whitefish Mountain Resort in Whitefish, Montana. There will be presentations along with a field trip to whitebark pine "plus" trees located on the site. If you are interested in attending the Whitefish meeting or want to find out more about the working group, contact Flathead National Forest Silviculturist, Melissa Jenkins, mmjenkins@fs.fed.us, (406)758-5333.

2011 Whitebark/Limber Pine Data Base

Updating the current version of the **Whitebark/Limber Pines Information System (WLIS)** has started. This effort is part of a larger project, Monitoring on the Margins (MoM), which is a Forest Health Monitoring program initiative for an integrated, enhanced monitoring program for critical ecosystems in areas threatened by insects, disease, and climate change. The MoM proposal is being developed as a template for any species of concern, using high elevation, five needle pines as a pilot for the program initiative. You may recall receiving email notices from Kristen Chadwick and/or Matt Bokach, who are working on other aspects of the MoM proposal.

The update of WLIS is meant to fulfill the need for collating **plot level data** that is available on all high elevation 5-needle pines: whitebark, limber, Rocky Mountain bristlecone, Great Basin bristlecone, foxtail, and southwestern white pines. The intent of this second phase of WLIS is to expand the current version to include the additional species, add new data available on whitebark and limber pines, and to update it as a password-protected internet database. WLIS will still have query capabilities, and will remain GIS linked so mapping will be available to create a visual display of the distribution and general condition of these species. It will remain a plot level summary database- **it is not meant to be a repository for raw data.**

The results from this effort will be a completed searchable database with mapping capabilities for viewing species distribution, known locations of blister rust, overall condition of the species, and obvious gaps in data on the condition of these species.

Please let us know if you have plot level survey information on whitebark, limber, Rocky Mountain bristlecone, Great Basin bristlecone, foxtail, or southwestern white pines that you think should be included in this database. John Popp, Rocky Mountain Research Station, is the person we have hired to collect the survey information and prepare it for input into the improved database. John will be searching the literature for published data, but he will also be seeking out unpublished data. If you have such information, please send an email to John Popp (jpopp@fs.fed.us). John will then contact you directly. If you have questions or concerns about this effort, please contact Blakey Lockman (blockman@fs.fed.us) or Gregg DeNitto (gdenitto@fs.fed.us) directly. Thank you for your time and input!!

If you have not seen the original WLIS, is can be downloaded from the following url: http://www.fs.fed.us/r1-r4/spf/fhp/prog/programs2.html

Wanted: Articles and News Items

Nutcracker Notes invites readers to submit articles about whitebark and the other high-elevation 5-needle pines, including research results or progress reports, commentaries based on observations, and news items. Writing style and guidelines are informal, flexible, and largely at the discretion of the author. Peruse an issue of the magazine for a general impression. Submissions should be understandable to a broad audience. Please minimize use of technical terms and define any that are necessary. Length can vary from a brief announcement to a maximum of about 1200 words. If necessary, the editor can help condense somewhat longer manuscripts. Photographs and relatively simple graphics (in black and white) that accompany articles are welcome. Two issues are produced each year, with deadlines for submission being April 30th and October 31st. Manuscripts should be sent as WORD files to the editor, sfarno@msn.com. ■

Kids Care for Nature [whitebark pine] on Mount Ashland - Johanna Thompson

[Reprinted with Permission from the Mail Tribune*, Medford, OR, July 26, 2010]*

A crew of Rogue Valley eighth- and ninth-graders in hard hats hiked the steep hillside on Mount Ashland, arms full of shovels and pickaxes, bags of compost and tree seedlings. Their goal Thursday morning: plant 19 whitebark pine seedlings at the top of the ridge to help the species survive.

The students are part of the Youth Summer Services Program, a volunteer-based series of one-week work sessions organized by Mount Ashland with the support of the Rogue River-Siskiyou National Forest. Groups of five to 10 young adults from throughout the valley learn about the forest, get community service credit and earn credit for a ski pass for the next season.

"When the kids come to us they've only seen the mountain in the winter as a user," said Ada Rivera, guest services manager. "This program lets them see it as a steward rather than a user." Projects include trash pickup, trail maintenance and forest pruning. Frank Bungay, who will be a freshman at Ashland High School this fall, has participated for two years. "It's pretty sweet," he said. "We work for four days and get $175 toward a pass. I'm a pretty avid snow boarder."

Wayne Rolle, a botanist for the Rogue River-Siskiyou National Forest, showed the students where and how the seedlings should be planted. Rolle said three of the whitebark pines were found on Mount Ashland during research for the ski area's expansion plans. Forest Service crews collected seeds from the cones four years ago, then grew seedlings from the seeds in a greenhouse.

Mount Ashland's expansion will not affect the existing trees, and the site chosen for the new seedlings is outside the expansion area. "The whitebark pine is a common tree, there are plenty, but they are declining," Rolle said. "They are all over Mount Shasta and Mount McLoughlin, but in the Siskiyou Mountains, as far as we know, there are only these three trees. Fifty years ago, if you had looked up here you would have seen many whitebark pines." Rolle attributed the decline to blister rust, a pathogen that was introduced in the early 1900s. The older trees are not killed by the pathogen, but a blister rust canker can girdle younger trees, starving them of nutrition and killing them.

At the top the ridge, the students dug 19 holes for the seedlings, sometimes sharing shovels and pickaxes, sometimes using just their hands. Their work for the week will earn them 20 hours of community service. On Monday, a new group of students will take over. ■

Whitebark Pine Fund-Raising Party

Edie Dooley

Last December 4th was a win-win day for whitebark pines and holiday celebrators. Master's students in the University of Montana's College of Forestry and Conservation (CFC) Katie Jorgensen, Megan Keville and Edie Dooley, hosted the Whitebark Pine Holiday Benefit Bash to which all graduate students and faculty of CFC were invited. Megan and I are attending CFC on a USDA National Needs Fellowship to study the disturbance ecology of whitebark pine, and Katie has been a whitebark fan ever since she first skied among them at Mammoth Mountain, CA. We realized that if we were going to make the effort to get the department together to celebrate the holidays, why not raise some money for a cause we all care about: whitebark pine restoration! So that is what we did. On the way back from my last whitebark field site visit of 2010, I told my advisor, Dr. Diana Six, of our plans for the whitebark fundraiser. She loved the idea and immediately offered to donate the keg of local Big Sky Amber Ale.

