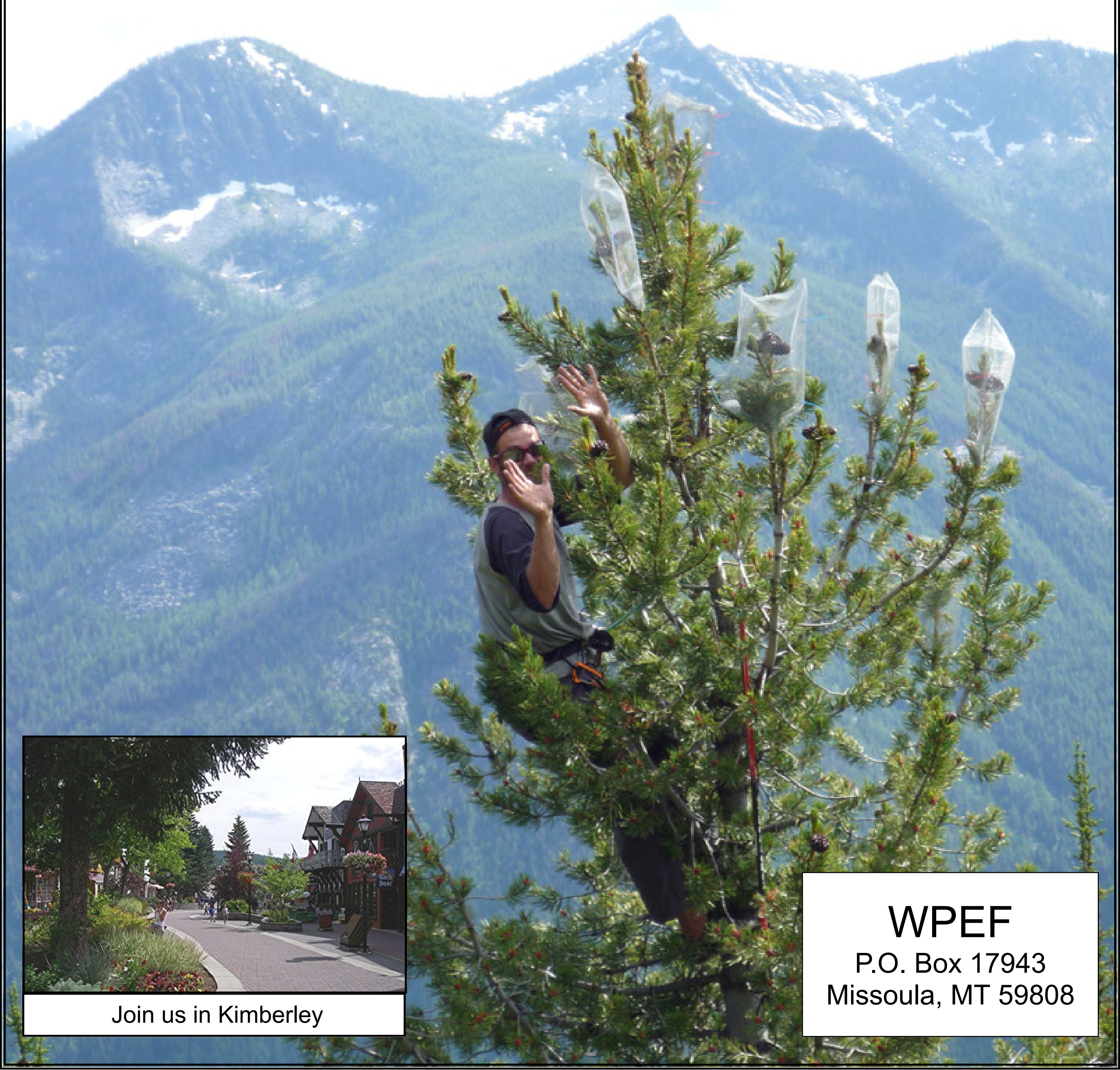
Whitebark Pine Ecosystem Foundation

Issue No. 22: Spring / Summer 2012

Nutcracker Notes

'Look, Mom, No Hands!'
see Leslie article



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Whitebark Pine Ecosystem Foundation

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Update

Web Site: **www.whitebarkfound.org**

Web Site Contact Person: Robert Keane (address above)

Web Site Provider: Chuck Crouter

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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Director's Message
Diana F. Tomback

Collaboration as the Future Strategy for Restoration Funding

In my previous Director's Message (Fall/Winter 2011) I noted "the power of multiple organizations working together, especially capitalizing on different strengths." The time for seeking collaborations is now: The challenges to forest health management are growing by the day with multiple stressors to the integrity of forest ecosystems, including the constant threat of new invasive species and diseases, damage from established invasives, and outbreaks of native pests. These challenges are operating along with the effects of climate change-- warming temperatures leading to altered hydrology and a myriad of consequences. At this time of rapid global change and serious threats to the integrity and function of our nation's forests, resource management agencies are confronted with the real possibility of budget cuts in the on-going debt crisis.

It is realistic to expect some cuts to the federal budget and some decrease in capacity of federal agencies to fund restoration, mitigate the impacts of new and existing invasive pests and disease, and respond to the challenges of a warming climate. We can argue that the amount of funding required to protect our natural heritage is small against the magnitude of the entire federal budget, and we truly hope that legislators will understand what is at stake if serious cuts were enacted, but the pressure to cut "non-essential" spending will be intense. This makes collaborative partnerships all the more important, especially for supporting the growing problems across our forests.

The Whitebark Pine Ecosystem Foundation (WPEF) has been working collaboratively but unofficially in various capacities with federal agencies for years, as well as with ski areas and other non-profit organizations. We are moving in the direction of formalizing some of these relationships and increasing our efforts towards collaborative work. We believe that these partnerships will increase awareness of the decline of whitebark pine and other high elevation five-needle white pines (the "High Five") and the implications to high elevation ecology and ecosystem services. We also hope they will produce successful fund-raising efforts for restoration through the public and private sectors

The Whitebark Pine Ecosystem Foundation (WPEF) signed a formal agreement in spring 2011 with American Forests to act in a [science advisory capacity] for any initiatives involving whitebark or the other High Five pines. American Forests first offered partnership opportunities in 2010, producing a special section in *American Forests* magazine on whitebark pine in time to publicize our conference, *The Future of High-elevation Five-needle White Pines in Western North America* http://www.treesearch.fs.fed.us/pubs/38187, held June 28-30, 2010, in Missoula, MT. With respect to our advisory relationship, we have been in discussions with their policy and planning staff as they explore potential ways of raising public awareness and supporting restoration in the High Five pines. This plan will take shape over the next few months, and we anticipate a formal plan to be announced sometime in fall of 2012.

This past spring, the WPEF finalized an agreement with the Northern Region (Region 1) of the U.S. Forest Service to partner in a number of educational, outreach, and restoration activities for whitebark pine (see the "news item" in this issue). This formal collaboration was initiated by Leslie Weldon, Regional Forester, who subsequently was became Deputy Chief of the U.S. Forest Service with oversight of the National Forest System. An outgrowth of this partnership is a potential collaboration with Forest Health Protection, Region 1, to produce a mutually useful website compiling important information on restoration. More details will be announced as our agreement is finalized.

The Whitebark Pine Restoration Fund

The Whitebark Pine Restoration Fund, under Forest Health Protection (FHP), Region 1 and the Washington Office, was established in 2006 by FHP Director Robert Mangold for the primary purpose of funding restoration and support activities for declining populations of whitebark pine. The establishment of this fund by was prompted by two U.S. Forest Service reports: Samman et al. 2003, "Managing for healthy white pine ecosystems in the United States to reduce the impacts of white pine blister rust," R1-03-118; and Schwandt. 2006, "Whitebark pine in peril: A case for restoration," R1-06-28.

John Schwandt, Forest Health Protection, Region 1, was asked to be in charge of this fund and to devise procedures for implementation. A Technical Committee, comprised of representatives from the U.S. Forest Service knowledgeable about whitebark pine management, has been responsible for ranking proposals based on their merit and probability for success. WPEF has been able to participate in an advisory capacity. This process is not always easy, in part because of the numbers of proposals received but also because of the diversity of opinion about essential activities. John's hard work and patience have made the process successful and consensus-based; he has always been willing to follow-up on committee concerns by asking authors for clarification and communicating suggestions. Furthermore, by requiring matching funds for most funded proposals, John has been able to leverage the total funding for whitebark pine restoration to very respectable levels each year.

Recently, John has asked to step down from overseeing this committee, and has plans to retire in the near future. I would like to thank him on behalf of the WPEF for all his efforts over the years administering this fund and for his important contribution to whitebark pine management and restoration.

Annual Whitebark Pine Science and Management Workshop

Please join us for our WPEF annual members' meeting and Whitebark Pine Science and Management Workshop and field trip, September 14 and 15, 2012, in beautiful Kimberley, British Columbia, less than two hours drive from the U.S. border in either Idaho or Montana. The meeting is being hosted by WPEF-Canada, thanks to our Canadian affiliate's director, Randy Moody. ■

Director's Message: WPEF Canada

Randy Moody

There has been an abundance of whitebark pine related activity in Canada since the last issue of *Nutcracker Notes*; most of this has been in the planning and recovery realm, although there has been some implementation of screening and some resort development approval that may impact whitebark pine.

The Alberta Whitebark and Limber Pine Recovery Team is working hard to complete recovery plans. Hopefully the completion of this document will motivate British Columbia and the Federal Government to get moving in this area. In B.C., a core group lead by Ministry of Forests personnel has been discussing whitebark pine-related activities with regards to getting some structured recovery underway. Unfortunately, though this process certainly had political support, the economic climate dictated that this could not be a government lead initiative. The group leaders invited WPEF Canada to lead this program. Although we are strictly a volunteer lead organization, this is an excellent opportunity for us, and we hope to initiate some activities in the near future.

Rust screening of whitebark pine in Canada has not occurred to any significant level in the past. Only five individual parent trees have been screened from B.C. (unsure about Alberta), all from the Coast Ranges and none from the mountains of the interior. In 2012 this changed, with seed from 10 parent trees sent to Dorena in Oregon for screening and another 40 trees selected for field screening trials that are presently being grown at the Kalamalka Nursery in B.C. The WPEF Canada was instrumental in securing funding to collect seed from half of these trees and in forming a partnership with the USDA Forest Service to allow for the screening in the U.S.

If ever there was a project that divided an area, Jumbo Glacier Resort is it. The developer seeks to create a year-round ski resort which will accommodate up to 6,000 visitors and possibly create a number of much needed jobs <jumboglacierresort.com>. Environmentalists claim that it will simply take jobs from other resorts in the area and destroy an ecologically and culturally significant area <keepitwild.ca>. Much of the debate around this ski area focuses on the impact of the development on grizzly bears and First Nations with little if any discussion about impacts on whitebark pine. The area is an important corridor for grizzly bears and the development is thought to interrupt bear movement in the Purcell Mountains and cause a population sink. Although some may view Jumbo as an opportunity to expose the public to whitebark pine, there are many existing resorts that are presently not achieving this role. Another viewpoint, is that as many people associate whitebark pine with wilderness, and by developing the area any wilderness associations are lost. Regardless of where one stands on this issue, let's hope that at least, the welfare of whitebark pine ecosystems is accounted for in the planning.

