Poster Abstracts

Whitebark Pine Ecosystem Foundation

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Teaching Students about Whitebark Pine and Fire Using Hands-on Activities

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Keywords: education, whitebark pine

FireWorks is an educational program about wildland fire science that provides interactive, hands-on activities for students in grades K-12. Activities from the Northern Rocky Mountains and Northern Cascades program feature whitebark pine forests along with two other forest types. Educators can focus exclusively on whitebark pine, or they can address all three forest types so students can learn about the diversity and interdependence of forests. Students use age-appropriate activities to learn about the organisms that live in each forest type, how fires typically burn there, and the historical fire regime. For example, young students learn about whitebark pine's historical pattern of "rollercoaster" (mixed- severity) fires by using feltboard materials to illustrate a story, while older students use the FireWorks Encyclopedia (a series of short essays) to learn about the organisms typical of whitebark pine communities. Each year, thousands of students use FireWorks to learn about fire in whitebark pine communities and many other ecosystems throughout the United States.

Challenges of Restoring a Unique Population of Whitebark Pine

by Robin Garwood | Deb Taylor | USFS | USFS

Keywords: planting, rust resistance, whitebark pine

The Sawtooth National Recreation Area has received support from the Forest Health Protection Whitebark Pine Restoration Program for planting seedlings on Railroad Ridge in the White Clouds Mountain Range. This area contains a unique population of whitebark pine based on having a unique allele. Management of this population is challenging due to its very low white pine blister rust resistance. Results of this planting effort will be explained and how it relates to management of this unique area.

Whitebark Pine Friendly Ski Areas

by Mike Giesey | WPEF

Keywords: conservation, education, guided hike, recreation, ski area, whitebark

This poster will provide an overview of the Whitebark Pine Friendly Ski Area Certification Program. Ski areas represent an excellent opportunity to improve public awareness of whitebark pine and the environmental challenges it faces. The intent of this certification program is to:

- Increase awareness among ski area employees and patrons of issues surrounding whitebark pine
- Guide ski areas in their efforts to conserve and restore whitebark pine
- Provide an opportunity for ski areas and their patrons to be involved in restoring whitebark pine by becoming directly involved in education, conservation and restoration efforts or through monetary donations
- Recognize ski areas that are leaders in whitebark pine education, conservation and management
- And, ultimately, preserve and manage for whitebark pine so that high-elevation recreationists can enjoy the many benefits of whitebark pine

Genetic and Remote Sensing Approaches to Identify White Pine Blister Rust Infection in Southwestern White Pine

by Jeremy Johnson | Marja Haagsma | Richard Sniezko | Gerald Page | Christopher Still | John Selker | Kristen Waring | Prescott College | Oregon State University | USDA Forest Service | Oregon State University | Oregon State University | Oregon State University | Northern Arizona University

Keywords: Hyperspectral Remote Sensing, Pinus strobiformis, genetic resistance, white pine blister rust

Southwestern white pine (SWWP, *Pinus strobiformis*), is a high-elevation, large, long-lived conifer native to the U.S. and Mexico that is susceptible to white pine blister rust (caused by the non-native fungal pathogen, *Cronartium ribicola*). SWWP has a suite of strategies (including Major Gene Resistance and Quantitative Disease Resistance), occurring at low population frequencies, for resisting the fungus. Even though resistance occurs in SWWP, it can be very difficult to identify trees with a resistance mechanism that could be included in breeding for restoration and reforestation. In this study we tested the ability of hyperspectral imaging, combined with a custom motion-control system and machine learning, to identify and track the progression of the disease in order to identify seed sources of potential genetic resistance. We conducted a greenhouse study on 175 open- pollinated seedlings from 10 seed sources selected across the latitudinal range of the species. Seedlings were randomized and half were artificially inoculated with *C. ribicola* spores while the remainder were used as controls. The seedlings were manually scored for disease symptoms and patterns of growth. A support vector machine learning approach was able to automatically detect infection with a classification accuracy of 87% (kappa = 0.75) over 16 image collection dates. Additionally, hyperspectral imaging was shown to accurately detect health vigor status (as a proxy for disease progression) using the normalized photochemical reflectance index, which is a proxy for photosystem II function. This fast and (semi-) automatic approach suggests a way forward to scale up early disease detection in forestry.