The potluck party was a great success with more food than could even fit on the table space. Overall about 70 people attended. Bob and Liz Keane brought a whitebark pine cake *[see photo on back cover]*, and also some hats, t-shirts and puzzles from the Whitebark Pine Ecosystem Foundation which we raffled off. Other whitebark pine researchers in attendance were Carl Fiedler and Diana Six. Adorning the wall were pictures of whitebarks that I had taken in my first field season. Some were beautiful, but most showed the true story of large swaths of beetle killed trees, and sordid, weeping blister rust cankers.

These photos, along with a glued whitebark pine puzzle helped to explain the importance and plight of whitebark pine ecosystems to partiers who were not aware. From the sale of raffle tickets and donations, we raised $200 for the foundation with the stipulation that the money be used solely for planting rust-resistant whitebark pine out in the landscape. Thank you to the foundation for donating the hats and t-shirts which allowed us to have the raffle. This party was a great illustration of the fact that while the whitebark pine situation may be bleak, it won't stop us from having fun educating others, and working for the cause of whitebark pine conservation! ■

Using Verbenone to Protect Whitebark Pine from Mountain Pine Beetle Attack-- the quest for a silver bullet

Sandra Kegley, U.S.F.S. Entomologist
Coeur d'Alene, ID

Verbenone is a natural anti-aggregation pheromone produced by mountain pine beetles (MPB) to prevent overcrowding in attacked trees. Verbenone gives a "no vacancy" signal to other MPB in the area causing them to avoid an already fully colonized tree. Since 1988, synthesized verbenone has been tested in protecting susceptible pines from MPB attack using several different releasers. Inconsistent performance during field trials required improvement of release devises and has resulted in three products currently registered with the Environmental Protection Agency—two pouch formulations, each containing seven grams of verbenone, that are stapled to tree boles (fig. 1) (available from Synergy Semiochemicals and Contech Enterprises, Inc.), and a laminated plastic flake formulation (fig. 2) (available from Hercon Environmental) that is aerially applied or applied on the ground using fertilizer spreaders.

Currently registered 7-gram verbenone pouches, placed two per whitebark pine, were tested for several years in northern Idaho and western Montana. In those tests, verbenone consistently protected 80% or more treated trees, even when using tree baits to lure beetles to the treated trees. Test plots were located in areas with high MPB populations. However, testing verbenone to protect limber pine on dry habitats in Colorado resulted in only 27 to 66 percent protection depending on the site (Sheryl Costello, personal communication). Similarly, in whitebark pine on dry sites in central Idaho, about 60% of verbenone treated trees were still alive after being treated annually for five years during a MPB outbreak (Dana Perkins, personal communication). In all these tests, untreated control trees suffered far greater mortality than verbenone treated trees.

Verbenone-releasing laminated flake formulations aerially applied to lodgepole and whitebark pine stands have reduced MPB attack over large areas. These small flakes allow verbenone to be released from many different points compared to pouches. Because of the possible increased efficacy of these multiple releasing points, tests were conducted applying flakes directly to tree boles. Results showed similar efficacy to pouches in protecting individual whitebark and limber pine, but not greater protection. With the labor intensive method of applying flakes with a sticker to individual tree boles, flakes are recommended for aerial, not individual tree applications.

Figure 2. Verbenone plastic polymer flakes.

Figure 1. Verbenone pouches on whitebark pine.

Non-host green leaf volatiles (GLVs) (a hexenol/hexanol blend present in many broadleaf plants), have also been shown to deter MPB. GLVs combined with reduced amounts of verbenone in either pouch or flake formulations have shown similar or greater protection of whitebark, lodgepole and ponderosa pine compared to using verbenone alone. Although not yet registered, non-host GLVs are much less expensive than verbenone and have the potential to decrease the cost of verbenone treatments. Registration is currently being pursued.

Verbenone has been used operationally in many areas to protect high-value, cone bearing, phenotypically blister rust resistant whitebark pine. However, there have been disappointing results in some areas with extreme MPB populations. Protection of lodgepole pine has been improved by removing currently infested trees in areas of concern. A similar strategy could be considered for increasing protection in accessible whitebark pine forests.

The use of verbenone in protecting pine trees from MPB appears to be more of an "art" than a "science" and there is no "cookbook" approach applicable for all situations. General recommendations for individual tree protection are to use two pouches per tree, placed on the north side of susceptible trees. It would be prudent to concentrate efforts on trees that are not infected with white pine blister rust. Unusually warm years may require replacing pouches at mid-season or using more pouches per tree. This also might be considered on warm, dry sites. The clumpy nature of whitebark pine that results in multiple stems in close proximity to each other may necessitate using additional pouches in each clump. Surrounding clumps of whitebark pine with verbenone pouches has successfully protected trees in some areas.

Verbenone is not the long-sought "silver bullet" and has never protected 100% of individual trees or areas of susceptible hosts where it's been applied. However, it certainly protects more trees than doing nothing at all. With the alarming decline of whitebark pine due to multiple factors, one could argue that any tree protected from MPB justifies the use of verbenone. Verbenone should be recognized as another tool useful in reducing beetle-caused mortality (particularly with developing populations) in the short term, with the understanding that environmental conditions and extreme beetle populations may decrease its effectiveness. ■

Bark Beetles, Fuels and Fires in High-Elevation Pine Forests

Michael Jenkins, Professor
Utah State University

Bark beetles in the genus *Dendroctonus* are native insects that play an important role in western North American coniferous forest ecosystems. At low population levels bark beetles infest large, old, often injured trees, thus recycling nutrients and creating openings for regeneration. When landscapes are composed of many susceptible host trees eruptive outbreaks are possible, especially during warm, dry periods which weakens otherwise vigorous trees and decreases bark beetle development time. Episodic bark beetle outbreaks have been a common feature of coniferous forests at least since the last glacial retreat about 13,000 years ago. New evidence, however, supports the hypothesis that anthropogenic forcing of global temperatures has increased the vulnerability of whitebark pine to mountain pine beetle MPB (*D. ponderosae* Hopkins) attack and bark beetle population potential (Bentz et al. 2010).

It is equally important to note, however, that bark beetle outbreaks are not possible without susceptible stands which are usually dense stands comprised of a large percentage (>60%) of mature, large diameter host trees. Changes to fuels complexes and fire behavior due to 20th century fire suppression and exclusion policies, livestock grazing and a more recent decrease in active timber management has created an abundance of large, old conifers in western North America. Baker (2009) suggested that the rash of large, human-caused wildfires in the late 1800s may have also contributed to susceptible landscapes. As a result, dramatic bark beetle outbreaks have occurred during the last 20-30 years involving spruce beetle (*D. rufipennis* Kirby) in Engelmann spruce, Douglas-fir beetle (*D. pseudotsugae* Hopkins) in Douglas-fir and mountain pine beetle in lodgepole pine (USDA 2009). Since about 2000 mountain pine beetle-caused tree mortality has increased in whitebark and limber pines and it is reasonable to assume that susceptible stands of other high-elevation, five-needle white pines are also at risk.