We are excited about the prospect of hosting the WPEF annual science meeting in Canada again in 2012 (see details in this issue). This event is scheduled for Kimberley, B.C., September 13-15. Kimberley is situated in the East Kootenay region of B.C., and September is a fantastic time to visit as the weather is often good and the alpine larch are in full colour. ■

Whitebark Pine Science & Management Workshop:

September 14-15, 2012, Kimberley, B.C.

WPEF's annual gatherings are an opportunity to increase awareness and understanding of high elevation pines. For ten years, we have steadily strengthened ties between managers, scientists, academics, and the public. This year, we return to Canada where interest and activities are growing. Come join us as we launch our eleventh annual workshop!

Kimberley is a Bavarian-themed mountain town located in the East Kootenay region of British Columbia. To the east rise the majestic Rockies and to the west stand the ancient Purcell Mountains and its expansive wilderness. Kimberley is a small, friendly community offering an abundance of recreational opportunities. It features three award-winning golf courses, a large ski resort, extensive nature trail systems, premier fly fishing, white-water rafting, kayaking and canoeing on the St Mary River, and access to wilderness and backcountry. Kimberley has its own whitebark pine tree within city limits! The city's core is a walking-friendly 'platzl' lined with shops and restaurants where you take a bite of a pretty platzl pretzl.

WPEF's eleventh annual workshop will showcase:

- The latest news, science, and management tips for practitioners, students, educators, the public, and others with an interest in dwindling five-needled pines.
- Exceptional on-the-ground learning experience by visiting high-elevation forests with interpretation by experts.
- Opportunities for improving cross-border networks.

Friday, September 14

Daytime Presentations: More than a dozen presentations on issues including ecology, decline status, management, federal listing developments, and restoration.

Evening Event: A non-technical presentation illustrating the values and plight of whitebark pine ecosystems (free admission for conference attendees and general public).

Saturday, September 15

Field Trip: We will either travel to the summit of nearby Puddingburn Mtn (elev. 7,626') which supports a variety of whitebark pine stands and alpine larch; or travel to the nearby Findlay Creek area to see examples of both limber and whitebark pine restoration work. We'll also put our hands to work in a restoration activity.

Sunday September 16

Bonus: Alpine Larch Trip: For those who are interested, author Steve Arno (USFS, retired) is collaborating with a few locals to guide a hike into some splendid alpine larch stands near Kimberley. Steve's Ph.D. study dealt with the ecology of alpine larch, and he identified some unusually extensive stands of alpine larch in this area during the 1960s that we plan to visit.

Venue

Kimberley, B.C. is located 60-70 miles north of the Idaho and Montana borders. It's a pleasant drive from Spokane (4 hrs) and Missoula (5-1/2 hrs). You can cross into Canada from the U.S. at the Eastport crossing in Idaho or Eureka, Montana. Flights come in daily from Calgary, Edmonton and Vancouver. Airport pickup can be arranged. We will convene at the Kimberley Arts Centre www.kimberleyarts.com.

Registration: We anticipate a minimal registration fee (~$20) collected at the door. We ask that attendees pre-register so we can best plan venues and refreshments. Contact Randy Moody, randy@keefereco.com.

Presentations: Contact Michael.Murray@gov.bc.ca (250-354-6852) if you'd like to offer a presentation about ecological aspects, research, or restoration of whitebark or limber pine.

Accommodations: Reservations for conference lodging is available at: Chateau Kimberley, www.chateaukimberleyhotel.com, 1-866-488-8886. It is a boutique style hotel with only 21 rooms at $75/night so book SOON. There are several other accommodation options a little further away. Check here for a full listing: www.kimberleychamber.com/memberdirectory.html#accommodation

Campground: Only 10 minutes from town! www.kimberleycampground.com

Returning to USA? Please see www.getyouhome.gov for current ID requirements to re-enter the U.S.

Further Information: Contact WPEF Canada Director: Randy Moody, randy@keefereco.com, 250-489-4140. ■

NUTCRACKER NOTES
Guidelines for Contributors

Here is a synopsis of what we're looking for in articles and news briefs:

Study findings, including initial findings, or commentaries or news items relating to whitebark pine, limber pine, or any of the other high-elevation five-needle pines, written in an informal or at least relatively non-technical style for our rather broad audience. Any length up to about 1200-1300 words maximum. We use a few digital color photos with each issue, favoring subjects related to the articles. Digital black-and-white figures or b & w photos can accompany the articles.

Submit draft manuscripts in Microsoft Word format by

April 30th for the Spring/Summer issue and by October 31st for the Fall/Winter issue to WPEF editor Steve Arno <sfarno@msn.com>. The editor will promptly make suggested changes--often quite minor--and return the manuscript to the author for approval. Authors who are not subscribers to *Nutcracker Notes* can view previous issues—prior to the two most recent ones--on our web site (www.whitebarkfound.org). ■

An Interview with Edie Dooley,
Graduate student and WPEF board member

Editor: How did you first become acquainted with whitebark pine and its ecosystem, including mountain pine beetles?

Edie: Having grown up in New York State, I had never even heard of a whitebark pine or mountain pine beetles until I interviewed for a University of Montana graduate position focused on the disturbance ecology of mountain pine beetles (MPB) in whitebark pine. During my phone interview, my future advisor, Diana Six, explained to me how warming temperatures are allowing MPB to prosper in whitebark pines and how the whitebark pine ecosystem may be one of the first to "blink out" because of the effects of climate change.

I immediately became interested in studying an ecosystem in such a precarious state, especially in the beautiful Greater Yellowstone Ecosystem. When I got to Missoula, I went hiking on Cha-paa-qn peak to orient myself in the Missoula valley. I took pictures of strangely beautiful ghost whitebark without realizing that they were whitebark pines or that these trees exemplified the very problem I was going to be studying for the next three years of my life. The first time I met a live whitebark pine was in October of 2009 on a field trip to a MPB-killed whitebark pine stand as part of an International Union of Forest Research Organizations (IUFRO) Forest Insects and Environmental Change meeting in Jackson, WY. It was particularly cold that weekend and snowed on us during the field trip. Through my research, I later realized that the inclement cold weather on the field trip was also severe for the MPB. That record-setting cold snap killed most of the MPB I was tracking for my research, and likely was responsible for slowing the MPB outbreak progression across much of the Greater Yellowstone Ecosystem.

Editor: What were your most notable findings about the relationship of bark beetles to whitebark?

Edie: Contrary to the conventional notion, I found no difference in beetle size, or in the number of beetles emerging from whitebark pine and lodgepole pine. I also found that the severity of blister rust infection likely does not affect MPB size or number. Therefore, I concluded that overall, the severity of MPB outbreaks in whitebark pine is likely not due to any superior host qualities offered by diseased or healthy, whitebark pine. Instead, the outbreaks are likely so extensive because there are extensive forests of mature whitebark pine with a climate that is now thermally adaptive for the beetle.

However, I haven't closed the book on the future of whitebark pines under the threat of MPB because over the course of my research, I witnessed how cold weather can kill MPB. The October 2009 cold snap at first appeared problematic to my research because it severely decreased the number of beetles I was able to collect. However, I later realized that this mortality event was a unique opportunity to use my field data to validate MPB cold temperature and phenology models created by Barbara Bentz, Jesse Logan and Jim Powell. Using localized temperature data, Jim Powell modeled the survival rate of the beetles for which I had attack- and emergence-rate data. The model showed that because of the relatively warm late summer, and the subsequent abrupt and sustained drop in temperature in October, the MPB were not "cold hardened" during the cold snap. Therefore, the -15˚C temperature (which is much warmer than the commonly cited -40˚C needed to kill beetles when they are cold hardened) caused widespread mortality among developing larvae.

This finding shows that although warming temperatures are currently allowing MPB to prosper in high elevation whitebark pines, cold weather events, particularly those that occur during the shoulder seasons, are still able to zap MPB populations. Therefore while climate models predict that the high elevations will remain thermally adaptive for MPB, these models can't predict the stocasticity in weather that can have serious consequences on beetle survival. Therefore, because of the complicated relationship of weather events and MPB survival, it should not be a foregone conclusion that whitebark pine will be decimated by MPB facilitated by warming temperature under climate change.

Editor: Now that you have finished your thesis research and are graduating, will you be continuing to work in whitebark pine forests?

Edie: Yes! I accepted a temporary research technician position on the silviculture crew of the Flathead

National Forest. This means that I will get to be working for two other WPEF Board Members--Melissa Jenkins and Bryan Donner. I eventually would like to be a silviculturist for the Forest Service, so this position will give me valuable field experience. Additionally, since there are many whitebark pine communities in the forest where I'll be working, I will get to spend much of my summer evaluating the health of whitebark pines to determine if they should be protected with verbenone or have their cones caged. Ultimately, I hope to end up in a place where I can manage whitebark pine forests as part of my job.

Editor: Given the trend toward a warmer mountain climate, what general strategies do you think have the most promise for retaining or restoring a significant amount of whitebark pine on the landscape?

Edie: I believe that the most effective whitebark pine restoration effort involves cone caging and collection. I think that MPB will continue to be a threat to whitebark pines, so cone caging efforts should be prioritized in areas where MPB outbreak is imminent or ongoing. After the rust resistant seed source is collected, outplanting on a landscape scale is required. While protecting trees with verbenone and prescribed burning may be important tactics, increasing the number of whitebark pine on the landscape (rust resistant or not) is the most important restoration strategy as it increases the genetic diversity that will be crucial to sustaining whitebark pine. In the future, whitebark pine will run the gauntlet of both immediate mortality factors (MPB and blister rust) as well as unknown physiological challenges related to climate change. To meet the physiological challenges, we will need the widest possible genetic diversity that we can plant, extending beyond the genes contributing blister rust resistance. ■

ELECTION NEWS

Cyndi Smith, WPEF Associate Director

At the Spring 2012, Board of Directors (BOD) meeting in Missoula, Montana, we welcomed Bryan Donner to continue the position as Membership / Outreach Coordinator. We also have a new Treasurer, Vick Applegate, who was unfortunately not able to attend that meeting. We thank Ward McCaughey for staying on for an extra year while we searched for his replacement, and for helping Vick in his new role. Neither of these positions were contested, but our Bylaws require the membership to ratify acclamations: we had 83 ballots returned from a possible 156 members, for a 53% participation rate, which satisfies this requirement.

The BOD consists of five office holders (Director, Associate Director, Secretary, Treasurer and Membership / Outreach Coordinator) and seven General Board Members. You may have noticed the following statement on the recent election ballot: "Three General Board Members are being nominated and elected by the existing Board of Directors, as per Bylaw E(f)." In Fall 2011, a close reading of the Bylaws made us realise that the general membership is only required to vote for <u>Executive Committee</u> positions, not General Board Members.

As a result, at the Spring 2012, BOD meeting, Shawn McKinney was re-elected to his position as a General Board Member. We also thank resigning BOD members Kate Kendall and Kirk Horn for their service to the Foundation, and will be nominating replacements in the next few months.