Identifying Patterns of Blister Rust Resistance in Southwestern White Pine

by Jeremy Johnson | Richard Sniezko | Kristen Waring | Christian Wehenkel | Prescott College | USDA Forest Service | Northern Arizona University | Universidad Juarez del Estado de Durango

Keywords: Pinus strobiforms, White pine blister rust, genetic resistance, quantitative disease resistance

Southwestern white pine (*Pinus strobiformis*), is a high-elevation white pine native to the U.S. and Mexico and is susceptible to white pine blister rust (caused by the non-native fungal pathogen *Cronartium ribicola*). The species has a major gene, discovered at low frequency in some populations, that conveys complete resistance to the disease but may be overcome in the future by virulent strains of the pathogen. Quantitative disease resistance has also been documented in the species. Even though resistance occurs in southwestern white pine, little is known about the type, frequency, and geographic pattern of resistances across its range. As part of a large collaborative and interdisciplinary study we present early results from a range-wide assessment of 446 families from 104 populations trials sown in 2014, 2016 and 2017, including the first tests of populations from Mexico. Seedlings were artificially inoculated with *C. ribicola* spores and scored for disease symptoms and patterns of growth. All populations show high infection; however, early results indicate that there is a suite of resistance mechanisms that can be leveraged for restoration and reforestation. The incorporation of, physiological, genetic, and remote sensing approaches are improving the speed and precision at which we can identify resistant versus susceptible trees and will aid in the selection, breeding and deployment of resistant candidates for reforestation and restoration. Field trials based on screening results have begun.

Pinus Flexilis Is a Highly Susceptible Host of Dothistroma Septosporum in Canada – First Report

by Jodie Krakowski | Renate Heinzelmann | Tod Ramsfield | Andy Benowicz | Richard Hamelin | Colin Myrholm | consultant | Department of Forest and Conservation Sciences, University of BC | Canadian Forest Service – Northern Forestry Centre, Natural Resources Canada | Alberta Agriculture and Forestry, Government of Alberta | Department of Forest and Conservation Sciences, University of BC | Canadian Forest Service – Northern Forestry Centre, Natural Resources Canada

Keywords: Dothistroma septosporum, limber pine, pathogen

After health surveys suggested *P. flexilis* and other *Pinus* species were infected with *Dothistroma* sp. At the provincial genetic research and conservation facility in Smoky Lake, Alberta, further assays were conducted to confirm the agent. The facility is 350 km northeast of the natural range of *P. flexilis*. Field phenotypic foliar assessments of a germplasm conservation and provenance-family field test, laboratory cultures on solid malt extract-agar (MEA) and in liquid V8 medium, and genomic ITS region sequencing all confirmed *P. flexilis* is a susceptible host of *Dothistroma septosporum* (syn. *Mycosphaerella pini*). This is the first confirmed infection of *D. septosporum* on endangered *P. flexilis* in Canada. Timely reports of potential field observations are important to characterize the extent and to develop appropriate management strategies for this pathogen.

The Great Basin Five-Needle Pine Proactive Strategy Engagement: A Collaborative and Science-based Approach

by Anna W. Schoettle | Maria Newcomb | David A. Charlet | Duncan Leao | Annabelle Monti | Kelly S. Burns | USDA Forest Service, Rocky Mountain Research Station, Ft. Collins, CO | USDA Forest Service, Intermountain Region Forest Health Protection, Ogden, UT | College of Southern Nevada, North Las Vegas, NV | USDA Forest Service, Humboldt-Toiyabe National Forest, Sparks, NV | USDA Forest Service, Humboldt-Toiyabe National Forest, Sparks, NV | USDA Forest Service, Rocky Mountain Region Forest Health Protection, Lakewood, CO

Keywords: Pinus longaeva, Pinus albicaulis, Pinus flexilis, Great Basin, white pine blister rust, Proactive management, management-research partnerships