Bark beetles are one of few native agents in nature capable of rapidly altering the quality of coniferous forest vegetation over large spatial scales. The effect of the altered fuel complex on the principle fire behavior descriptors including rate of spread, fireline intensity and flame length over the course of a bark beetle rotation in Engelmann spruce, lodgepole pine and Douglas-fir was described by Jenkins and others (2008). However, little research has been conducted to describe the relationship between bark beetle-caused tree mortality and wildfire in other forest systems, particularly for high-elevation five-needled pine species.

The most important influence of bark beetle-caused tree mortality on fire behavior is the reduction in sheltering that occurs as crown bulk density decreases. The opened canopy allows for greater solar insolation and dryer fuels, and increased mid-flame wind speeds (Page and Jenkins 2007a). The combined effect of increased fine fuels with reduced foliar moisture content and increased wind speed during the epidemic phase is an increase in fireline intensity under moderate fire weather conditions (Page and Jenkins 2007b). The increase in the amount and depth of litter and fine woody fuel increases the probability of ignition under bark beetle killed trees.

Coarse woody fuel accumulation and the increase in fuel bed depth that occur during the post-epidemic phase do not influence fire ignition or spread, but may add to surface fire energy release especially during periods of drought. The coarse woody fuel contained in standing snags may contribute to an increased period of flammability and fireline intensity when the site is shared with advanced regeneration in the decades following the outbreak.

High intensity, stand-replacing crown fires are a common feature of conifer forests in western North America, with or without bark beetle-altered canopy fuels. Where high-elevation five-needle pines form climax forests and fuels are discontinuous and sparse, low intensity surface fires have been characteristic. At lower elevations where five-needle pines are seral and grow with other conifers, a mixed severity fire regime may be more common (Arno and Hoff 1990; Agee 1994). Real-time fire weather characterized by low relative humidity, high wind speeds, and low fuel moisture across live and dead fuel classes will dominate fire behavior regardless of fuel bed characteristics (Bessie and Johnson 1995). However, bark beetle-affected fuels may create conditions capable of producing high-intensity surface fires with the ability to transition to crown fires across a wider range of fire weather conditions. This is particularly true at higher elevations where narrow fire weather conditions exist due to a shorter snow-free period, higher relative humidity, and lower temperatures. In all cases fire occurrence and intensity will be determined by the combination of the weather at the time of ignition and the nature of the fuel complex.

The infinite array and complex assemblages of coniferous species, bark beetle-altered fuels condition classes, and the activity of other biotic and abiotic disturbance agents over complex terrain and large spatial and long temporal landscape scales also complicates potential fire behavior. Disturbance agents alter the landscape-scale fuel complex which may affect actual fire spread, severity and intensity within the affected landscape.

The specific pattern and size of the affected area also has the ability to alter fire intensity and severity beyond the affected area.

The potential for crown fire in high-elevation, five-needle pines is greatest in mixed, transitional forests at lower elevations where five-needle pines are a minor seral species in stands composed of lodgepole pine, Douglas-fir and/or true firs (*Abies* spp.) and Engelmann spruce. In these forests, hazardous fuel pathways may have resulted from; 1) the suppression and exclusion of fire; 2) recent mountain pine beetle outbreaks that developed in pine types at lower elevations and spread up into pure five-needle pine stands; 3) bark beetle outbreaks triggered by drought in the numerous susceptible stands of Douglas-fir and Engelmann spruce; 4) vertical fuel ladders resulting from cyclic western spruce budworm, *Choristoneura occidentalis*, outbreaks affecting true firs and Douglas-fir; and 5) other agents of disturbance including dwarf mistletoes (*Arceuthobium spp*), root pathogens and rust fungi that are increasingly common in overmature conifer forests characteristic of the fire suppression era. The net result is a variably flammable, disturbance-altered complex of surface, ladder, and canopy fuels that may extend up in elevation to stands where high-elevation five-needle pines are a major seral or climax species.

In climax high-elevation, five-needle pine stands, surface and crown fire flammability are probably more closely governed by the mountain pine beetle-induced surface and canopy fuel changes. Climax stands are generally fire-prone only during the period in the bark beetle rotation when green-infested, yellow and red crown classes share the canopy with green trees. As gray trees become dominant, shrubs and forbs increase, crown base height increases in the absence of conifer reproduction, canopy fuels decrease and fire potential is reduced. Climax high-elevation, five-needle pine stands are most vulnerable to high intensity, high severity fires where extensive landscapes of disturbance-altered, mixed conifer fuels exist at lower elevations.

Literature Cited

Agee, James K. 1994. Fire and weather disturbances in terrestrial ecosystems of the eastern Cascades. Gen. Tech. Rep. PNW-GTR-320. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 52 p.

Arno, Stephen F.; Hoff, Raymond J. 1990. Pinus albicaulis Engelm. whitebark pine. In: Burns, Russell M.; Honkala, Barbara H., technical coordinators. Silvics of North America. Volume 1. Conifers. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 268-279.

Baker. W.L. 2009. Fire ecology in Rocky Mountain Landscapes. Island Press. 605 pp.

Bentz, B.J., J. Régniére, C.J. Fettig, E.M. Hansen, J.L. Hayes, J.A. Hicke, R.G. Kelsey, J.F. Négron and S.J. Seybold. 2010. Climate Change and Bark Beetles of the Western United States and Canada: Direct and Indirect Effects. BioScience 60: 602–613.2010

Bessie, W.C. and E.A. Johnson. 1995. The relative importance of fuels and weather of fire behavior in subalpine forests. Ecol. 76:747-762.

Jenkins, M.J., Hebertson, E., Page, W., Jorgensen, C.A., 2008. Bark beetles, fuels, fires
and implications for forest management in the Intermountain West. Forest Ecol.
Manage. 254, 16–34.

Page, W.G., Jenkins, M.J., 2007a. Mountain pine beetle induced changes to selected lodgepole pine fuel complexes within the Intermountain region. For. Sci. 53 (4), 507–518.