We will be proposing Bylaw changes for membership approval that will require the membership to elect five of the General Board Members, leaving two positions to be voted on by the existing BOD. The Board feels that requiring 10 of the 12 BOD positions to be elected by the membership maintains participation and oversight, while keeping two positions to be elected by the existing BOD allows the Board to target particular skills and expertise, and to help balance geographical representation.

Watch for either a mail-in ballot or an on-line survey in the next few months, in which all members will be asked to vote on a number of proposed Bylaw changes. We encourage members to nominate individuals to serve on the BOD whenever these opportunities arise. Your active participation is critical to keeping the Foundation relevant to the general membership. ■

WPEF Tax Filings &Treasurers Report On-line

WPEF members can access the organization's non-profit tax forms (IRS 990), treasurer's reports, and minutes of Board of Directors' meetings on-line. From our web site <www,whitebarkfound.org> select the tab "Members Only," and then select "Board Business." ■

Calendar Photos Chosen

Congratulations John Tangney, Janet Tangney, Rob Mutch, Jubilee Cacaci, and Nancy Bockino! The WPEF received 33 beautiful photograph submissions for our Whitebark Calendar Contest and we are excited to announce these winners. Also, thanks to everyone who contributed a photo and to those who voted. At least one photo taken by the voters' favorite photographers will be included in our 2013 calendar. Because we want to include photos taken throughout the range of whitebark pine, we will add a few other photos to attain the desired variety.

Photos will be available for purchase at the 2012 Annual Science and Management Workshop in Kimberely, and will be sent to new members as an incentive gift.

Visit www.whitebarkfound.org to see the winning photos. ■

Student Research Grants Available

The mission of the Whitebark Pine Ecosystem Foundation (WPEF) is to "promote the conservation of whitebark pine and other high elevation five needle white pine ecosystems through education, restoration, management, and research." In support of this mission, the WPEF will be offering a research grant of $1000 to an undergraduate (writing an undergraduate thesis) or graduate student (MS or PhD) conducting research on whitebark pine. Relevant areas of research include, but are not limited to: threats to whitebark pine, including mountain pine beetle, white pine blister rust, successional replacement, and climate change (only in whitebark ecosystems); interactions with wildlife, such as Clark's nutcracker or other birds, red squirrels and grizzly bears; restoration strategies for whitebark pine, including both field operations and nursery seedling production; and ecosystem level impacts of whitebark pine die-off.

Funding will only be awarded for travel expenses for field work, or consumable research supplies. Grants shall not be used to buy equipment that will be used beyond the duration of the project (and thus would be retained by the lab in which the student works).

Please submit a short (two single-spaced pages or less) proposal covering the purpose and need for the research, and a brief description of the study plan and methods, including expected dates of data collection and writing completion, and expected outcomes of the research. The application should include contact information and academic affiliation of the student, as well as a brief explanation of how the money will be spent. Grant recipients are encouraged to present the findings of their research at the WPEF's annual meeting and are expected to publish a summary of the research in *Nutcracker Notes*. In addition to the proposal, applications should include a CV as well as a letter of recommendation from the student's research advisor. All applicants are encouraged to join WPEF and the grant recipient will receive a free subscription to Nutcracker Notes for one year.

Please send application materials (electronic only) to Cyndi.smith9@gmail.com by August 31st, 2012.

Whitebark Pine "Listed" in Canada

Cyndi Smith, WPEF Assoc. Director

On April 24, 2012, the federal government of Canada published its intention to list whitebark pine as Endangered. There is a 30-day period in which comments on the order can be taken, but the listing should now occur in late June. Apparently there were only nine comments received during the full consultation period, all of which were in favor of listing. ■

Whitebark Pine Restoration in the USFS, Region One

Steve Shelly, Regional Botanist
USFS, Missoula, MT

In July, 2011, the U.S. Fish and Wildlife Service (USFWS) determined that listing of whitebark pine as threatened or endangered under the Endangered Species Act is warranted, although precluded by higher priority actions. The five primary threats to the species that were identified by the USFWS are: fire suppression, white pine blister rust, mountain pine beetles, climate change, and the lack of adequate regulatory mechanisms for conservation and recovery of the species.

One of the subsequent outcomes of this finding was that all five regions of the U.S. Forest Service (USFS) where whitebark pine occurs (Regions 1, 2, 4, 5, and 6) designated the species as "sensitive." This designation means that the National Forests must take precautions, in any projects that involve the species, to not cause any declines that would further threaten it. What is unique in this case, however, is that restoration – and ultimately, recovery – of whitebark pine will depend on active management across large areas of its range. Simply protecting the species from impacts ("no action") will not lead to recovery in this case, and in fact serves to compound the ecological threats identified by the USFWS. Restoration activities include thinning of competing conifers, prescribed fire, planting of blister rust-resistant stock, and promotion of regeneration. Given this, the objective of the USFS is to design and implement projects that may have a beneficial effect on whitebark pine.

In USFS Region 1, whitebark pine occurs on approximately 5 million acres of National Forest land, on all 12 National Forests in Montana and northern Idaho (this represents about 20% of the public lands managed by Region 1). The species is early successional on some of these lands, and also occurs as a climax species at higher elevations. While Region 1 has been conducting active restoration of whitebark pine for over 20 years, its designation as a sensitive species has raised its priority. A number of activities are being implemented to advance restoration, including:

- Development of a fire management approach that supports the use of wildland fire (unplanned ignitions) for resource benefit within the range of whitebark pine. This is important because the use of prescribed fire, while an important tool for targeting specific stands for restoration, will not be adequate for restoring fire as an ecological process on a landscape scale.
- Continuation and enhancement of the genetic improvement program for outplanting blister rust-resistant whitebark pine.
- Development of a regional list of priority restoration projects that can be used to seek internal and partnership funding.
- Mapping: funding proposals have been submitted to develop a current condition map for whitebark pine in Region 1. In addition, a habitat modeling map is being refined.
- Completion of collection and participating agreements between Region 1 and the Whitebark Pine Ecosystem Foundation, to facilitate partnership funding for restoration efforts.
- Development of consistent approaches that support active management of whitebark pine as a sensitive species, through the NEPA process for evaluating proposed projects.
- Continued refinement of a restoration opportunity map for whitebark pine in Region 1.
- Implementation of restoration projects for whitebark pine on the National Forests; these projects, and other activities, will be tiered to the range-wide restoration strategy that will soon be available.

To help achieve these various activities, Region 1 has developed a website for whitebark pine. This can be accessed at http://www.fs.usda.gov/main/r1/plants-animals, and clicking on the link for "Whitebark Pine." Detailed information concerning the listing status, sensitive species designation, and restoration activities in Region 1 can be found on this site.

Recovery of whitebark pine will require an interdisciplinary approach, through coordination of USFS programs in fire, silviculture, wildlife, botany, vegetation ecology, forest health protection, tree improvement, and public education. A team of resource specialists at the regional and National Forest levels is collaborating on the implementation of restoration activities. Partners such as WPEF will be vital to success as well. ■

Nutcracker / Whitebark Factsheets

Eight well-illustrated "Factsheet" publications have been developed by Teresa Lorenz and Carol Aubry and are available on-line at the Ecoshare website, under Projects, Whitebark pine:

http://ecoshare.info/projects/whitebark-pine/

The factsheets highlight new information about Clark's nutcracker life history, habitat use and role in whitebark pine seed dispersal in Washington State. Each factsheet is 4 pages and is easy to print. Titles are as follows: Clark's Nutcracker Factsheet 1: Caching at the Landscape Scale; No. 2:Caching at the Habitat Scale; No. 3:Caching at the Microsite Scale; No. 4:Home Ranges and Whitebark Pine Regeneration; No. 5:Migratory Behavior; No. 6:Population Trends; No.7:Seed Cache Recovery; and No. 8: Seed Dispersal Effectiveness.

The authors would like to receive comments both on the content and the factsheet format. Please send comments to caubry@fs.fed.us.

Citation: Lorenz, T.; Aubry, C.A. 2011. Clark's nutcracker factsheets (8). Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 32 p. ■

Yellowstone Whitebark Pine Committee Receives Award

Nebraska City, Neb. (April 24, 2012) – The Greater Yellowstone Whitebark Pine Committee is the recipient of a 2012 Arbor Day Award in honor of its outstanding contribution to tree planting, conservation and stewardship, the Arbor Day Foundation announced today.

The Montana, Wyoming and Idaho-based Greater Yellowstone Whitebark Pine Committee is one of 16 individuals and organizations being recognized by the Foundation at the annual Arbor Day Awards. The Whitebark Pine Committee received a Forest Lands Leadership Award in honor of its leadership in advancing sustainable forestry efforts on public forestland.

Whitebark pine was recently determined to be warranted for listing under the federal Endangered Species Act.The interagency Committee released a comprehensive Whitebark Pine Strategy to guide protection and restoration in 2011. The Strategy continues a robust monitoring program; has planted hundreds of acres in rust resistant whitebark pine and has collected over two million seeds for future planting.

"This innovative, multi-agency partnership is a true collaboration around a high-stakes challenge," said John Rosenow, founder and chief executive of the Arbor Day Foundation. "Because of the work of the Greater Yellowstone Whitebark Pine Committee, some of most precious forestland in the western United States will be preserved for the next generation."

Since 1972, the Arbor Day Foundation has recognized the inspiring and life-changing work of leading environmental stewards and tree planters through the annual Arbor Day Awards. ■

Blister Rust Researchers Receive Award

Anna Schoettle, Team Leader, and the Proactive Strategy Team of **Kelly S. Burns**, Forest Health Protection, Rocky Mountain Region, and **Richard A Sneizko**, National Forest Systems, Dorena Genetic Resource Center, Pacific Northwest Region, are recipients of the 2011 National Forest System Invasive Species Program Award for Innovative Control and Management. This national award recognizes a Forest Service individual or group who demonstrates outstanding, dedicated leadership in control and management of invasive species threatening national forests or grasslands. The Proactive Strategy Team was recognized for its leadership and integration of research, strategic planning, and management activities to proactively manage Rocky Mountain bristlecone and limber pine populations to mitigate the impact of invasion by the pathogen that causes the lethal disease white pine blister rust.

The Proactive Strategy program 1) provides the cohesive science foundation of population and disturbance ecology, genetics, disease resistance, and economic and silviculture knowledge on which management options are developed to increase the resilience of threatened ecosystems to prepare them for invasion; and 2) through extensive partnerships, coordinates its implementation across boundaries in the southern Rocky Mountains and Great Basin. The Program has actively engaged the public in gene conservation efforts through extensive outreach. The recent national-level directive on the management of invasive species across aquatic and terrestrial areas of the National Forest System (12/5/11 *Federal Register*) includes an aspiration to sustain healthy ecosystems - the high elevation pine forests, under the threat of multiple stressors, serve as an excellent flagship to lead the paradigm shift away from crisis management and toward proactive management for ecosystem resilience.