Great Basin bristlecone pine, limber pine, and whitebark pine protect watersheds, play important ecological functions, are symbols of perseverance and longevity, and are valued by the public. These high-elevation five-needle pines of the Great Basin face direct and indirect effects of climate warming and the threat of the continued spread of *Cronartium ribicola*, the non-native fungus that causes the lethal disease white pine blister rust. The Great Basin ecosystems are unique, and the scope of the threats requires landscape-scale solutions. The primary objective of this ongoing project is to coordinate a cross-boundary partnership of managers, researchers, and professionals to identify critical information gaps and outline priorities for building a strong science foundation that can assist in timely decision making for managing and conserving the high-elevation five-needle pines for resilience to white pine blister rust in a changing climate. We brought together representatives from the USDA Forest Service (R&D, NFS, FHP), USDI Park Service, USDI Bureau of Land Management, USDI Fish and Wildlife Service, academia, and State, Tribe, and non-governmental organizations for a field workshop in July 2021 in eastern Nevada to share knowledge and build a collaborative High-5 group in the Great Basin (figure 1). This project was supported in-part by the USDA FS Region 4 - Rocky Mountain Research Station BeSMART Program intended to spur Intermountain Region (R4) management – FS research partnerships to bring innovative approaches to management challenges.

Preparing for Invasion: Rust Resistance in Limber, Great Basin Bristlecone, and Rocky Mountain Bristlecone Pines

by Anna W. Schoettle | Angelia Kegley | Richard A. Sniezko | Detlev Vogler | Kelly S. Burns | Gretchen Baker | Jeff Connor | USDA Forest Service, Rocky Mountain Research Station, Ft. Collins CO | USDA Forest Service, Dorena Genetic Resource Center, Cottage Grove, OR | USDA Forest Service, Dorena Genetic Resource Center, Cottage Grove, OR | USDA Forest Service, Pacific Southwest Research Station, Placerville, CA (retired) | USDA Forest Service, Rocky Mountain Region Forest Health Protection, Lakewood, CO | USDI Park Service, Great Basin National Park, Baker, NV | USDI Park Service, Rocky Mountain National Park, Estes Park, CO (retired)

Keywords: Pinus aristata, Pinus flexilis, Pinus longaeva, Proactive intervention, genetic resistance, white pine blister rust

Great Basin (GB) bristlecone pine, Rocky Mountain (RM) bristlecone pine, and limber pine are high-elevation five-needle pines threatened by the non-native pathogen *Cronartium ribicola* that causes the disease white pine blister rust (WPBR). The pathogen continues to spread, and the infection front is now in the Southern Rocky Mountains and Great Basin. WPBR is increasing in these areas on limber pine and RM bristlecone pine as well as whitebark pine; GB bristlecone is the only North American five-needle pine that has not been found in the field with the disease. Because these populations are still healthy, they offer the opportunity to assess the baseline frequency of WPBR resistance traits in largely naïve populations, make comparisons among the species, and speculate on the evolutionary origins of resistance traits. Information on genetic resistance traits and their frequencies also supports development of proactive interventions to increase the frequency of resistance in populations before pathogen invasion to mitigate future impacts and sustain ecosystem function during pathogen naturalization. We present results from artificial inoculation common garden studies to assess qualitative and quantitative resistance traits in seedling families for limber and the bristlecone pine species. All three species are highly susceptible to the disease though they differ in their response to inoculation. Variation in disease progression and mortality following inoculation among seedling families and source areas was observed. Disease resistance was evident in some families of each species and varied among species. Limber pine is more easily infected than either of the bristlecone species under common garden conditions. Within the ecological context of each species, genetic resistance to WPBR is likely to be a significant determinant of the species' population trajectory in the presence of *C. ribicola*.

Climate Correlates of White Pine Blister Rust Infection in Whitebark Pine in the Greater Yellowstone Ecosystem

by David Thoma/Erin Shanahan | GRYN-NPS

Keywords: Cronartium ribicola, Greater Yellowstone Ecosystem, Pinus albicaulis, relative humidity, white pine blister rust, whitebark pine

Whitebark pine, a foundation species at tree line in the Western U.S. and Canada, has declined due to native mountain pine beetle epidemics, wildfire, and white pine blister rust.These declines are concerning for the multitude of ecosystem and human benefits provided by this species. An understanding of the climatic correlates associated with spread is needed to successfully manage impacts from forest pathogens. Since 2000 mountain pine beetles have killed 75% of the mature cone-bearing trees in the Greater Yellowstone Ecosystem, and 40.9% of monitored trees have been infected with white pine blister rust. We identified models of white pine blister rust infection which indicated that an August and September interaction between relative humidity and temperature are better predictors of white pine blister rust infection in whitebark pine than location and site characteristics in the Greater Yellowstone Ecosystem. The climate conditions conducive to white pine blister rust occur throughout the ecosystem, but larger trees in relatively warm and humid conditions were more likely to be infected between 2000 and 2018. We mapped the infection probability over the past two decades to identify coarse-scale patterns of climate conditions associated with white pine blister rust infection in whitebark pine.