Page, W.G., Jenkins, M.J., 2007b. Predicted fire behavior in selected mountain pine beetle infested lodgepole pine stands within the Intermountain region. For. Sci. 53 (6), 662-674.

***[Editor's Note:** See also the Associated Press article (5-3-11) "New study shows beetle-killed trees ignite faster" at* http://tinyurl.com/3nggugz*]* ■

The Economics of Blister Rust Management

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Traditional invasive species management plans focus on prevention, early detection, and eradication or containment of the pest. If such efforts are unsuccessful, damage mitigation and potential restoration of the ecosystem usually follows. However, in the case of *Cronartium ribicola*, the invasive fungus that causes White Pine Blister Rust (WPBR), neither prevention, eradication, nor containment has proven successful. This has led to growing interest in "proactive" management, in which intervention into the forest ecosystem takes place prior to the arrival of the pest. The idea is to "prepare the battlefield" for the inevitable invasion...in the case of WPBR, to increase the proportion of genetic resistance to the disease within a given stand in order to ensure the continued survival of the reproductive cycle over time.

This article reports the preliminary results from an investigation into the economics of proactive management in the context of WPBR. The research, part of a larger project funded by the USDA's Program of Research on the Economics of Invasive Species Management (PREISM), uses a spatially-explicit stochastic dynamic programming model to explore the optimal timing of intervention, subject to the evolution of the forest ecosystem, the spread of the fungus, and constrained budgets. Results suggest that proactive management can indeed be optimal from an economic standpoint when spatial configuration is explicit, but depends on stand/forest benefits, management costs, and the probabilities associated with pathogen spread.

Methodology and Assumptions

Assume that a sole resource manager chooses costly management intervention into an *N* stand forest threatened by an uncontrollable, stochastically-spreading pest like *Cronartium ribicola*. The state of each stand in the forest is represented by a particular flow of ecosystem service benefits associated with a discrete level of forest "health", such that benefits are inversely related with health. At any point, a stand may be infected or uninfected by WPBR, as well as treated or untreated by the manager. An uninfected, untreated stand is assumed to remain in that state until infection occurs. Once infected, the stand degrades (ecosystem service benefits decline) over time to a steady state of low benefits in the absence of management action. However, if the manger intervenes, the stand is then treated and ecosystem service benefits gradually recover and are maintained at the uninfected level in perpetuity. Only one treatment method is available to the manager, and it is assumed to be 100% effective, in that the stand will regain benefits over time, and will not degrade at any time in the future. Intervention may occur at any time, including in forest stands that have not been degraded (the maintained definition of proactive management for this article), but is costly and is limited to a certain number of stands per period (a budget constraint). Per stand treatment costs are assumed to be increasing in the health of the forest.

Spread of the invasive is assumed independent of management actions, and is probabilistic and directional in spread. The probability of any stand in the forest becoming infected is increasing in the number of infected neighboring stands, which allows for probabilities that vary with the spatial configuration of the forest, the assumption regarding direction of spread, and the intensity of the WPBR infection status of the forest as a whole.

Behaviorally, the manager is assumed to maximize the expected net present value of the forest over an infinite time horizon, subject to the budget constraint and the evolution of the forest. The net present value of the forest is assumed to be additive across stands, and stands are assumed to be homogeneous (identical benefit and cost schedules). The manager is assumed to have a positive discount rate.

Results

The model was solved to obtain optimal management strategies under a number of assumptions and parameter values assuming N=4. The most simple specification assumed that a stand will be infected in period t+1 if at least one neighboring stand is infected at time t, which renders the model deterministic. Relaxation of this constraint to allow for probabilistic spread resulted in only small changes in the optimal policy rules; as such, the results documented here pertain to the deterministic formulation.

Frequency of Proactive Management under Differing Budget Constraints

The relative frequency of optimal proactive management decisions can be calculated by dividing the number of times it is optimal to intervene into a healthy, uninfected stand by the number of possible forest configurations with a healthy, uninfected stand. If the budget constraint is such that only one stand per time period can be treated, a proactive strategy is optimal for 13% (145 of 1,105) of potential forest configurations. In most of these cases, intervention is for an immediately threatened stand, with the rest of the forest either healthy or already treated. Economically, this strategy is optimal because the opportunity costs of treating a stand proactively are small due to the surrounding conditions.

If the constraint is relaxed to allow for two stands to be treated in a given period, the proportion of optimal proactive strategies increases to 41%, and includes cases where 2 stands have been infected but one of these has already been treated. However, the manger must trade off against the benefits gained from reactive management when there are two actively degrading stands. As such, while proactive management can be optimal under a variety of budget scenarios, it is not always the preferred strategy.

The Effect of Discounting

The process of discounting net benefits across future time periods is standard in dynamic economic analysis, and represents the opportunity cost of capital and any risk premium that may exist. The baseline parameterization of the dynamic management model assumed a discount factor (1/(1+r)) of .9, or a discount rate of r=0.11 over time periods. Note that identification of the appropriate discount rate is confounded by a) the relatively long length of time implied by the time step in the management model (how long it takes for a forest stand to degrade and/or recover); and b) the interest in managers of public lands to value outcomes far in the future. The point in a) tends to argue for a relatively high discount rate in the model, while b) suggests a lower rate.

Model results conform with expectations that a higher discount rate reduces the incentives for proactive management. At very high discount rates (corresponding to discount factors less than 0.6), optimal management strategies are to treat only fully degraded stands. However, proactive management makes up a small percentage (<1%) of optimal strategies for discount factors between .6 and .7, and are unchanged from the baseline scenarios for higher factors (lower rates). As such, so long as there are reasonably high weights on future benefits and costs, proactive management strategies are part of optimal forest management.

Changes in Benefits and Costs

Economically, the relative shape and magnitude of the benefit and cost schedule with respect to forest health is an important determinant of optimal management strategies. To illustrate, consider a case where the cost of treatment doubles for healthy stands relative to the baseline case, but is cut in half for fully degraded stands, thus increasing the marginal cost of intervention into a healthy forest. Interestingly, the solution to this new parameterization results in an *increase* in the relative frequency of proactive management strategies to 57% of the total, despite the increase in the cost of such actions. What, then, explains this rather unintuitive result?