This Program has positioned land managers of the southern Rocky Mountains and Great Basin as leaders for this shift by providing the information and technologies to make informed decisions to sustain mountaintop ecosystems. The Program exemplifies successful collaboration across all three branches of the Forest Service, among Regions, among Agencies, and among university and non-profit partners. ■

Whitebark Pine Strategy for the Greater Yellowstone Area

Nancy Bockino, Ecologist, Grand Teton National Park

In many places in the Greater Yellowstone Area (GYA) mortality from white pine blister rust and mountain pine beetle is at unprecedented levels. This situation has presented land managers with the challenge of creating a proactive approach to whitebark management that links administrative units throughout the GYA. In order to protect healthy whitebark pine and restore it in areas with extensive overstory mortality, appropriate management actions must be coordinated, consistent, efficient, and science-based. This article reports progress in this effort.

The GYA's Whitebark Pine Subcommittee, has worked successfully across boundaries since its inception in 2000, and in May 2011 completed the Whitebark Pine Strategy to promote the persistence of this species over time and space by: (1) extensive spatial mapping and documentation of the current condition of whitebark pine; (2) establishment of criteria to prioritize areas for management action; (3) provision of techniques and guidelines to protect and restore whitebark pine; and (4) communication and distribution of this information. This strategy is intended to enable land management units to maximize the use of their limited resources to maintain whitebark pine in the GYA.

This Whitebark Pine Strategy for the GYA is a living document that will be regularly updated to reflect changes in ecosystem conditions, advances in the understanding of whitebark pine ecosystems and management techniques, and improvements in the technology available to characterize and map whitebark pine. In addition, reviews by a variety of resource staff such as fire managers, wildlife biologists, interpreters, and recreation specialists will provide the basis for integration of this strategy within individual management units as well as across the GYA.

The Whitebark Pine Strategy for the Greater Yellowstone contains four sections.

Section 1. Introduction, Purpose and Need, and Strategic Objectives

Details the strategic objectives developed for assessing and conserving whitebark pine ecosystem condition in the GYA, and describes the Whitebark Pine Subcommittee and their work to date, which aims to:

- ✓ Ensure natural regeneration and genetic diversity through protection of cone-bearing whitebark pine.
- ✓ Maintain and restore the role of whitebark pine in ecosystem function.
- ✓ Augment natural regeneration through strategic planting.
- ✓ Promote population resilience through genetic conservation and planting of rust resistant seedlings.
- ✓ Promote fire planning and use that protects high value whitebark and provides for long-term restoration.
- ✓ Work collaboratively across administrative boundaries to implement the Whitebark Pine Strategy for the Greater Yellowstone.

Section 2. Methods

Describes the assessment and prioritization of whitebark stands in the GYA by the Whitebark Pine Subcommittee, which has:

- ✓ Sponsored work to characterize whitebark pine stands across the GYA, which resulted in the *2009 GYA Whitebark Pine Distribution Map* (GYCCWBPSC 2009, completed by Bockino, Whitley, and Mellander, a USFS and NPS cooperative effort).
    - This includes a change detection analysis by the USFS Remote Sensing Applications Center that identified change in whitebark pine canopy condition from 2000 to 2007 (Goetz et al. 2009).
- ✓ Supported long-term monitoring to track status and health trends of whitebark pine
- ✓ Developed ecological criteria to determine each stand's priority for restoration and protection, which resulted in the *2010 Whitebark Pine Distribution and Condition Assessment for the Greater Yellowstone* (GYCCWBPSC 2010, completed by Bockino and Macfarlane as a USFS and NPS cooperative effort).
    - ◦ This includes an update to the 2009 Whitebark pine Distribution Map.
    - ◦ Findings from the *Landscape Assessment of Whitebark Pine in the GYA*, a classification of overstory mortality by sub-watershed based on aerial surveys (MacFarlane et al. 2009)
    - ◦ A spatially explicit dataset that combines multiple data sources to create an ecologically-based score indicating each whitebark pine stand's need for protection (Figure 1) and restoration (Figure 2) activities.
- ✓ Further prioritizated stands by considering logistical factors such as land status and distance from roads or other access.

Section 3. Site Selection, Management Strategies, and Action Plan

Describes how whitebark stands within the GYA will be selected for management actions and addresses considerations for resistance, resiliency, and adaptive management relative to climate change. A three-year action plan based on current restoration and protection efforts and priorities is also presented.

Section 4. Tools for Protection and Restoration of Whitebark Pine Stands

Describes potential tools and techniques for protecting and/or restoring whitebark pine stands.

Information about the GYCC Whitebark Pine Subcommittee can be found at: http://fedgycc.org/WhitebarkPineOverview.htm

The Whitebark Pine Strategy for the GYA is available at: http://fedgycc.org/documents/WBPStrategyFINAL5.31.11.pdf

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Whitebark Pine Stands with High Priority for Protection

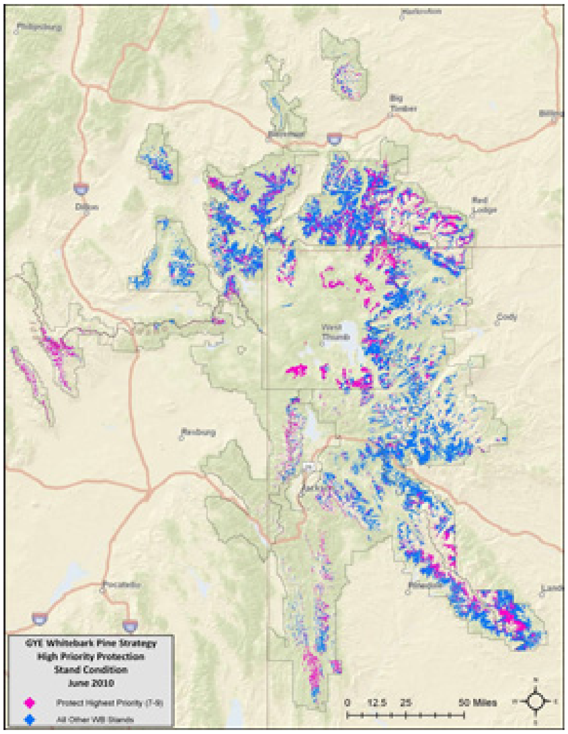

Figure 1. Stands with the highest protection score for overall stand condition are pink; all other stands are blue. All whitebark pine stands are represented on this map.

Whitebark Pine Stands with High Priority for Restoration

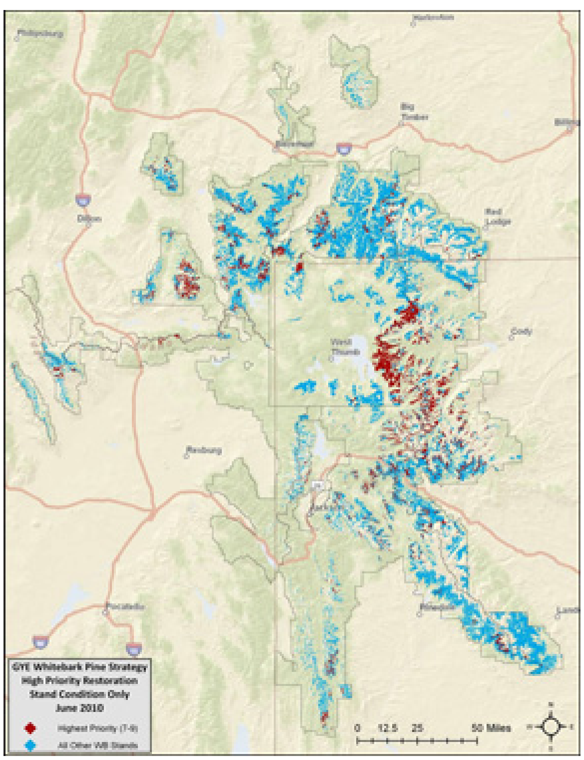

Figure 2. Stands with high restoration score for overall stand condition are red; all other stands are blue. All whitebark pine stands are represented on this map.

Whitebark Restoration Trials in the West Kootenays, B.C.

Adrian Leslie, White Bark Consulting
Castlegar, B.C.

In the summer of 2011, whitebark pine restoration trials were initiated in the mountains of the West Kootenays in southwestern British Columbia. The field trials involved cone collection, direct seeding, screening for blister rust resistance. With funding from the Columbia Basin Trust (CBT), and partnering with The Nature Conservancy of Canada (NCC), the Harrop-Procter Community Co-op, Selkirk College and the BC Ministry of Forests Lands and Natural Resource Operations, cones were collected from healthy whitebark pine trees in the South Selkirk Range near Nelson, and seeds were planted at five restoration sites. The goal was to locate a network of blister rust- resistant trees from which seeds can be collected for future restoration work, and to determine if direct seeding is a viable way to carry out larger scale restoration projects with limited funding.

Whitebark pine trees are relatively uncommon in the West Kootenay compared to other regions within the tree's range. Infection rates of white pine blister rust are as high as 90%, and mountain pine beetle has had a serious impact in recent years. Generally, whitebark pine tends to be a small component in subalpine forests in the region, with very few pure stands at treeline, which makes locating healthy trees within heavily infected stands a challenge. The cone crop in 2011 was very good and throughout the month of July cages were placed over cones of 41 healthy trees. Most of these trees were located at four sites in the Darkwoods Conservation Area, a 55,000 hectare property owned by NCC, with three more sites on nearby publicly owned crown land. The maturing of cones was delayed due to a colder than normal spring and a very late snow melt, so when we went to collect the cones in mid September they were still not mature. Collections were made as the October snow began to fall, with a total of approximately 40,000 seeds harvested.

The nutcrackers in the Selkirk Mountains appear to have been particularly hungry last summer because, in several cases, they had crawled up under the cage and harvested the seeds, leaving the core of the cone in the cage. Several cage designs were tested using 1/4 and 1/8 inch hardware cloth, and were placed over cone-bearing branches either by hand when the trees were climbable or with long tongs (up to 30 ft off the ground) on the trees that were not safe for climbing. Cages placed by tongs were only effective 11% of the time because it was not possible to cinch the base around the branch. Most tong-placed cages were either blown off or accessed by squirrels and nutcrackers. The most effective cages were built with 1/8 inch hardware cloth and placed by hand and folded over at the base. Even these were only 82% effective. Incredibly determined nutcrackers getting under cages highlighted the importance of tightly folding and securing the base of the cages around the branch.

Approximately 500 seeds from 20 of these trees were given to the BC Forest Service to screen for rust resistance (see the article by Michael Murray in this issue). The goal is to grow seedlings in the greenhouse, and then, in 2013, plant them in field research trials in the Kootenays to test for rust resistance. A direct seeding trial was initiated at four sites within Darkwoods and one site at the top end of the Harrop-Procter Community Forest, just to the north of Darkwoods. Approximately 20,000 seeds were planted 2-4 cm below the surface in two timber harvest units, a recently burned area, an old burned area with very little natural regeneration and a forested area with mostly mountain pine beetle-killed whitebark pine. To test a theory that delayed germination in naturally regenerating seeds is due to a lack of moisture in the fall, seeds were either planted directly in the ground, or placed under a 48-hour running water soak before being planted. Transects were set up in each of the five areas to follow the germination and survival of a subset of soaked and unsoaked seeds. The remaining 10,000 seeds will be planted in the spring of 2012 to test if spring planting (as soon as snowpack recedes) is a viable option. Germination rates and survival of seedlings in the greenhouse can then be compared to those that were directly seeded following the three different seed stratification methods.