Maintaining *Pinus strobiformis*, a Tree Species Threatened by Climate Change and White Pine Blister Rust

by Kristen Waring | Richard Sniezko | Nicholas Wilhelmi | Gregory Reynolds | Jeremy Johnson | School of Forestry, Northern Arizona University | USDA Forest Service, Dorena Genetic Resource Center | Forest Health Protection | Forest Health Protection | School of Forestry, Northern Arizona University, USDA Forest Service, Dorena Genetic Resource Center, Department of Environmental Studies

Keywords: Cronartium ribicola, Pinus strobiformis, climate change, genetics, southwestern white pine, white pine blister rust

Climate change and invasive species pose significant threats to forest health and resilience. Southwestern white pine (SWWP; *Pinus strobiformis*), native to the southwestern US and Mexico, faces increasing pressure from hotter, drier conditions and the non-native disease white pine blister rust. Seed sources with durable genetic resistance to WPBR and the adaptive traits needed to survive warmer, drier conditions in the future are essential to sustain this species on the landscape. Seedlings from across the range of SWWP were tested for resistance to WPBR at Dorena Genetic Resource Center in Oregon. Major gene and quantitative resistance were documented. Data were also used to estimate resistance levels and frequency of resistance across the range of SWWP. Scion from parent trees identified as resistant is collected and grafted into John T. Harrington Forestry Research Center in Mora, NM. Seed will be collected from these orchards as well as resistant parent trees to be planted on the landscape. In addition, progeny identified as resistant at Dorena Genetic Resource Center will be grafted into a clone bank orchard at Tyrell Seed Orchard in Oregon to maintain these genetics. We have also established two common garden field trials in the Southwest to validate resistance results, monitor the long-term durability of resistance, and assess adaptive traits. This work provides information critical to identifying seed sources for future planting. Current challenges include funding ongoing activities (testing, outplanting and monitoring previous plantings), variable and unpredictable planting conditions, and mortality of original parent trees. This interdisciplinary, collaborative project includes international, academic, federal, and tribal partners. We will present details of the project, early results, and applications for management and restoration.

Conifer Regeneration Hinders Digital Estimation of Understory Plant Cover in Post-fire Whitebark Pine Communities

by Brandi E. Wheeler | Andrew J. Andrade | Elizabeth R. Pansing | Diana F. Tomback | University of Colorado Denver | University of Colorado Denver | University of Colorado Denver | University of Colorado Denver

Keywords: 1988 Yellowstone fires, digital image analysis, seral vegetation, subalpine forest, understory plant cover, visual estimation

Monitoring post-fire recovery of whitebark pine communities during climate change will enable us to determine the resilience of these communities. Evaluation of post-fire forest community recovery usually requires estimates of understory (non-conifer) plant cover. Photographic digital image analysis (DIA) is a commonly used method for estimating plant cover. However, DIA efficacy in multi-strata, post-fire plant communities may be reduced where visual obstructions (tree regeneration, coarse downed wood, and shadows) may conceal plant cover in digital imagery. We estimated recent understory plant cover in seral whitebark pine communities using permanent plots established at two study areas following the 1988 Yellowstone fires. Our goals were to 1) determine differences in visual obstructions between study areas in our digital imagery; 2) compare plant cover estimates derived from DIA, visual plot-level (20 m_2) estimation (PLE), and quadrat-level (1 m_2) estimation (QLE); and 3) determine relationships between estimated plant cover and visual obstructions measured *in situ*. DIA confirmed significant differences (odds ratio = 8.34) in percent conifer pixels between study areas. At the study area with fewer conifer pixels, DIA estimated, on average, 9% (95% CI = 3 – 14%) and 16% (95% CI = 10 – 21%) more plant cover than PLE or QLE, respectively, and had similar variability. At the study area with more conifer pixels, DIA estimated less plant cover than PLE or QLE by 28% (95% CI = 24 – 32%) and 22% (95% CI = 18 – 26%), respectively, and was more variable. Furthermore, subcanopy conifer regeneration was negatively associated with plant cover estimated by DIA but showed no relationship with visual estimates. We conclude that conifer regeneration hindered the detection of understory plant cover by DIA. We recommend visual estimation of plant cover in whitebark pine communities with multi-strata vegetation, although digital estimation may be advantageous early in succession.