The answer lies in the opportunity costs of treatment, which is determined by the relative magnitudes of marginal benefits and costs of treatment over time. In this case, one can show that the marginal benefits from pursuing a proactive rather than reactive strategy allows the manager to capture some (discounted) benefits of the reduction in stand treatment costs as an infected stand degrades in the next period, which outweighs the loss of ecosystem benefits from that degradation. In addition, s/he gains protection for the proactively treated stand, which is valued into the future. As such, we illustrate that proactive management strategies are more favorable when the costs of stand treatment are increasing rather rapidly in stand health, and conversely, when benefits are relatively constant across potential states.

Conclusions

This research helps document the conditions under which proactive management is generally preferred over more reactive strategies. In short, proactive action is generally more attractive when: a) budgets are larger; b) the discount rate (factor) is low (high); and c) treatment costs are rapidly increasing in forest health. Future research will use this general structure in conjunction with collected benefit and cost data on high elevation pine forests in the western United States to build and solve more realistic models to help inform and improve management in the face of this invasive threat. ■

Efficient Whitebark Pine Seed Collection

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It is no secret that funding for restoring whitebark pine is limited, especially in Canada. With so few dollars to go around, we need to be sure that the limited resources get used in the most efficient manner possible. Whitebark pine stands are often difficult to access in areas where roads are confined to the valley bottoms, so when stands need to be visited, long slogs up steep terrain or expensive helicopter time is required. Currently, when collecting seeds for research or restoration purposes, stands must be visited at least twice if cages are to be placed over the cones to protect them from harvest by wildlife. Usually the first trip to the subalpine area is to locate and identify healthy trees that show some resistance to white pine blister rust and have a cone crop that is accessible. If the timing is right, cages can then be placed over the cones, either by climbing the tree, or using tree tongs [see photo and article in *Nutcr. Notes No. 9,* Fall/Winter 2005, accessible at www.whitebarkfound.org]. The stands must then be accessed for a second time to remove the cages and collect the cones at the end of the growing season when the seeds have matured.

It would be so much easier, faster and less expensive if we were able to go to the stands only once, earlier in the season, before all the cones have been harvested by wildlife and collect them without the need for cages. After several years of scrambling around the Canadian Rocky Mountain National Parks looking for whitebark, Dr. Brendan Wilson and I wanted to be sure that the added time and expense of repeated visits to the same site was necessary, and to ensure that when cones were collected, it was done at a time when the maximum germination potential was realized.

Methods

We selected ten trees in a healthy stand of whitebark pine about 20 km north of Lake Louise, in Banff National Park, Alberta, to collect cones and monitor wildlife harvest. In late June, before red squirrels and Clark's nutcrackers started harvesting cones, we placed cages over half of the cone bearing branches. Every 10 to 12 days until late September, we returned to the stand to count the number of unprotected cones that remained unharvested by wildlife, and to collect a subsample of cones from the caged branches. The following winter, we put all the collected seeds through a stratification process outlined by Burr, Eramian and Eggleston (2001) then attempted to germinate them in a climate-controlled greenhouse. This gave us data on both the timing of wildlife harvest, and the rate of seed germination throughout the growing season.

Results and Discussion

Our results clearly show that caging cones is necessary in order to collect viable whitebark pine cones (Figure 1). Seeds did not start to become viable until early August, by which time nearly all of the unprotected cones were gone.

While our study area had low blister rust infection rates, the cone crop was relatively poor when compared to previous years. In years of abundant cone availability, wildlife harvest may occur at a slower rate, leaving some viable cones available for collection later in the season (McKinney and Tomback, 2007). However, if cones are to be collected from trees that are resistant to white pine blister rust, they will likely be found in heavily infected stands where there are few cones available (Mahalovich and Dickerson, 2004). This suggests that the cone crop in our study area may have mimicked the cone availability in areas that will be used for cone collecting for restoration work, and that similar wildlife harvest rates are likely.

Timing of seed maturation will vary from location to location, and between years as conditions vary. Therefore, the dates of wildlife harvest and germination rates may vary considerably, so perhaps the more important thing to look at is the morphology of the cones and seeds rather than the dates presented here. Following cone collections, a subset of seeds from each collection was dissected in the lab and morphological attributes such as the length of the megagametophyte and embryo size were measured. However, we found that the simplest and most useful indication of seed viability was the physical description of the cones at the time of collection.

Cones that contained seeds that were not viable were purple-red in colour, very sticky, and cone scales were extremely difficult to pull apart. Once cone scales were pulled apart, cone scale tissues remained attached to the seed coat. The seed coat was soft and could be easily sliced in half to expose megagametophyte tissue, which was clear white and shrunk away from the seed coat.

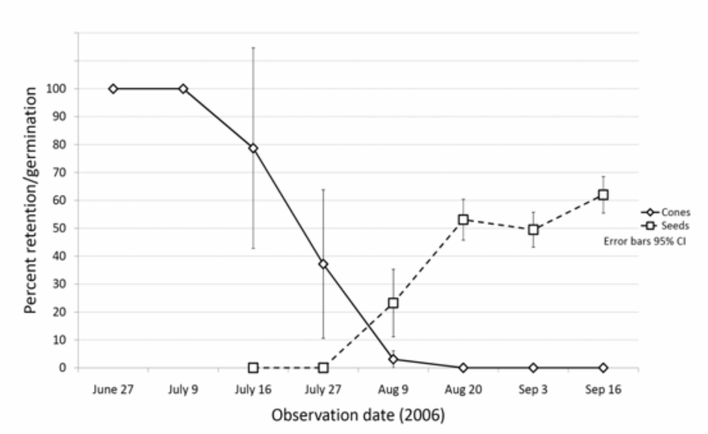
By the time the seeds reached their maximum viability (August 20th during this study) the cone were brown and scales could be removed with less difficulty. The seeds were light red, could be removed easily from the cone, and no cone scale tissue remained attached to the seed coat. Although the germination rates did not increase significantly past the August 20th collection, extracting the seeds did become much easier. By mid-September the cones were much less sticky, and the scales had opened slightly, exposing the red-brown seeds that were almost falling out of the cone.

Conclusion

The take home message is that caging is necessary, and that for ease of seed extraction, cones should be left on the trees as long as practicable, although they can be removed earlier, if necessary. A quick examination of a few cones in the field should indicate if the seeds they contain are viable. For more details, see the article entitled "No free lunch: Observations on seed predation, cone collection, and controlled germination of whitebark pine from the Canadian Rockies" by Leslie and Wilson in the upcoming Proceedings of the High-Five Pine Symposium.

Lessons learned in this study will be used as seed collection efforts expand to areas outside our National Parks in the summer of 2011. We hope to locate more parent trees, grow some greenhouse seedlings, and begin a restoration trial to see if those limited funding dollars can be used even more effectively by planting seeds directly in the ground.