The 2011 field activities were intended to be a pilot project and will be expanded in 2012 with the help of more funding from CBT, increased public involvement and volunteer labour. Depending on the cone crop, seeds will be collected from healthy trees over a larger geographical area to be screened for blister rust resistance and used in restoration trials. Due to the patchy distribution of whitebark in the West Kootenays, we are hoping to get help from the public in locating good stands for further investigation. A publicity campaign is being launched in the spring of 2012.to inform and encourage people who are out hiking, biking and skiing in the mountains to keep their eyes open for healthy whitebark pine Updates on this project can be found at kootenaywhitebark.blogspot.com. Anyone interested in helping out is encouraged to contact Adrian Leslie at 250-505-2669 or Adrian.whitebark@gmail.com ■

Limber Pine Seed Mutualisms: Between the Devil and the Deep Blue Sea

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Eighty years ago, D.H. Lawrence used the famous phrase "between the devil and the deep blue sea", when speaking of two difficulties that a loveless Englishman was caught between (Lawrence 1928). About the same time, expanding white pine blister rust (WPBR; *Cronartium ribicola*) infestations were placing limber pine in a predicament, where the phrase equally applies. The time-tested mutualism between limber pine and the Clark's nutcracker is now what stands between a devastating disease and an old nemesis to successful regeneration, the red squirrel. Red squirrels are efficient seed predators of conifer cones in a wide array of ecosystems, and place strong selective pressures on cone and seed size, shape, and dispersal mechanisms. This pressure is sufficient to have led most conifer species in North America to produce unpredictable cone crops that alternately starve seed predators in poor cone years, and overwhelm their capacity to consume the seed in high cone years. This phenomenon is known as masting, and occurs in most temperate and boreal ecosystems world wide, at varying scales of synchrony amongst individual masting species (Koenig and Knops 2000).

Finely tuned ecological interactions facilitate regeneration dynamics for tree species in healthy ecosystems, but what happens when the balance is upset? White pine blister rust has caused significant amounts of tree mortality throughout the range of limber pine, thereby reducing the number of trees that produce seed. Concurrent declines in habitat quality that support squirrels may vary spatially, leaving similar numbers of seed predators in habitats where other conifer species meet the dietary needs of squirrels. At present, the opportunities for successful production of extra seed for dispersers may be limited because the balance may have shifted amongst seed consumers. Our study investigates whether supra-annual variability in cone production assists in cone escape in the endangered limber pine and whether cone escape depends on the severity of white pine blister rust infections. This study will provide the first estimate of squirrel cone predation of limber pine relative to inter-annual variation in cone production.

Methods

Province-wide WPBR surveys by Smith et. al (2011) were used to identify a southern region with high WPBR severity (lat. 49.60°N, long 114.20°W), and a northern region with low WPBR severity (lat 52.00°N, long. 116.50°W). We sampled eight and nine forest stands in the high- and low-WPBR study areas, respectively, and recorded cones on a total of 40 trees per stand. Cone production, and cone predation were recorded annually over one masting "cycle" (2008 – 2010; n = 440, 679, and 678 trees respectively). Poor seed years occurred in 2008 and 2009, and a high seed year (mast year) occurred in 2010 (Peters and Gelderman 2011). Cone counts were recorded annually prior to cone harvesting by squirrels (June 15 – July 10th), and again each year following cone harvesting (Sept 14th – Sept 21st).

We used Analysis of variance to test whether significant differences occurred in the number of cones escaping seed predators in: 1) low versus high seed years, and 2) low versus high WPBR landscapes.

Results and Discussion

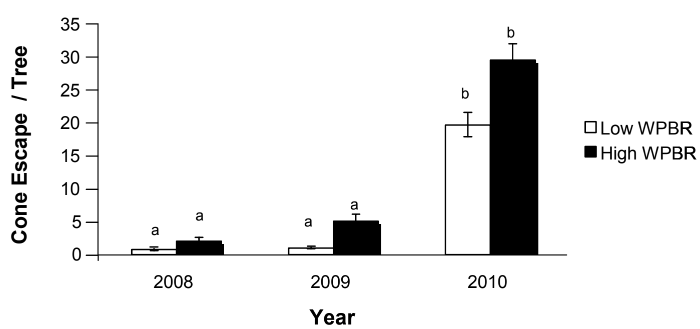
High cone crops in 2010 allowed limber pine to successfully produce large numbers of cones that escaped seed predators. The 2010 cone crop was 3 – 5 times greater than the 2009 and 2008 crops, respectively; however, 8 – 18 times more cones escaped squirrels in 2010 than in 2009 and 2008, respectively (**Fig. 1**). While this result may appear surprising, a lot of literature has built up around the concept of masting that suggests trees frequently gain substantial benefits in seed escape by having large seed crops at intermittent intervals. One of the key caveats for the evolution of masting behaviour in trees is that proportionately more seeds escape seed predators in high seed years (Silvertown 1980). Over the course of our study, this prediction held up: squirrels harvested a higher percentage of cones in low cone years (78.3 and 80.6 % in 2008 and 2009, respectively), than in the high cone year (46.5 %). In other words, despite more food being available in 2010, squirrels were only able to harvest a smaller proportion of it.

Seed escape is a necessary requirement for successful regeneration of trees in healthy ecosystems, but what happens when disease, specifically WPBR, alters the abundance of live trees, and the very structure of limber pine forests? Interestingly, cone removal rates did not differ significantly between landscapes with low versus high WPBR, varying only 3 – 5 % between study areas across all three years. In fact, significantly more cones escaped seed predators in the high WPBR study area than in the low WPBR study area (50 – 150 % more across study years). This latter result is counterintuitive, largely because fewer live individuals remain in severe WPBR infestations, thereby reducing the number of individuals that contribute to reproduction in the stand (McKinney 2009). In our study system, it appears that either: 1) natural variation in cone production between high and low WPBR study areas resulted in 69.8 % greater cone production in the high WPBR landscape, or 2) that our low WPBR study area had lower seed production because it occurs at the northern limits of limber pine's geographic distribution (400 km NW of our high WPBR site).

While seed predation is natural in many coniferous ecosystems, the role of seed predators in potentially exacerbating seed supply for endangered species has not been assessed. Few trees retained cones following squirrel predation in 2008 and 2009 (24.4 % and 29 % respectively), while most trees (80 %) retained many cones for dispersers in the high cone year of 2010. When we move from tree-level to stand-level scales, other researchers have raised concerns that dispersal mutualists need thresholds of 1000 or more cone/ha to be attracted to individual stands, a threshold that may only be attained in mast years (McKinney 2009). Our results suggest that mast years provide high levels of escape from seed predators like red squirrels, but very few cones escape in low or moderate cone years. On the plus side, we see evidence that even in heavily infested WPBR areas, cones are still able to escape seed predators.

Seed escape in time (i.e. mast years), appears to be more important in facilitating seed dispersal opportunities for the Clark's nutcracker, than cone escape in space. This has important implications for recovery planning, since many management prescriptions are tailored toward spatial differences in stand condition to facilitate natural or artificial regeneration. Dispersal mutualists such as the Clark's nutcracker are likely to respond to temporal differences in seed availability, when performing important ecosystem services for maintaining high elevation pine communities. And thank goodness they perform this task; human-aided recovery efforts for limber pine need all the help they can get.

Figure 1.



Acknowledgements

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Lessons Learned from Whitebark Pine Genetics Program

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The genetic restoration program is made up a coalition involving three USFS Regions (Northern, Rocky Mountain, and Intermountain Regions) across 20 Forests, three National Parks, the Bureau of Land Management, and our Alberta neighbors (Parks Canada and Alberta Tree Improvement and Seed Centre). We have the benefit of the western white pine blister rust resistance and restoration program to serve as a guide, affording us the opportunity to take one-third of the time to complete a generation of improvement. Studies in genecology, identifying and harnessing blister rust resistance, and molecular genetics yielded some surprising findings.

Whitebark pine has a moderate level of blister rust resistance (47%), which is *higher* than comparable open-pollinated western white pine progeny (30%) evaluated in the 1950s. It is as genetically diverse as limber pine and aspen, exhibits no inbreeding, and has ample genetic variation in key adaptive traits, which have moderate to high heritabilities. Simply stated, whitebark pine can favorably respond to selection and breeding. Five-needle pines, including whitebark pine, are just a few conifers where patterns in adaptive traits (survival, blister rust resistance, late winter cold hardiness) closely track with patterns in neutral molecular markers (isozymes, mitochondrial and chloroplast DNA).

Integration of the results of these studies have provided valuable management direction: (1) blister rust resistant stock is available for planting, (2) provisional seed zones have been combined into four seed (breeding) zones, (3) no additional requirements are needed for operational cone collections or seed orchard designs, and (4) a comprehensive genetics profile highlights areas with high levels of rust resistance, cold hardiness and genetic diversity for gene conservation. Dunraven Pass, Yellowstone National Park, one of the most studied whitebark pine populations over the last 40 years, still boasts a high level of genetic diversity.

Our program as of 2011 is comprised of 115 Phase I and 1,110 Phase 2 selections ***(see map figure on back cover)***. Since these plus trees were designated, 21% have been lost primarily due to mountain pine beetle and fire, with six total trees lost to blister rust, wind throw or prescribed fire. A tie for the oldest plus tree is between the Bridger-Teton NF and Grand Teton NP. The tallest tree (32 m) is on the Bridger-Teton NF and the largest diameter tree (170 cm) is on the Boise NF. The youngest plus tree (29 years) is on the Flathead NF. Our Alberta partners hold the records for the shortest, smallest diameter and only Krummholz plus trees. Identification of plus trees was not designed to assess age of onset for cone production, but it did reaffirm earlier findings that cone production begins as early as 20-30 years of age; 29% of the plus trees are under the age of 50.

The selective breeding strategy provides broadly adaptable, genetically diverse, blister rust resistant whitebark pine for restoration planting. The emphasis is on durable resistance where selection pressure in the host (whitebark pine) doesn't prompt a negative response in the pathogen (increased blister rust virulence). Past experience tells us we cannot erase blister rust off the landscape, so how does that relate to our strategy? We are still going to see spotting, branch flagging, and cankers in our genetically improved stock, as some rust resistance traits (bark reactions and canker tolerance) *require* infection and canker development before resistance genes can be expressed. Our goal is not immunity or rust-free trees-- neither are desirable or attainable. Rust resistance data also applies to current monitoring efforts. Using the Greater Yellowstone Ecosystem as an example, 20% blister rust infection does not equate to 20% susceptibility, as the frequency of bark reaction and canker tolerance traits (5.6%) needs to be deducted. Susceptibility in this example is 14.4%.

Characterizing progress in the program is assessed with two measures of gain. Expected gain is typically larger than realized gain, as it is calculated on the performance of seedlings planted in experiments designed to control environmental variation, such that the variation expressed can be attributed to genetics. Realized gain is a measure of the performance of genetically improved stock relative to control (woodsrun) lots grown under operational (field) conditions for half a life history or half rotation age. Using western white pine as an example, expected gain is 66% blister rust resistance in F_2 stock, whereas realized gain is around 20%, which is still remarkable in a first generation program of an undomesticated species. Said another way, I wish my bank account returned 20%.

But back to whitebark pine, 47% blister rust resistance is *expected* gain.