Figure 1: Comparison between the observed percent of cones remaining on study trees to success of seeds germinating from seedlots harvested at the same time as the observations.



References:

Burr, Karen E.; Eramian, Aram; and Eggleston, Kent. 2001. Growing whitebark pine seedlings for restoration. In: Tomback, Diana F.; Arno, Stephen F.; Keane, Robert E., eds. Whitebark pine communities: ecology and restoration. Washington, DC. Island Press: 325-345.

Mahalovich, M.F.; Dickerson, G.A. 2004. Whitebark pine genetic restoration program for the intermounain west (United States). In: Sniezko, Richard A.; Samman, Safiya; Schlarbaum, Scott E.; Kriebel, Howard B. eds. Breeding and genetic resources of five-needle pines: growth, adaptability and pest resistance. 2001 July 23-27; Medford, OR. Proceedings RMRS-P-32 Fort Collins, CO: USDA: 181-187.

McKinney Shawn T.; Tomback Diana F. 2007. The influence of white pine blister rust on seed dispersal in whitebark pine. Canadian Journal of Forest Research. 37(6): 1044-1057. ■

Conservation Genetics of High-Elevation Five-Needle Pines

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There are six species of high elevation five-needle white pines widely distributed across much of western North America; whitebark pine (*Pinus albicaulis*), limber pine (*P. flexilis*), southwestern white pine (*P. strobiformis*), foxtail pine (*P. balfouriana*), Great Basin bristlecone pine (*P. longaeva*), and Rocky Mountain bristlecone pine (*P. aristata*). All face conservation challenges such as habitat fragmentation, introduced disease and insect pests, the effects of fire suppression, and climate change (Tomback and Achuff 2010). They have low timber value, yet they have high ecological value; and they are all susceptible to the introduced disease white pine blister rust (Schoettle and Sniezko 2007). Potential range shifts resulting from global climate change pose an additional threat to these high elevation species, as in the future suitable climates may only occur above the mountaintops (Warwell et al. 2007). The impacts of blister rust differ by species and also within the geographic range of each species (Schoettle and Sniezko 2007). The combined impacts of these threats have necessitated active management and conservation activities for all of these species, including management and conservation of genetic diversity.

Why is Genetic Diversity Important?

Conservation of genetic diversity has become a priority for many species. Genetic diversity can be used to identify unique subspecies or populations. For example, these may be populations that have been geographically isolated for a long time and have diverged from each other by adapting to their local environments. Genetic diversity provides the raw materials for adaptation to changing environments. Maintaining high levels of genetic diversity is also important because it may help offset the generally harmful effects of inbreeding depression (Altizer et al. 2003; Spielman et al. 2004). Maintenance of genetic diversity and knowledge of the distribution of genetic variation in traits related to adaptation is important in developing guidelines for the movement of seed in reforestation by way of developing appropriate seed transfer guidelines. It will be especially important in predicting the potential effects of climate change.

Types of Genetic Conservation

Genetic conservation approaches may be categorized as either *in situ* or *ex situ*. *In situ* conservation means that genetic resources are protected within a species' natural habitat. This type of conservation is relatively inexpensive and simple, and includes protected areas where management activities are limited. The network of currently existing reserves serve *in situ* conservation purposes well; however, there are risks associated with this conservation strategy. Large-scale disturbances, such as fires, disease, and insect outbreaks, could potentially wipe out large areas of protected habitat. In *ex situ* gene conservation, the resources are protected outside their natural environment. This includes seed orchards, clone banks, long-term seed storage, and cryopreservation (low temperature storage). While more secure in some respects, *ex situ* gene conservation can be costly and requires sampling, preferably range-wide, in order to capture as much of the existing genetic diversity as possible. This method focuses on long-term storage and contingency usage of the seed, and does not explicitly accommodate the ecological processes or linkages among species inherent with *in situ* conservation approaches.

Genetic Diversity and Population Structure

While the genetics of some of these species have been well studied, large information gaps remain regarding the genetic diversity and population structure of others. This information is crucial for the development of management strategies designed to conserve genetic diversity. To date, most assessments of genetic diversity have utilized genetic markers such as proteins or small bits of DNA. Genetic diversity (expected heterozygosity, H_e) for these species is generally at or below the average of other widespread western North American conifers. However, there is a great deal of variation among species, both in the number and the range of published values. For instance, a value reported for Great Basin bristlecone pine is one of the highest observed in any conifer, while reports for its closest relative, Rocky Mountain bristlecone pine, have been low. Population differentiation (F_{ST} or G_{ST}) also varies considerably among species. Pines with bird-dispersed seed on average exhibit levels of population differentiation only one third of those with wind-dispersed seed, due to the more efficient mechanism of seed dispersal leading to population homogenization (Bruederle et al. 2001). Whitebark and limber pine both rely on the Clark's Nutcracker for seed dispersal, and have relatively low levels of population differentiation. The other species have average or above levels of population differentiation, possibly due to their patchy and discontinuous distributions on mountaintops across large areas.

Genetic Management

Gene conservation strategies have been developed and implemented for whitebark and Rocky Mountain bristlecone pines. The Pacific Northwest Region of the USDA Forest Service developed a restoration strategy for whitebark pine in Oregon and Washington (Aubry et al. 2008) and a range-wide restoration strategy is in development (Keane et al. *In preparation*), and extensive seed collections have been made for whitebark pine and Rocky Mountain bristlecone pine. In some instances, the threats to the high-elevation five-needle pine species are acute, while other threats are more slow acting. Nevertheless, all of these species are vulnerable to population declines, and active management is necessary to preserve the existing genetic resources and restore degraded populations. Extensive gene conservation efforts are under way for most high elevation five-needle pine species. Development of blister rust resistant planting stock is a crucial part of a restoration plan for any of these species and rust resistance trials are under way for all of them. Rust resistance screening has identified some resistance in all of these species, including a hypersensitive reaction type of resistance they conveys immunity in several species (Kinloch and Dupper 2002).

Knowledge Gaps

Knowledge gaps regarding the conservation genetics of these high elevation pines include:

Range wide genetic diversity and population structure of *P. longaeva* and *P. strobiformis*,
Genetic variation of traits important for local adaptation of all species except *P. albicaulis* (results of several species are forthcoming).
Potential impacts of climate change.
Levels, types, durability of white pine blister rust resistance.

Future Research Needs

Understanding the genetics of these species will be helpful in developing and implementing strategies for the conservation and restoration of these species to minimize the negative consequences of blister rust and climate change, in particular. The following research and conservation needs have been identified:
Further investigate the ability of different populations to withstand warming temperatures using *in situ* and *ex situ* common garden experiments
Continue screening for rust-resistant individuals and populations that can be used for restoration planting
Establish policy frameworks regarding whether and how to assist the migration of species threatened to be extirpated within their current ranges
Establish conservation strategies for species currently without them

*[**Editor's Note:** a more detailed version of this article will soon appear in the Proceedings of the High Five Symposium, USDA Forest Service, Rocky Mountain Research Station, RMRS-P-63, available at*: http://www.fs.fed.us/rm/publications/titles/rmrs_proceedings.html*]*

References

Altizer, S., D. Harvell, et al. (2003). "Rapid evolutionary dynamics and disease threats to biodiversity." Trends in Ecology & Evolution **18**(11): 589-596.
Aubry, C., D. Goheen, et al. (2008). Whitebark pine restoration strategy for the Pacific Northwest Region, 2009-2013, USDA Forest Service, Pacific Northwest Region.
Bruederle, L. P., D. L. Rogers, et al. (2001). Population and evolutionary implications. *In* D. F. Tomback, S. F. Arno & R. E. Keane [eds.]. Whitebark Pine Communities; ecology and restoration. Washington, D.C., Island Press.
Keane, R. E., D. Tomback, et al. (In preparation). "A range-wide restoration strategy for whitebark pine (Pinus albicaulis). General Technical Report RMRS-GTR-XXX. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 183 pp.".
Kinloch, B. B., Jr. and G. E. Dupper (2002). "Genetic specificity in the white pine–blister rust pathosystem." *Phytopathology* **92**: 278-280.
Schoettle, A. W. and R. A. Sniezko (2007). "Proactive intervention to sustain high-elevation pine ecosystems threatened by white pine blister rust." Journal of Forest Research **12**(5): 327-336.
Spielman, D., B. W. Brook, et al. (2004). "Does inbreeding

and loss of genetic diversity decrease disease resistance?" Conservation Genetics **5**(4): 439-448.
Tomback, D. F. and P. Achuff (2010). "Blister rust and western forest biodiversity: ecology, values and outlook for white pines." Forest Pathology **40**(3-4): 186-225.
Warwell, M. V., G. E. Rehfeldt, et al. (2007). Modelling contemporary climate profiles and predicting their responses to global warming for whitebark pine *(Pinus albicaulis)* Proceedings of the conference whitebark pine: a Pacific Coast perspective, 2006 August 27-31. Ashland, OR, Pacific Northwest Region, Forest Service, U.S. Department of Agriculture. ■

Sprayer Protects Back-Country Pines

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In the past decade, whitebark pine trees have been killed in massive numbers by mountain pine beetles. Pheromones and insecticides are both used to protect high value whitebark pines, with the insecticide carbaryl being the most effective at protecting trees, especially during major beetle outbreaks. Not only are the pheromones less effective than carbaryl, they must be applied annually versus applications every other year with the insecticide. Carbaryl does have its drawbacks. Because it is an insecticide, application may not be allowed under some land management direction. It also cannot be applied close to water. Detailed information about protecting trees with carbaryl is explained in the paper: "Individual Tree Protection Using Carbaryl Insecticide for Western Conifer-Infesting Bark Beetles", published by USDA Forest Service, Forest Health Protection, Intermountain and Northern Regions, June 2009. This publication discusses how to apply carbaryl effectively and some of the restrictions of its use http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5155228.pdf

Protection of cone-bearing whitebark pine is often a critical part of restoration efforts. Individual whitebark pine that are determined to have rust resistance will have cone bearing branches removed and grafted on to root stock to establish seed orchards. It is critical that we keep the trees alive until the rust screening process has been completed. Other high value whitebark pine such as those at ski areas or in areas that are targeted for operational cone collections are also a high priority for protection from bark beetles.

When whitebark pine is growing in remote locations, protecting them with insecticide has not been practical in the past. Equipment capable of spraying to adequate heights that is portable over steep, rough terrain has not been available. A proposal to develop portable spray equipment capable of spraying remote whitebark trees was submitted to Forest Service Technology & Development in 2009. The request was for: 1) a lightweight system that is compatible with the chemical pesticides that are needed to protect high value trees from the mountain pine beetle, 2) high altitude performance to meet spray height requirements specified by the entomologists, and 3) accessibility to get the system into rough, remote locations.

In response to the proposal, Missoula Technology and Development Center (MTDC) invented a spray system consisting of an engine/pump module that is compact, portable, and capable of spraying 35 or more feet vertically at 10,000 feet elevation. A compact mixing system permits continual agitation of the chemical mixture. A state-of-the-art diaphragm pump can handle a wide range of pesticides as well as suspended solids. Drip-less, quick-connect fittings are included to reduce chance of toxic spills. The system components can be mounted on an ATV or UTV. In less accessible areas, horses or mules can be utilized **[see photo on back cover]**. The system components can also be transported into the backcountry via human power with a game cart or specialized stretcher handles. The system is designed to safely mix regulated chemicals in the field using local water supplies or water that is brought in.

The system was tested in a field trial on the Flathead National Forest June 21-23, 2010. MTDC supplied the prototype sprayer system. A private certified pesticide applicator was hired to use the prototype system to apply carbaryl to seventeen phenotypically blister rust resistant whitebark pines that were widely dispersed over the site. The mules were supplied by the Hungry Horse Ranger District. The Forest Service supplied four employees to help move equipment and supplies around the slopes. Water was supplied from a five gallon "cubitainer" dropped at each tree. The field trial was successful with all trees being sprayed to heights of approximately 40 feet. It was determined that once on site, moving the equipment between trees by people rather than reloading it on mules was most efficient. Modifications were needed to improve the ease of moving equipment between trees with people. A lighter pack frame and the game cart or stretcher handles options were added to address this need. The improved system is planned for use to spray remote whitebark on the Flathead National Forest again in July 2011.

Because it is relatively light and portable, other uses may increase the economic efficiency and attractiveness of the equipment. Since all pines are susceptible to mountain pine beetles, it could be used to spray other trees in the genetic tree improvement program or on recreation sites, along trails or in campgrounds. The system is compact enough that it could be kept in the back of a pick-up truck to treat individual high value trees as they are identified. Owners of ski resorts may want protect trees on ski slopes that are important for snow deposition or aesthetics. In addition, other types of insecticides and fungicides could be applied with this equipment. Private contractors may want a portable system like this that allows them to spray in areas that cannot be easily reached with truck-mounted sprayer equipment. Of course the most important example of its usefulness is to protect cone-bearing, blister rust resistant whitebark pine from mountain pine beetles. Where carbaryl use is allowed, we now have the technology needed to very effectively protect remote whitebark pines.