This spring marks the beginning of our fifth rust screening, keeping the tree improvement staff hopping with four, concurrent rust screenings at Coeur d'Alene Nursery. Another big surprise in the Northern Rockies was two masting events in 2009 and 2011. We broke our old record with 250 plus tree cone collections and over 555 lbs of operational seed received in 2011, the latter capable of restoring 3,556 acres.

We are just beginning to monitor natural regeneration, with federal and state sources reporting, "It's out there." Accomplishment reporting shows 3,004 acres have been planted with whitebark pine. What does that mean for wildlife? Prior to hibernation, if a hyperphagic grizzly bear consumes 200 pounds of food a day, that equates to 533,638 pine nuts. It was now time to check out the seed inventory. There is enough seed on hand to feed ***one*** bear for two weeks and that food bill exceeds my government purchasing authority. So while the natural and artificial regeneration matures over the next 20-30 years, bears will bulk up on pine nuts from the remaining cone-bearing whitebark and limber pines, false truffles and berries.

But not to be deterred, we have four seed orchards (one for each seed zone) at various stages of development. Since branches remember their position in the crown of the mother tree, 200-year old scion grafted onto four-year old rootstock has the potential to begin cone production 4-5 years after the graft is planted in an orchard. Once the diameter of the graft is over an inch, seed orchard managers can then begin to apply GA 4/7 to stimulate flowering, which will also help overcome cone crop periodicity. Cone production at more regular intervals, combined with accessible locations, will minimize the time and resources spent chasing cone crops across the landscape. Lastly, since there is genetic improvement on both the maternal (cone) and paternal (pollen) sides, we have the capacity to double our blister rust resistance in seed orchard stock. But as the grafts began to produce cones, we'll need to spend a little more time on wildlife-proof seed orchards. I suspect the only wildlife to be excluded and electrocuted will be the Regional Geneticist on a service visit…

For the Greater Yellowstone-Grand Teton seed zone, May 31, 2011 marked a major milestone in the release of the Whitebark Pine Strategy for the Greater Yellowstone Area, prepared by the Whitebark Pine Subcommittee of the Greater Yellowstone Coordinating Committee (GYCC). On April 17, 2012, GYCC Managers representing the USDA Forest Service, USDI National Parks and Bureau of Land Management, and the US Fish and Wildlife Service signed a Memorandum of Understanding for the joint development of the Little Bear seed orchard and a long-term genetic test.

Favorable biology, positive genetic attributes and a generalist adaptive strategy, combined with the energy, enthusiasm, and commitment among our partners, indicates we have the capacity to restore whitebark pine, maintain vital ecosystem processes and biodiversity, and provide critical wildlife habitat. Here's hoping for a good cone crop this field season! ■

Influences of Blister Rust and Mountain Pine Beetle on Whitebark Pine

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In a recent paper published in the *Journal of Biogeography* I examined the relationship between the biophysical environment and two of the primary drivers of whitebark pine dynamics – white pine blister rust and mountain pine beetle (MPB) (Larson 2011). My study area included sites in southwest Montana, central Idaho, eastern Oregon, and western Oregon. Some of the results from this study carried a note of sadness that is familiar to most who work in whitebark pine communities. An active mountain pine beetle outbreak was sweeping the sites examined in the Gravelly Range of southwest Montana while the sites in Idaho had been decimated by mountain pine beetle, blister rust, and recent severe fires. In contrast, however, a sense of optimism could be cautiously drawn from sites in the Pioneer Mountains of southwest Montana and the Wallowa Mountains of eastern Oregon that supported vibrantly healthy stands of whitebark pine with low-severity rust infections and abundant regeneration. Also, there was the near absence of blister rust at sites on Paulina Peak in central Oregon. Some of the results from comparing patterns in blister rust infection levels and mountain pine beetle-caused mortality to variables describing the biophysical environment echoed previous findings, while others offered new insights to the influences and interactions of these disturbance agents.

I inventoried 2666 whitebark pine trees between 2006 and 2008. The proportion of living trees infected by blister rust throughout my study areas was 37%, but it varied from 0 to 100% at different sites. Infection levels were higher at sites supporting at least one of the rust's alternate hosts (e.g., *Ribes spp.*), in stands with a greater proportion of whitebark pine basal area, and in more open forests on steeper slopes. Stands of whitebark pine on north-facing exposures had generally more trees with blister rust infections.

Of the inventoried whitebark pine, 37% were dead with the primary cause of mortality being 20th century MPB activity. Beetle-caused mortality was more common in stands with a greater total basal area of whitebark pine, in areas with drier spring weather and warmer fall temperatures. Tree age was not as important as tree size, with greater mortality among larger trees. In general these results are similar to those found by others investigating patterns of blister rust and MPB effects in whitebark pine and other subalpine communities (e.g., Campbell and Antos 2000, Smith and Hoffman 2001, Perkins and Roberts 2003, Kearns and Jacobi 2007, Smith *et al.* 2008), yet the differences in the type and strength of relationships identified in my study, when placed in the context of the other studies, illustrates important geographic differences in the factors that drive whitebark pine disturbance regimes.

The potential interactive effects of rust and MPB seem compelling. MPB outbreaks kill mature whitebark pine with no deference to blister rust resistance, create more open stand structures that may increase the likelihood of surviving trees becoming infected by airborne basidiospores. In areas where blister rust infections are severe and whitebark pine seed stock is diminished, the advent of a MPB outbreak can accelerate the loss of whitebark pine to the point of extirpation. However, in areas with relatively moderate blister rust infections, whitebark pine regeneration under beetle-killed canopies may create an environment that facilitates an increase in blister rust resistance (Figure 1—*see back cover*). Ray Hoff and his coauthors predicted that blister rust resistance could increase significantly over the course of only a few generations (Hoff *et al.* 2001). This may be particularly true where abundant early regeneration is exposed to moderate levels of blister rust, essentially sharpening the selective pressure of blister rust by infecting younger trees that more quickly succumb to the infection.

The number of whitebark pine monitoring programs has grown tremendously over the past two decades, in no small part due to the efforts of the Whitebark Pine Ecosystem Foundation. As the first wave of MPB outbreaks of the 21st century subsides, the data collected through these monitoring efforts can be used to identify whitebark pine populations that had moderate levels of blister rust before the MPB outbreaks began. Efforts should be made to return to these sites to monitor whitebark pine regeneration in the wake of the outbreaks, as the sorting of seedlings and saplings that follows may favor individuals with greater rust resistance.

The potential for MPBs to facilitate the development of blister rust resistance in whitebark pine communities may be too simplistic or hopeful. It is also possible that pressures from increasing blister rust infections and changing climate are too great and will overwhelm the ability of whitebark pine to adapt fast enough. However, if the concerted efforts to preserve this foundation species in substantial numbers are to succeed, it will depend on land managers, scientists, and concerned citizens exploring every possible opportunity to advance the cause.

The potential role of MPB in driving adaptation in whitebark pine could be tested through retrospective studies that estimate blister rust infection levels at the times of other widespread mountain pine beetle outbreaks, such as those that affected the U.S. Northern Rocky Mountains in the 1930s and 1980s, and assessing the frequency of rust resistance among the regeneration associated with these outbreaks. I strongly urge those of us who spend time in whitebark pine communities to look for regeneration following the recent MPB outbreaks, and to encourage or engage in efforts to screen for blister rust resistance among the next generation of whitebark pine.

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Comparing Mountain Pine Beetle Preference for Whitebark and Lodgepole Pines

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As many of us have witnessed over the past several years, mountain pine beetle (MPB) outbreaks pose a significant threat to high elevation forests in the Rocky Mountains. Whitebark pine is particularly at risk from MPB range expansion (Logan and Powell 2001, Raffa et al. 2008), and many researchers also suspect that these insects prefer whitebark pine over more abundant lodgepole pine. Beetle preference for whitebark pine might be due to a combination of poorer defenses, infection by white pine blister rust, and greater phloem thickness or nutritional quality in comparison with lodgepole pine (Amman 1982, Six and Adams 2007, Bockino and Tinker 2012). Therefore, where whitebark and lodgepole pines co-occur, beetles might select host trees based on species rather than diameter. This is an important distinction to test directly, because in lodgepole pine, tree diameter is a highly consistent cue for beetle host selection (Cole et al. 1969, Amman and Cole 1983, Raffa and Berryman 1983, Bentz et al. 1993, Boone et al. 2011). However, if whitebark pine is also present, MPB might prefer it to large diameter lodgepole pines.

To evaluate the importance of tree species versus diameter as mountain pine beetle host-selection cues, I used a canopy foliage scoring system to reconstruct beetle outbreaks at three sites in western Montana. At each site, whitebark pine and lodgepole pine co-occurred, and MPB activity was of moderate severity. Canopy foliage scores based on needle color and needle loss were used to estimate the date of MPB attack for all trees in multiple 400 m^2 quadrats at each site. I used logistic regressions to determine whether species or diameter significantly predicted mountain pine beetle attack at each site, and I then used the logistic regression equations to determine whether there was a difference in tree diameter for whitebark pines and lodgepole pines given the same probability of beetle attack.

I found that tree diameter predicted MPB attack at all three sites, and that for both whitebark pines and lodgepole pines, beetles preferred larger trees. Tree species also predicted MPB attack at two of the three sites, and whitebark pine was more likely to be attacked than lodgepole pine. Since lodgepole pines were of larger overall diameter at all of the sites, preference for whitebark pine resulted in beetles attacking smaller diameter whitebark pines relative to lodgepole pines. However, MPBs also attacked progressively smaller and smaller whitebark pines over time while the diameter of attacked lodgepole pines remained constant. Thus, while tree diameter was overall a more consistent predictor of MPB attack across sites and time, tree species was also relevant in MPB host selection.

An important finding of this study was that MPBs showed preference for small diameter whitebark pines even when relatively larger lodgepole pines were available nearby. I used logistic regression equations to calculate that at the two sites where tree species influenced beetle attack, whitebark pines were as likely to be attacked as lodgepole pines that were 10.7 or 14.7 cm larger in diameter. In other words, from the beetle point of view, small whitebark pines are equal to much larger lodgepole pines as host trees. This might occur because whitebark pine provides better nutrition to beetles, by having thicker phloem or higher nutrient concentrations in the phloem (Lahr and Sala, ms. in prep). If that is the case, small whitebark pines may be just as nutritious for beetles as larger but potentially better-defended lodgepole pines. Tree nutritional quality, in addition to tree defenses, may therefore be an important factor to consider in understanding MPB outbreaks at high elevations.

This information may improve our understanding of the intensity and duration of MPB outbreaks in whitebark pine and potentially in other host species as MPB range continues to expand in the future. In particular, I hope that data on the differential susceptibility of whitebark and lodgepole pines to by tree diameter to beetle attack are useful in assessing stand risk. For example, these results suggest that presence of small but potentially higher quality host trees (whitebark pines) may enable MPBs to persist in stands where outbreaks would otherwise end after all large trees were killed. Over the course of an outbreak, such a difference in host tree species, and the ability to maintain an eruptive population in small diameter host trees, might allow MPBs to persist at high elevations better than was previously believed.