The cost of producing the spray system is approximately $4,000. While MTDC can produce a small number of them, large scale production is not part of their mission. If you are interested in using or acquiring one of these spray systems or want to find out more about it, contact Keith Windell, Project Engineer at the Missoula Technology and Development Center, kwindell@fs.fed.us. 406-329-3956. If enough interest is expressed, MTDC will actively pursue finding a manufacturer for the system. The drawings could also be made available to those who would like to pursue having one manufactured locally. ■

Effects of Blister Rust in Two Whitebark Pine Ecosystems: Implications for Restoration

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Since white pine blister rust was introduced into British Columbia in the early 1900s, the disease has spread to the point where some level of infection occurs across much of whitebark pine's range. Two areas in the U.S. Rocky Mountains are of special concern – the Northern Divide Ecosystem (NDE), including Glacier National Park and the adjacent Flathead National Forest, and the Greater Yellowstone Ecosystem (GYE), including Yellowstone National Park and the adjacent Gallatin and Shoshone National Forests. Monitoring in the NDE has found infection levels approaching 90 percent in some whitebark populations (Kendall and Keane 2001). In the GYE, the apparent importance of whitebark pine seeds to grizzly bears raises concerns about potential impacts of blister rust in that ecosystem.

Whitebark pine is faced with multiple challenges to its long-term persistence, including white pine blister rust, mountain pine beetle infestations, successional replacement by shade-tolerant conifers, and potential impacts of climatic change. However, the study we report on here focused solely on white pine blister rust, for several reasons. First, blister rust is currently the most widespread threat across whitebark's range. Second, we rarely encountered mountain pine beetle-infested trees or beetle-caused mortality at the time of our field sampling. While bark beetle activity is currently at epidemic levels in some whitebark communities (including the GYE), it is a recent and ongoing phenomenon. Hence, our study provides a comparison of rust-infected whitebark communities in two major ecosystems under virtually beetle-free conditions, and establishes a baseline for assessing impacts of beetles in the future. Climatic change may also influence whitebark pine sustainability; however, assessing these longer-term effects was not part of this study.

Our analysis had three objectives: 1) describe and quantify stand density, species composition, blister rust infection, and mortality of whitebark pine in the NDE and GYE ecosystems, 2) compare ecosystems based on these variables, and 3) suggest alternative restoration strategies based on differences between ecosystems.

Field data were collected in 2004-2006 to quantify stand conditions at 10 research sites in the NDE and eight in the GYE. Research sites within each ecosystem were selected to capture variation in tree species composition and the elevational range of whitebark pine. Individual research sites were subdivided into 1-ha squares (100 m × 100 m) to increase efficiency and control over sampling.

Overall stand densities (trees/ha >7-cm diameter) were relatively similar between the two ecosystems, both in terms of whitebark pine and other species combined (Table 1). However, the relative health and functionality of the whitebark component in each ecosystem varied dramatically. For example, about 74% of all whitebark pine trees in the NDE were dead, compared to only 22% in the GYE, and approximately 92% of the living whitebark in the NDE were infected with blister rust vs about 62% in the GYE (Figure 1). Furthermore, all large whitebark pine (i.e., trees ≥37cm DBH) that we investigated in the NDE were infected, whereas about 28% of the large whitebark in the GYE were not yet infected (Figure 1). Forests in the NDE also had significantly lower live whitebark basal area (1.9 m^2 ha^{-1}) relative to the GYE (14.5 m^2 ha^{-1}). These differences portend potentially large differences in cone production between the two ecosystems in the future.

Table 1. Estimated density of whitebark pine (live plus dead) and all other species combined in the Northern Divide (NDE) and Greater Yellowstone Ecosystems (GYE).

Ecosystem	Whitebark	Other Species	Total
	----------------	trees/ha	--------------------
NDE	306	563	869
GYE	346	427	773

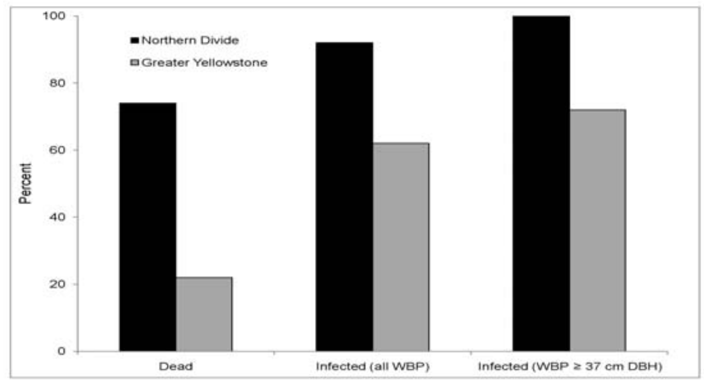

Figure 1. Percent of whitebark pine in the Northern Divide and Greater Yellowstone Ecosystems that are dead or infected with blister rust.

Fundamental differences in mortality, blister rust infection levels, and cone production potential of whitebark pine communities in the NDE and GYE suggest that different restoration strategies will be needed to address characteristics unique to each ecosystem. For example, McKinney et al. (2009) reported evidence indicating that stands with less than about 5 m^2 ha^{-1} of live whitebark basal area provide too little cone production to reliably attract nutcracker seed dispersal. This suggests that planting rust-resistant whitebark pine seedlings should be a high-priority restoration strategy in the NDE, where whitebark basal areas average about 2 m^2 ha^{-1}. Conversely, the relatively high average whitebark pine basal areas of about 15 m^2 ha^{-1} in the GYE indicate that nutcracker seed dispersal should be reasonably dependable during good cone years in that ecosystem. One final caveat is that the current mountain pine beetle epidemic may be profoundly affecting whitebark populations in the GYE, and that these changes may require alternative restoration strategies.

References

Kendall, K.C. and R.E. Keane. 2001. Whitebark pine decline: infection, mortality, and population trends. In: Tomback DF, Arno SF, Keane RE (eds) Whitebark pine communities: ecology and restoration. Island Press, Washington, D.C. p 221-242.

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

Whitebark Pine Cake

Whitebark party organizers

Mules with back country sprayer.