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Carbon and Nitrogen Cycling in Whitebark Pine Ecosystems Following Mountain Pine Beetle Outbreak

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The ongoing mountain pine beetle (MPB) outbreak is thought to be causing unprecedented widespread mortality across the range of whitebark pine (Logan et al. 2010). While several impacts of this disturbance have been studied in whitebark pine, the potential consequences for ecosystem processes like carbon (C) and nitrogen (N) cycling are poorly understood. This is in spite of the fact that potential nutrient cycling shifts accompanying the MPB outbreak may play a critical role in regulating the future of whitebark pine ecosystems in terms of both regeneration and C storage potential. In addition, no studies have been published describing the C and N characteristics of whitebark pine ecosystems in general, meaning that baseline data is needed to assess the effects of MPB attack.

Previous research has uncovered a wide variety of C and N cycling responses to ecological disturbances, responses that hinge upon characteristics of both the ecosystem and the disturbance itself (Vitousek et al. 1979, Allen 1985, Hicke et al. 2012). Regardless of the disturbance or ecosystem in question, the mortality of dominant vegetation produces some predictable structural and physiological changes. These changes cause important elements, such as carbon (C) and nitrogen (N), that were previously locked up in living biomass to arrive as a large pulse on the forest floor and become available for decomposition and immobilization by microbes (Chapin et al. 2002). The likely increase in inputs of C and N to the system, at least in the short term, leads to two primary possibilities: they will be absorbed by the ecosystem through mechanisms that include increases in biomass and microbial immobilization, or they may be lost from the system through leaching of N and soil CO_2 efflux (Clow et al. 2011, Hicke et al. 2012).

Widespread whitebark pine mortality caused by the MPB outbreak drives changes in whitebark pine forests, which could produce shifts in pools and fluxes of C and N within these ecosystems. Shortly after beetle attack, nutrient and water uptake by host trees stops, potentially altering soil moisture and soil nutrient pools (Huber 2005, Clow et al. 2011, Griffin et al. 2011). Within two years of attack, needles on the tree typically turn red and begin falling to the ground, signifying the "red" stage of beetle infestation. In host tree species where litterfall nutrient content has been analyzed, attacked tree litterfall has higher N content than normally senescing litterfall, because the attacked trees do not resorb nutrients from their needles before they fall (Morehouse et al. 2008, Griffin et al. 2011). Five years after attack, trees have typically lost all their needles to the forest floor and reach the "gray" stage. The large, relatively rapid pulse of needlefall to the ground provides a substantial pool of C and N for the ecosystem to process (Chapin et al. 2002). All of the above characteristics of mountain pine beetle attack have the ability to impact belowground internal C and N cycling, as well as above and belowground C and N fluxes (Clow et al. 2011, Hicke et al. 2012). Previous research in other MPB-infested ecosystems such as lodgepole and ponderosa pine has documented measurable shifts in C and N cycling including increases in soil inorganic N and N mineralization (Morehouse et al. 2008, Griffin et al. 2011), as well as increases in downed dead C stocks following beetle attack (Morehouse et al. 2008).

The overarching objectives of this research project were to determine how the current MPB outbreak affects C and N cycling in whitebark pine ecosystems in the short- term. To address these objectives, I measured above and belowground N and C pools and fluxes around trees at three different stages of beetle attack (green or unattacked, red, and gray) in the Pioneer Mountains of southwestern Montana over the summer of 2010. Given the widespread whitebark pine mortality that is occurring in my study area and whitebark pine ecosystems all over western North America, I predicted that there would be measurable shifts in C and N cycling with time since beetle infestation.

I documented differences in C and N inputs under 10 focal trees at each infestation stage by collecting litterfall and measuring N content of the litter. To determine if shifts in belowground C and N cycling were occurring, I collected data on soil inorganic N (NH_4^+ and NO_3^-), total soil C and N, microbial biomass C and N, and N mineralization under the same trees. Finally, in order to discover if there were shifts in outputs of C and N from whitebark pine systems, I measured belowground N fluxes and soil CO_2 efflux under the focal trees.

Litterfall inputs under beetle-attacked trees were more than ten times higher than those under unattacked trees. Litterfall N content was also higher under attacked trees. In response, soil ammonium (NH_4^+) concentrations in the organic horizons increased under attacked trees compared to unattacked trees. However, there were not significant differences in NH_4^+ concentrations in the mineral, lower soil horizons. Overall, soil nitrate (NO_3^-) concentrations were low and highly variable, but generally increased following beetle attack. Additionally, there was no change in microbial biomass N in the soil between attacked and unattacked trees, implying that changes in N cycling in response to the initial stages of whitebark pine attack were subtle. Soil CO_2 efflux rates were generally higher under unattacked trees, but overall, the similarities were more apparent than the differences. Finally, there were no indications of significant N losses from the system through leaching.

My results indicate that while beetle attack drives a large pulse of C and N canopy to the forest floor after beetle attack, changes in litterfall quality and quantity do not have immediate and profound effects on soil C and N cycling. Considering the extent of whitebark pine mortality at the study site, the lack of many significant responses was unexpected. Looking at the characteristics of whitebark pine ecosystems, however, provides some insight into potential lags in response time to the disturbance, which may allow regeneration to catch up before any long-term nutrient shifts occur. For example, the very short growing season and extreme climatic conditions that exist in whitebark pine ecosystems most likely cause many microbial processes to progress more slowly than occurs in other ecosystems. In the case of a large-scale, high mortality disturbance, this may be a positive characteristic as far as ecosystem response to significant shifts in C and N cycling is concerned. However, long-term monitoring is required to determine whether wholesale C and N cycling changes merely take longer to manifest themselves in whitebark pine ecosystems.

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Interactions Between Mountain Pine Beetle and Whitebark Pine

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Editor's Note: *The following are abstracts from a newly completed thesis on the important subject of bark beetle-whitebark pine relationships. For further information readers are invited to contact the author:* <eesch@ualberta.ca>

Overall Abstract

Laboratory and field experiments compared life history traits between mountain pine beetles (MPB) utilizing whitebark pine and lodgepole pine to better understand the beetle's impact in the Rocky Mountains of Alberta. Host species influenced the assemblage of dead wood inhabiting beetles and the life history traits of the MPB. One host was not obviously better in terms of quality or susceptibility for the MPB. Large diameter whitebark pines with thick phloem will contribute as much or more to the transition of MPB populations from endemic to epidemic status than will similarly large lodgepole pines. For some MPBs, a univoltine life-cycle was observed, suggesting that climatic barriers likely to have constrained high altitude MPB populations in the past are moderating, meaning that this endangered pine is at greater risk of MPB attack.

Chapter 2 Abstract: Gallery success, brood production and condition of mountain pine beetles reared in whitebark and lodgepole pine bolts

Mountain pine beetles (MPB) were reared in the laboratory using cut bolts to compare life history traits of beetles reared in whitebark pine and lodgepole pine, the MPB's primary host in Alberta. Mountain pine beetles were more likely to establish galleries that produced brood in cut bolts with thicker phloem, and to establish galleries in lodgepole pines than whitebark pines. Brood production, beetle size and female beetle mass were lower in whitebark than lodgepole pines when phloem was thin. In bolts with thicker phloem, however, brood production was similar between the two species and beetle size and female mass were greater if reared in whitebark pine bolts. Fat content was higher in female beetles from lodgepole pines across the entire range of phloem thicknesses. It is concluded that large diameter whitebark pines with thick phloem will contribute as much or more to the transition of MPB populations from endemic to epidemic status in sub-alpine zones of the northern Rocky Mountains than will similarly large lodgepole pines.

Chapter 3 Abstract: Survival, development and reproductive rates of mountain pine beetles in whitebark and lodgepole pines in northern and southern Alberta

I baited adjacent pairs of whitebark and lodgepole pine with pheromones of MPB to induce simultaneous mass attacks in study sites on the east slopes of the Rocky Mountains in Alberta. Host species had relatively small effects on MPB attack density, gallery and brood characteristics compared to climatic factors and local population size. Whitebark pine did not have thicker bark and/or phloem than lodgepole pine in the stands chosen for study, possibly explaining the lack of larger host mediated differences in these characteristics. MPB egg mortality was higher in whitebark pine, possibly reflecting significantly greater densities of radial resin ducts than in lodgepole pines. Among the few MPB brood that survived the cold winter of this experiment, a substantial component of the cohort exhibited a univoltine life cycle, in contrast to earlier reports of longer life cycles for this bark beetle at high altitudes. The univotine development observed here suggests that climatic barriers likely to have constrained high altitude MPB populations in the past are moderating, meaning that this endangered pine is at greater risk of MPB attack.

Chapter 4 Abstract: Beetle diversity in subalpine whitebark and lodgepole pine snags killed by mountain pine beetle

Whitebark pine, a foundational species of subalpine ecosystems, is endangered across its range because of attacks by the exotic fungal pathogen *Cronartium ribicola* and the native MPB, and direct effects of climate change. These factors promise to promote significant changes in the distribution and abundance of whitebark pine, but little is known about the invertebrate fauna associated with this species. I show that the structure of saproxylic beetle assemblages differed between co-occurring whitebark and lodgepole pines that had been recently killed by mountain pine beetle, using data from both emergence and flight intercept traps. Ordinations with Redundancy Analysis (RDA) suggest that host species and snag age had relatively small effects on the overall beetle assemblage, except for differences between recently killed and the oldest snags. In contrast, these two factors were significant predictors for assemblages of MPB and its associates, as driven mainly by data about five species (*Ips pini* (Say), *Corticeus praetermissus* (Fall), *Hylurgops porosus* (LeConte), *Thanasimus undulatus* (Say) and *Quedius velox* Smetana).

Although no common species appeared to be exclusively associated with whitebark pines, differences in abundance and distribution Scolytinae were notable. Nonetheless, rarefaction analysis revealed no difference in species diversity between the two hosts. Eight scolytinae species were identified (using a formal Indicator Species Analysis) as good indicators for lodgepole pine in various situations; however, only *Pityophthorus murrayanae* Blackman, as collected in emergence traps on snags 3-4 years after

tree death, was a good indicator for whitebark pine. Seven rarely collected species (*Microstagetus parvales* Wollaston, *Agathidium fenderi* Hatch, and four species of *Pityophthorus* another of *Corticaria* that could not be confidently identified), found exclusively on whitebark pine, have potential for strong associations with this host and merit further study. However, with these possible exceptions, falling and burning mountain pine beetled infested whitebark pines to control the mountain pine beetle will not likely endanger the biodiversity of saproxylic beetles associated with this tree. ■

Blister Rust at Treeline: Topographic Influences

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My doctoral research is but one component of an NSF-funded research study that is examining the whitebark pine-pathogen-climate system, with the purpose of understanding the effects of white pine blister rust on treeline whitebark pine ecosystems and its implications on treeline dynamics. This NSF study is a collaborative project between Virginia Tech, University Colorado Denver, and The University of Iowa. Here, I will discuss some of the collaborative research in assessing the geographic variation of blister rust infection, and topographic factors influential to the disease, on two Montana treeline communities dominated by whitebark pine.

Whitebark Pine, Treeline, and Blister Rust

In whitebark pine-dominated landscapes of the alpine treeline ecotones (ATE), the unique relationship between the Clark's nutcracker and whitebark pine, and successful germination after seed-dispersal to higher elevations, typically provides the foundation for tree island development. Research in northern Rocky Mountain treelines in Glacier National Park has shown that cold-and wind-tolerant whitebark pine is a frequent initiator of tree island colonies, by sheltering less tolerant conifers (Resler and Tomback 2008). The invasive pathogen *Cronartium ribicola*, which causes white pine blister rust, has spread nearly throughout the range of whitebark pine into the more extreme climates previously thought to limit blister rust spore production including the dry and cold upper limits of the ATE of the northern Rocky Mountains.

Topography at Treeline, and Blister Rust

The alpine landscape (at varying spatial scales) is typically characterized by hummocky topography and patterned ground, that affects soil moisture, sun exposure, snow retention, and local microclimate in sheltered versus exposed sites. These topographic features can ameliorate the harsh environmental conditions at treeline, facilitate seedling establishment, and affect tree colonization (e.g., Butler et al. 2004).

Topography affects mountain climate, and in particular wind and moisture. Cool, moist conditions during fungal spore production stages in spring, summer, and fall months favor disease spread and transmission from alternate host to host five-needled pines (Mielke, 1943). Topographic characteristics that influence moisture and solar radiation may indicate areas potentially susceptible to fungal infection, and the role of topographic factors in relation to blister rust infection is evident in other research studies (e.g.,White et al. 2002).

In treeline communities where whitebark pine is the predominant conifer species, blister rust-induced decline of krummholz (stunted, wind-battered) whitebark pine may impact interpretations of changing treelines that are responding not only to a warming climate, but to a disease-altered ecosystem as well. These reasons underscore the importance of studying topographic factors that influence the effects of an invasive pathogen on a keystone and foundation species.

Data Collection/Analysis

We studied two whitebark pine treeline communities in July 2010 located near the mid- and southern-latitudes of whitebark pine's Rocky Mountain range. We sampled in Glacier National Park, and the Beartooth Plateau, Montana, US, in order to 1) determine if blister rust is present (and if present, to what intensity), 2) determine which microtopography variables spatially correlate with blister rust infection presence/intensity among the sampled whitebark pine trees, and 3) assess the geographic variation of these results between treeline study areas.

We collected tree, disease, and topographic data at each treeline study area, sampling from 30 plots (15 m x 15 m) stratified by aspect, for a total of 60 plots. For each plot we 1) recorded whitebark pine tree GPS positions, 2) quantified blister rust presence and canker intensity of solitary and tree island whitebark pine, and 3) characterized the microtopography of each sampling plot by creating high resolution GPS-derived digital elevation models (DEM) using methods from Smith et al. (2011). Sampled whitebark pine trees ranged in size from seedlings to those growing in krummholz form, with most trees under 1 m in height. Digital elevation models had submeter resolution, and helped characterize the microtopography (i.e. microsites, depressions) over such a small area (15m plot). Following fieldwork, we derived topographic features from our DEMs using GIS (Geographic and Information System) spatial analyst tools, and incorporated these variables in our statistical analyses.

To determine any correlations between topography and blister rust presence/intensity for each sampled tree, we ran our analysis at the tree-level. We considered topographic features important in controlling runoff, cool air drainage, sun exposure, and distances to water features potentially influential for blister rust development. We geolocated each whitebark pine tree to compare tree and disease characteristics (blister rust presence/absence, and number of cankers) with microtopography variables (Figure 1). Our statistical analyses involved zero-inflated Poisson regression models to test relationships of variables associated with the presence of blister rust on trees, and the number of cankers per tree.

Results/Discussion

Nearly one-fourth of our sampled whitebark pine trees were infected with blister rust, with slightly higher infection rates at our northern study area (Glacier National Park: 24% infected, N=585 trees) compared with our southern study area (Beartooth Plateau: 19% infected, N=328 trees). Consistent with previous studies (Resler and Tomback 2008; Smith et al. 2011), we found that whitebark pine trees growing within tree islands had higher infection rates, and more cankers per tree, than whitebark pine trees growing solitary (Table 1).
Our model results suggest surrounding topography, topographic position (in relation to sun exposure, depressions, and breezes), and proximity to moisture resources are important in predicting blister rust canker intensity. Predicting blister rust presence/absence alone proved more difficult. When comparing our two treeline models, results indicated the importance of differing local site factors of each treeline study area. For example the Beartooth Plateau southern study area is located at a higher elevation, on a more exposed slope, and has more arid summers than the northern study area in Glacier National Park. The southern treeline model uncovered more significant moisture predictor variables than the northern site, possibly indicating an escalated importance of moisture resources in the higher and drier Beartooth Plateau. Due to the complexity of the blister rust disease cycle, more environmental factors deserve further investigation and possible incorporation to these types of regression models. For example, future models might include incorporating a distance from host tree to alternate host species, or microclimate data. Incorporating these factors at a fine scale, may prove an important contribution to blister rust research at treeline.

Acknowledgments

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Figure 1. Example of a microtopography surface variable, and whitebark pine spatial locations.

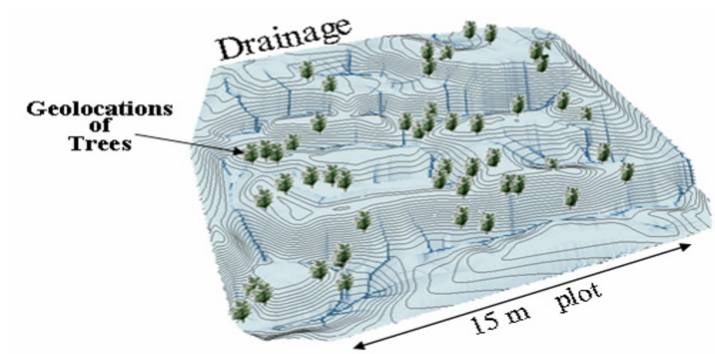

Table 1. Tree and disease statistics for sampled whitebark pine at two treeline study areas.*

Parameter	Glacier National Park	Beartooth Plateau
Number of sampled *PIAL*† (N)	585	328
Number of **solitary** *PIAL*	269	191
Number of **tree island** *PIAL*	316	137
Number of blister rust-infected *PIAL* trees	138	63
Total % blister rust infection	23.6%	19.2%
% blister rust-infected **solitary** *PIAL*	17.1%	13.6%
% blister rust-infected **tree island** *PIAL*	29.1%	27.0%
Canker density (number cankers per infected tree)	3.7	6.9
Canker density on **solitary** *PIAL*	0.4	0.6
Canker density on **tree island** *PIAL*	1.3	2.3

*Thirty 15 m x 15 m plots were sampled per study area; †PIAL: *Pinus albicaulis* (whitebark pine)

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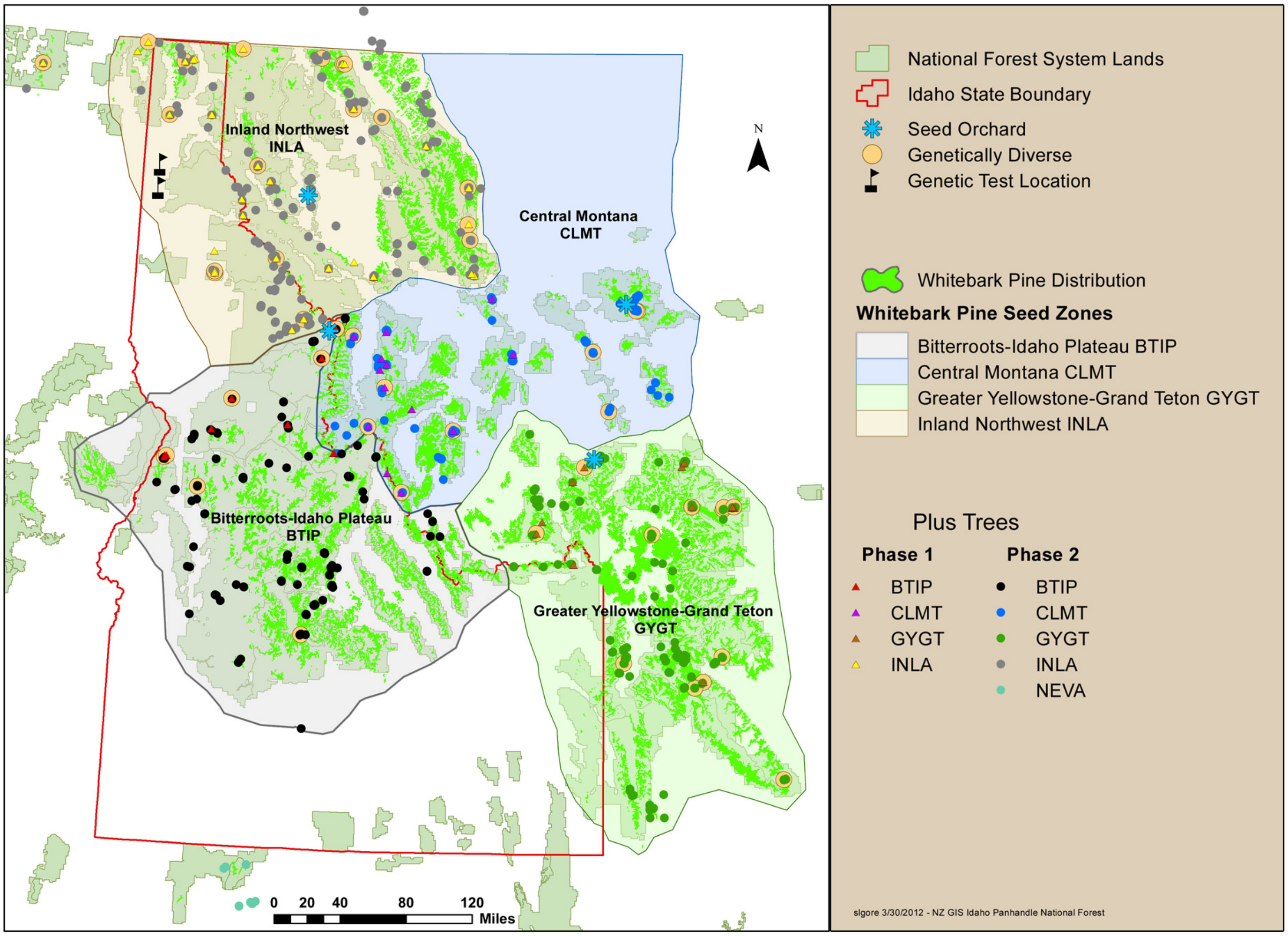
[from Larson article]

Figure 1. One of the keys to the preservation of whitebark pine on western landscapes may be natural regeneration following recent and historical mountain pine beetle outbreaks. Pictured above are (A) newly emerged seedlings on Mount Bachelor under a patch of whitebark pine still holding red needles after being killed in 2007 by mountain pine beetles, (B) rust-free whitebark pine saplings beneath a stand of whitebark pine on Brundage Mountain, Idaho, killed by mountain pine beetles in the 1980s, and (C) a healthy, mature whitebark pine that established soon after the death of a neighboring tree in the 1930s, also on Brundage Mountain.



Genetic Catalog-Map of Whitebark Pine, including plus trees and revised seed zones, (*see Mahalovich article*).